Selection of Landfill site for Disposal of MSW by using Geographic Information System- A State of the Art Literature Review

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Abstract - This study overview survey of Geographic Information system (GIS) applications in identifying effective design parameter for the landfill site selection. The eminence of the review is on three important areas of landfill site selection. In this study, integrated solid waste management, influential design parameters of site selection and different methods of multiple criteria decision analysis are introduced according to their applications in integrated solid waste management. The purpose of this study is to provide fusion of published research article in this area and perceptions on the GIS modeling concerns over the selection criteria.

This paper takes an unified and fresh look into the area of site selection of landfill for disposal of MSW. Using the rich body of available literature, including earlier reviews that had relatively limited perspectives, the literature on site selection of landfill by using GIS is classified on the basis of the different criteria for influential factors.Finally, the findings and interpretations are summarized, and the main research issues and opportunities are highlighted.

Index Terms - *solid waste management, Landfills; Site selection; Multi-criteria decision analysis (MCDA), Geographic information system (GIS)*

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I. INTRODUCTION

Selecting a landfill site is a difficult achievement when the chances are that wherever in the world that you want to put one, there will beseveral objections. In any landfill site selection process, environmental protection and public health considerationsshould be followed.. So, all our initial efforts will go towards the selection of an appropriate site that will minimize potential environmental impacts and provide a sound basis for effective management. Siting a landfill typically requires processing a significant amount of spatial data with respect to various siting rules, regulations, factors, and constraints. Manually performing such a spatial analysis with drawing tools is generally tedious. A modem geographical information system (GIS), although capable of manipulating spatial data to facilitate the analysis, lacks the ability to locate an optimal site when compactness andother factors are simultaneously considered. A modern geographic information system (GIS) is capable of processing a large amount of spatial data, thereby potentially savingtime that would normally be spent in selecting an appropriate site.Optimized siting decisions have gained considerable importance in order to ensure minimum damage to the various environmental sub-components as well as reduce the stigma associated with the residents living in its vicinity, thereby enhancing the overall sustainability associated with the life cycle of a landfill.

Sufficient literature exists about various aspects and factors which has been considered in site selection process of landfill. GIS-based approach for optimized siting of MSW landfill (V.R.Sumathi et al 2007, JacekMalczewski 2004 and SenerBasak 2004), GIS-based simulated annealing (Muttiah and Engel 1996), Multifactor spatial analysis for Landfilling siting (Jehng-Jung Kao et al. 1996), Optimizing landfill site selection by using simple additive weighting method (Eskandari and Mahmoodi 2015), Planning for the Suitable Land Use Suitability (Hwan yongkim et al. 2014), GIS overlay analysis with MCDA method Analytical Hierarchy process (Hassan and Alireza 2014, Demesouka et al. 2013, NadaliAlavi et al. 2013), EVIAVE method based on territorial indices (Emilio Molero et al. 2008) case study of Beijing by using AHP (Wang Guiqin et al. 2008), MCDA integrated with GIS (M. Yesilnacar et al. 2011) Analytic Network process (ValentinaFerretti 2013) landfill suitability analysis with AHP method in Serbia (Tamara Zelenovic et al. 2011),Weighted Linear Combination and Ordered WeightedAveraging (Solomen peter Gbanie et al. 2012), OWA MCDA method (Katerina 2011) have been published. Earlier works and reviews have a limited focus and narrow perspective. They do not cover satisfactorily all the influential factors of landfill suitability. For example, M.Yesilnacar presents only information of hydro-geology and environmental factors.Our objective is to present a comprehensive integrated view of the published literature on all the aspects and factors considered in analysis of landfill site selection taking a broad view so as to facilitate further study, practice and research.To meet this objective, we define a few relevant terms in this section. Either these have been taken from the existing literature, or we define them appropriately. The second section describes Qualitative analysis was applied to classify the different factors from various categories. We also map the tools/techniques with reference tothe spatial MCDA. Finally, we provide a short review of all parameters indicating relevant papers for the benefit of academicians, researchers and practitioners. At the end of the paper, we appeal certain conclusions and identify potential issues and problems in the territory of landfill site selection.

II. INTEGRATED SOLID WASTE MANAGEMENT DEFINED

Waste is an unavoidable product of society; managing this waste more effectively is a need that society has to address. In dealing with the waste, there are two fundamental requirements: less waste, and then an effective system for managing the waste still produced. Solid Waste Management is defined as the disciplineassociated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental considerations.To control Non-hazardous waste is job of local government authorities.In its scope, solid waste management includes planning, financial, administrative, engineering and legal functions in the process of solving problems arising from waste materials. SWM should aim to improve the environment, provide direct health benefits, support economic productivity, and provide safe, dignified and secure employment.In this context integrated solid waste management (ISWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. Because numerous state and federal laws have been adopted, ISWM is also evolving in response to the regulations developed to implement the various laws[16]. An integrated system would include Recovery of secondary materials Recycling, Biological treatment of organic materials, thermal treatment, Landfill. 'Waste minimization', 'waste reduction' or 'source reduction' are usually placed at the top of the conventional waste management hierarchy. In reality, source reduction is a necessary originator to effective waste management. Source reduction will affect the volume, and indirectly the nature of the waste, but still some waste is remains for disposal. Hence an effective system is needed beyond source reduction to manage this waste.An effective system for solid waste management must be both environmentally and economically sustainable. It must reduce as much as possible the environmental impacts of waste management, including energy consumption, pollution of land, air and water, and loss of amenity. As well as It must operate at a cost acceptable to the community, which includes private citizens, businesses and government. The costs of operating an effective solid waste system will depend on existing local infrastructure, but ideally should be little or no more than existing waste management costs. [3]

LANDFILLING: WASTE DISPOSAL METHOD

Landfilling is considered as a waste treatment process, with its own inputs and outputs, rather than as a final disposal method for solid waste. Landfilling essentially involves long-term storage or inert materials along with relatively uncontrolled decomposition of biodegradable waste.Solid waste residues are waste components that are not recycled, that remain after processing at a materials recovery facility, or that remain after the recovery of conversion products and energy. Landfilling or land disposal is today the most commonly used method for waste disposal purpose. This can deal with all type of waste materials. Landfill management incorporates the planning, design, operation, closure, and post closure control of landfills. This can increase amenity via land reclamation but will at least minimize pollution and loss of amenity.

Landfills are the physical facilities used for the disposal of residual solid wastes in the surface soils of the earth. Landfilling is the process by which residual solid waste is placed in a landfill. Landfilling includes monitoring of the incoming waste stream, placement and compaction of the waste, and installation of landfill environmental monitoring and control facilities.Today, sanitary landfill refers to an engineered facility for the disposal of MSW designed and operated to minimize public health and environmental impacts. Landfills are less expensive and incineration tends to be preferred over recycling programs.

GIS WITH MCDA TECHNIQUES: ANALYTICAL TOOL FOR LANDFILL SUITABILITY ASSESMENT

According to Chang and others (2008) landfill site selection is often a difficult and complex process that requires many different criteria, as well as large volumes of biophysical, environmental, and sociopolitical data (Basnet and others 2001). ‘‘It is evident that many factors must be incorporated into landfill siting decisions, and geographic information systems (GIS) are ideal for preliminary studies due to the capacity to manage large volumes of spatial data from a variety of sources’’ [6]. GIS can facilitate spatial decision-making and planning processes as it allows entering, storing, manipulating, analyzing and displaying large volumes of spatial data (Congalton and Green 1992). Due to this complementary aspect, multi-criteria analyses integrated into GIS can provide proper manipulation and data presentation with consistent ranking based on a variety of factors that could influence the analyses.[12]. A number of multi-criteria evaluation techniques have been used in the landfill siting processes in the past.[6] integrated GIS and multi-criteria decision analyses to solve the landfill site selection issue and developed a detailed ranking of potential landfill sites in accordance with the selected criteria. The Analytic Hierarchy Process (AHP, introduced by Saaty,1980) is an analytical tool that enables researchers to explicitly rank tangible and intangible criteria against each other for the purpose of selecting priorities (Chang and others 2008). The AHP has many advantages for the analysis of management problems, such as the ability to be used in subjective weighing of attributes, while reducing inconsistency of judgment (Saaty 2000),as well as for developing importance structures between criteria and/or potential policy (Mardle and others 2004). According to Sener and others (2010b), the integration of GIS and the AHP can be a powerful tool to solve the landfill site selection problem (Basagaoglu and others 1997; Allen and others 2003; Sener B. and others 2006). A review of literature reveals numerous successful applications of GIS and AHP in the landfill site selection process (Siddiqui and others 1996; Sener and others 2006; Guiqin and others 2009; Sener and others 2010, Nas and others 2010).

Table 1: A summary of the most often used MCDA

MCDA method	Input Data	Output Data	Decision Types
Scoring (SAW)	Attributes scores, weights	Ordinal ranking	Individual DM, Deterministic
Multi-Attribute value	Value functions, weights	Cardinal Ranking	Individual and group DMs, Deterministic, Fuzzy
Multi-Attribute Utility	Utility functions, weights	Cardinal Ranking	Individual and group DMs, Probabilistic, Fuzzy
Analytic Hierarchy Process	Attribute scores, pairwise comparison	Cardinal Ranking (ratio scale)	Individual and group DMs, Probabilistic, Deterministic Fuzzy
Ideal point	Attribute scores, Weights, Ideal point	Cardinal Ranking	Individual and group DMs, Probabilistic, Deterministic Fuzzy
Concordance	Attribute scores, Weights	Partial or ordinal ranking	Individual and group DMs, Probabilistic, Deterministic Fuzzy
Ordered Weighted Averaging	Fuzzy Attribute, Weights, Order weights	Cardinal or Ordinal ranking	Individual and group DMs, Fuzzy

Identification of Design Factors Affecting Site Selection of Landfill

The major goal of the landfill site selection process is to ensure that the disposal facility is located at the best location possible with little negative impact to the environment or to the population. For a sanitary landfill siting, a substantial evaluation process is needed to identify the best available disposal location which meets the requirements of government regulations and best minimizes economic, environmental, health, and social costs.There are several key parameter Selecting the most influential parameters is one of the superior challenges in process of siting new landfill site. Therefore, many researchers studied these parameters and implemented their models according to various parameters.Following are the influential factors that applied in selection of landfill site for MSW disposal in developed GIS models and affects more effectively in solid waste management .

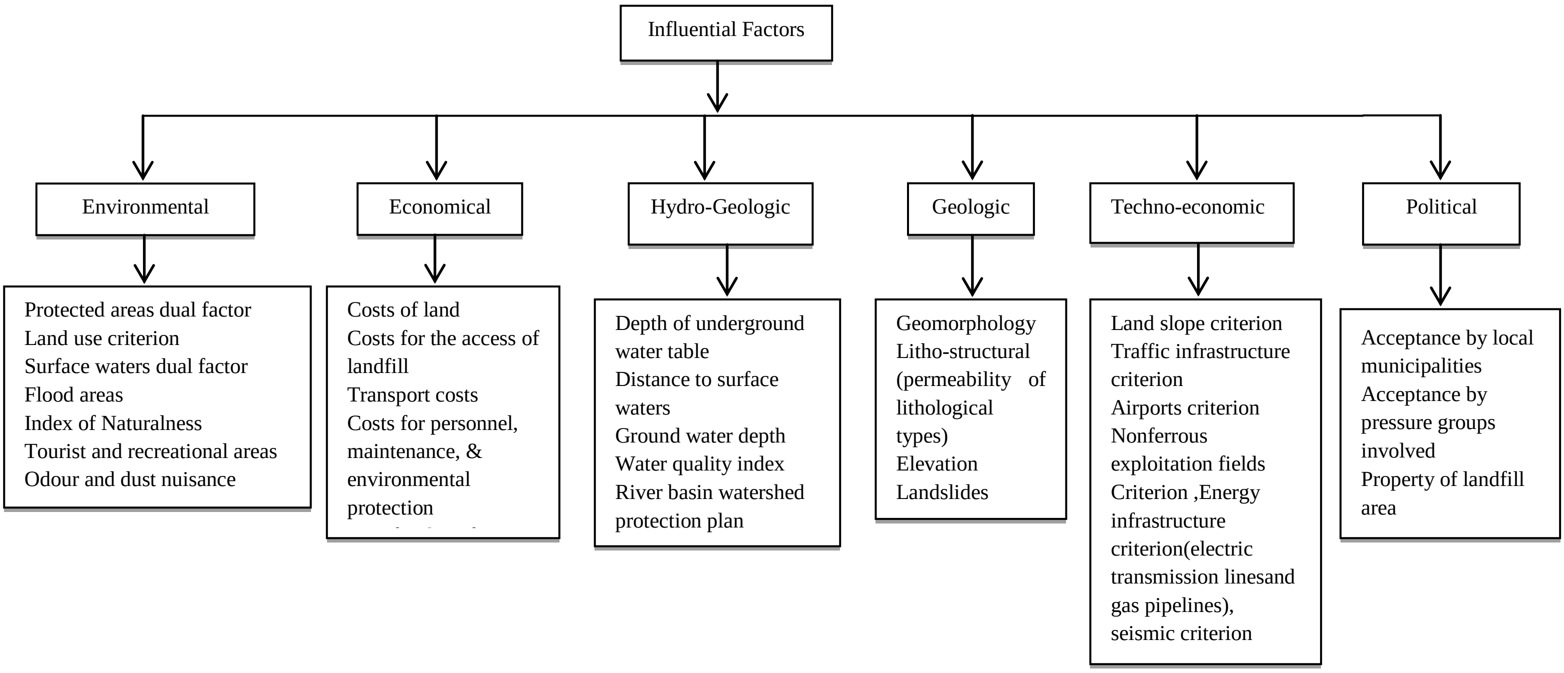

Table No.2: Summary of GIS Modeling for landfill site selection parameters on Environmentalgroup criterion.

Researchers	Main Criterion	Description of sub-criterion	Range of Buffer zones (Distance)
Tamara ZelenovicVasiljevic (2014)	Land use criterion Protected areas dual factor	Non degraded artificial surfaces, Forest and semi natural areas , Wetlands semi natural areas, Agricultural areas , degraded artificial surfaces	<500 m, 500–1000 m <500 m* , 500–1000 m , 1000–2000 m , <2000 m
FerrettiValenttina. (2011).	Protected areas Flood areas Index of Naturalness	Protected areas were excluded from analysis. Flood areas with return period less than 50 years are excluded from the analysis. It was calculated by assigning a value between 0 and 1 to each patch of area under consideration.	Natural protected areas are standardized to 0; remaining areas are standardized to 1 Flood areas with return period ≤ 50 years are standardized to 0, remaining areas are standardized to 1 Linear standardization (The higher the index lower the score)
BasakSener(2004)	Ecological value of flaura& fauna Odour and dust nuisance Nuisance by traffic generation Risks for explosion/ fire Ecological scientific/ historical areas Tourist and recreational areas	Ecological value is based on diversity, naturalness and characteristic feature. Local wind direction, speed and safe distance ,soil cover Routing vehicle traffic through low density population areas National parks and natural conservation areas were excluded Existing recreational areas were excluded from analysis.	

Table No. 3: Summary of GIS Modeling for landfill site selection parameters on hydro-geologic group criterion.

Researchers	Main criterion	Description of sub-criterion	Range of Buffer zones (Distance)
Tamara ZelenovicVasiljevic (2014)	Surface waters dual factor Depth of underground water table Regional resource for water supply restriction factor	 Maintain distance from underground water table	<2000 m ,<500 m 500–1000 m ,1000–2000 m. <2m, 2-5m, >5m <2000m

FerrettiValenttina. (2011)	Ground water depth Water quality index River basin watershed protection plan Distance to surface waters	Ground waters depth in order to avoid contamination Distance to best performing classes of water quality index Riparian buffer protections were excluded from the analysis This represents distance to surface water bodies.	Areas with ground water depth bet. 0-3m are excluded from the analysis The higher distance from high quality classes,the higher the score Riparian buffer protections were standardised to 0 and remaining areas to 1 Distance ≤150m is standardized to 0 and distance> 150m is standardised acc. To max. linear function.
M. IrfanYesilnacar (2012)	Surface water (perennial stream) Intermittent stream Aquifers	Perennial & intermittent streams were digitized as lines from 1:25000 scale topographical maps.	0-350m 0-125m Major aquifer Minor and non-aquifer

Table No.4: Summary of GIS Modeling for landfill site selection parameters on geologic group criterion.

Researchers	Main criterion	Description of sub-criterion	Range of Buffer zones (Distance)
Tamara ZelenovicVasiljevic (2014)	Geomorphology Litho-structural (permeability of lithological types)	Lineaments restriction factor Eluvial, deluvioproluvial, colluvial, fluvial and krast Bottom of the fluvio-marshy environment of the Pannonian plain Gravels and sands Loess, marl and fleece Schistes without gneisses, gneisses and serpentinite	<1000m
FerrettiValenttina. (2011)	Elevation Landslides Lithology	Areas with elevation higher than 1000m were excluded from the analysis Active slide areas were excluded from analysis. Criteria classifies area in 15 classes according to composition of soil	Areas with altitude ≥1000m are standardized to 0 Active slides were standardized to 0 Linear standardization (higher clay percentage, higher score)
M. IrfanYesilnacar (2012)	Geology/ lithology Elevation	Geological maps Digital 1/25,000 topographic contours	Qal-Tpa,Tmp-Tem TvolTkg-Kmb 500-650m, >650m

Table No.5: Summary of GIS Modeling for landfill site selection parameters onsocialfactor group criterion.

Researchers	Main Criterion	Description of sub-criterion	Range of Buffer zones (Distance)
Tamara ZelenovicVasiljevic (2014)	Aspect criterion (wind direction) Settlements dual factor Cultural heritage restriction	W, E , SE, SW, NE	 <500m, 500-1000m 1000-2000m,2000-25000, >25000m <500m

Table No.6:Summary of GIS Modeling for landfill site selection parameters on techno-economic factor group criterion.

Researchers	Main Criterion	Description of sub-criterion	Range of Buffer zones (Distance)
Tamara ZelenovicVasiljevic (2014)		Land slope criterion Traffic infrastructure criterion Airports criterion Nonferrous exploitation fieldsCriterion Energy infrastructure criterion(electric transmission linesand gas pipelines) seismic criterion State border restriction	>20, 0-2, 10-20, 2-10 <500m, 500-1000m 1000-2000, >5000m <500m, 500-1000m <500m, 500-1500m >1500m, <500m 500-1500m >1000-1500m > 1500m >8^0, 7-8°MSC, <6°MSC <2000m
M. IrfanYesilnacar (2012)	Airport Infrastructure power lines Roads- highways Small roads Industrial sites	Different values were studied and maps were digitized. Layer was classified as suitable or unsuitable for landfill site Distance from main access roadsshould be smaller than 3 km (Allen 2002) and between 0.2 km and 10 km of a majorroad. Organized and smallindustrial districts/sites.	0-1500m, >1500m 0-30m 0-500m, 500-1000m 0-100m,100-500m

Table No.7: Summary of GIS Modeling for landfill site selection parameters on politicalfactor group criterion.

Researchers	Main Criteria	Description of sub-criterion	Range of Buffer zones (Distance)
Basaksener (2004)	Political factors	Acceptance by local municipalities Acceptance by pressure groups involved Property of landfill area	

Table No.8: Summary of GIS Modeling for landfill site selection parameters on Financial factor group criterion.

Researchers	Main Criteria	Description of sub-criterion	Range of Buffer zones (Distance)
Basaksener (2004)	Financial factors	Costs of land Costs for the access of landfill Transport costs Costs for personnel, maintenance, & environmental protection Cost for the After-care	

III. CONCLUSION

We present a state of the art literature review of landfill selection process by indicating different factors affecting on evaluation process of siting. Our literature review highlights all the categories of factors with MCDA method. Before the spatial analysis is performed to site a landfill,siting criteria and factors should be evaluated for their applicabilityfor the siting area from related legislation, restrictions,rules, experiences, and expertise in various aspects. Criteriaare rules that prohibit a landfill from being placed within aspecific area; factors are important attributes that should beused to evaluate the suitability of a site. Other than assessingand comparing the suitability of a candidate site, the foregoingcriteria and factors are used to screen out unsuitable areas anddefine a model objective for implementing the spatial analysismodel described later in this section.[siting 1996]. Our classifications of factors from different categories will help academicians, practitioners and researchers in the process of siting landfill to understand concept of all influential factors which may need to be considered in suitability analysis of landfill with respect to its different selected ranges for buffer zone layers. Previous research studies does not include the factors which may need to be eliminated at an early stage as are generally not suitable for siting a landfill. Our classification along with timeline and cited reference may be used as a broad frame of reference to develop concepts and models that facilitate managers and other stakeholders trying to integrate different factors from various categories into landfill site selection process. Practitioners can also gain good insight into real-life problems while selecting optimal site location for landfilling as purpose of disposal of MSW. This can serve as a platform for them to adapt and develop their own initiatives and practices.

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