2nd International Conference on Emerging Trends in Engineering and Management Research (ICETEMR-17)
(IETE) Institution of Electronics and Telecommunication Engineers, Pune, India
28th May 2017, www.conferenceworld.in
ISBN: 978-93-86171-46-7

LAND SUITABILITY ASSESSMENT FOR DISPOSAL OF SOLID WASTE BY USING GIS -REVIEW

Ms. Priyanka S. Deshmukh[1], Prof. Upendra R. Saharkar[2]

[1]P.G Student, [2]Head, Department of Civil Engineering, Dypiet, Ambi,
Savitaribai Phule Pune University, Pune, Maharashtra (India)

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.

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

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 be several objections. In any landfill site selection process, environmental protection and public health considerations should be followed. So, all our initial efforts will go towards the selection of an appropriate site that will minimize potential environmental influences and provide a comprehensive 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 and other factors are simultaneously considered. A modern geographic information system (GIS) is capable of processing a large amount of spatial data, thereby potentially saving time 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

ISBN: 978-93-86171-46-7

residents living in its premises, 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),overlay analysis with MCDA method Analytical Hierarchy process by using GIS (Hassan and Alireza 2014, Demesouka et al. 2013, NadaliAlavi et al. 2013), EVIAVE method based on territorial indices (Emilio Molero et a. 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 (Valentina Ferretti 2013) landfill suitability analysis with AHP method in Serbia (Tamara Zelenovic et al. 2011),Weighted Linear Combination and Ordered Weighted Averaging (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 certainconclusions 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 discipline associated 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. [(9) from book]. 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. [ISWM 1995]

III. 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.

IV. 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 socio-political 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’’ (Sener and others 2006). 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.(Malczewski 2010). A number of multi-criteria evaluation

ISBN: 978-93-86171-46-7

techniques have been used in the landfill siting processes in the past. Sener and others (2006) 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).GIS have the capability of storing, analyzing and displaying spatially reference data with integratedaspatial data.

4.1 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.

4.2 Literature Review

A. This study presented process of landfill site selection in Srem of Serbia, seventeen factors divided into three types according to the nature and role in the decision making procedure. All factors wereassembledaccording to their domain of influence into geo-natural, environmental, social and techno-economic, hydrological. Mainly focused on factors such as land use criterion, (Non degraded artificial surfaces, Forest and semi natural areas , Wetlands semi natural areas, Agricultural areas , degraded artificial surfaces) protected areas dual factor, Depth of underground water table Regional resource for water supply restriction factor,Geomorphology ,Litho-structural (permeability of lithological types), Aspect criterion (wind direction),Land slope, Traffic infrastructure, Airports, Nonferrous exploitation fields, Energy infrastructure (electric transmission lines and gas pipelines) seismic criterion, State border restriction etc. these factors were evaluated by experts from different field using an AHP extension in Arc GIS. In this study, Weighted spatial layers were combined into a landfill suitability map which was then overlapped with four restriction maps, resulting in a finalsuitability map. This study does not involve political and financial criterion.

B. The study have targeted in the Province of Torino (Italy), proposes a spatial multi-criteria approach for siting process of MSW landfill. Analytic network process (ANP) is used as MCDA method for evaluating

best site selection for landfilling. The main findings of this research have proved that the spatial ANP is a useful tool to help technicians to make their decisionprocess traceable and reliable. This approach will help to decision makers to undertake a sound reflection of the siting problem. Thus it represented the difference between spatial multicriteria decision analysis and conventional multicriteria techniques. A thematic raster map has been constructed for each of the identified factors and constraints. Maps were computedthrough basic GIS operations (map overlay, buffering, distance mapping, spatial queries, etc.). A weighted linear combination has been used, that combines the factors and constraints maps. Sensitivity analysis was carried out based on variation of the criteria weights considered in process in order to judge suitability of obtained results.

C. In this study an GIS model had developed to finding optimal location for landfill site in Ankara city. It has shown different 14 maps consisting elevation, slope, settlements (urban and village), roads (highways and small roads), airport, infrastructure (powerlines), geology/lithology, aquifers, surface waters (perennial and intermittent streams), industrial sites (organized and small industrial sites), land use were evaluated and prepared to be involved in the analysis within GIS environment.ArcView v.9.0 and TNT-MIPS v.6.4 software were used in this study to process and create map layers. The 'simple additive weighting method (SAW) was selected to be applied in site selection problem. The results obtained from this study indicated that GIS with MCDA integration offers a good solution for landfill site selection issue and forms a good alternative for conventional methods.This study stated that the vector data model could produce spatially more accurate results, the speed and versatility are compromised relative to raster data models.

D. This study have presented a methodological framework for identifying municipal landfill sites in urban areas in Sierra Leone involving a multi-criteria GIS approach that combinations two aggregation techniques: Weighted Linear Combination and Ordered Weighted Averaging.The developed model in this study was assembled into ten categories ranging from not suitable to very very high suitability. The proposed GIS model developed in this paper was designed to assist planners, civil engineers and developers to help protect ground and surface waters from contamination, communities from air pollution and harmful smells of inflaming degradable waste materials, smoke from burning waste, public health and to reduce financial burden. Community acceptance were factor were not considered in this study. Low suitability was caused by high ground water level characterized the area. They have prepared five constraints map and 14 factor maps. Social factor were also considered in this study with environmental and economical factors. Finally they proved that Unlike the DUPIT model in which factor weights were assignedarbitrarily, the use of WLC and OWA through consistency matrixwas ideal. Instead of assigning factor weight to the variouscriteria arbitrarily, a mathematical approach, a matrix,will help inreducing the human error.OWA offered the opportunity for controllingthe level of risk in a multi-criteria analysis and the degree ofinfluence which the factor weights will have on the final suitabilitymap.Solomon Peter Gbanie et al. (2012)

E. GIs with AHP model was presented as the technical, useful and accelerator tool for disposal site selection.They suggested that geological conditions should be considered primarily then other factors were taken into consideration.The most suitable sites for burial were in northwest and west of Qom Province and ultimately five zones were introduced as the sample sites.Seven effective factorswere applied for determining hazardous waste landfill in Qom Province, central Iran. These study mainly included

ISBN: 978-93-86171-46-7

significant factors such as water, slope, population centers, roads, fault, protected areas and geology, . The Analysis Hierarchical Process (AHP) model based on pair comparison was castoff in evaluation process of landfill. First, the weight of each factor was determined by experts; subsequently each layer of maps entered to ARC GIS and with special weight multiplied together, finally the best suitable site was introduced. The results of this study indicated that Landfill sites should be located where impermeable lands, homogeneous bedrock, and groundwater levels are low.Mehdi Rezaeimahmoudi et al. (2014)

F. Planners are required to perform miscellaneous duties such as land use planning, policy making and evaluation processes. In this extent, a land suitability analysis which would one of the oldest forms of decision making system is still referred as an effective method that will improve the complicate planning decision environment. This study have presented a suitability analysis to determine the most acceptable location for a proposed landfill facility in Hays Country in the State of Texas. They have been used the Delphi panel discussion, Analytic Hierarchical Process (AHP), and map algebra in GIS environment, three most suitable sites for a future landfill facility were identified. This paper also has provided an in-depth overview on the latest decision support systems research and spatial multi-criteria decision sciences. Simple map algebra was used in conjunction with ArcGIS and geographic data sets, suitability scores were compared using zonal statistics. Flood plain and hydrology were selected as other factors .Hwan Yong Kim et al.

G. Municipal solid waste disposal is a major environmentalanxiety throughout the world.Proper landfill sitinginvolves many environmental, economic, technical, and socioculturalchallenges. This study presented a new quantitative method for landfill siting that reduces the number of evaluation criteria, simplifies siting procedures, and augments the utility of available land evaluation maps was proposed for Marvdashtin Fars Province, Iran. Simple abdicative method was used as MCDA method. The approach involves two separate stages, necessary criteria for preliminary landfill siting using four constraints and eight factors were obtained from a land classification map initially prepared for irrigation purposes.They were standardized criteria using a rating approach and weighted to obtain a suitability map for landfill siting, with ratings in a 0–1 domain and divided into five suitability classes.They were evaluated six best alternative site for final landfill siting using four additional criteria. Sensitivity analyses were conducted to assess the stability of the obtained ranking. Results indicated that the method provided a precise siting procedure that should convince all pertinent stakeholder. M. Eskandari& M. Homaee (2015)

H. This paper addressed the siting of a new landfill using a multi-criteria decision analysis (MCDA) and overlay analysis using a geographic information system (GIS). The proposed system has been obliging new information on the landfill site selection by updating its knowledge base. Several factors were considered in the siting process including geology, water supply resources, land use, sensitive sites, air quality and groundwater quality. Weightings were assigned to each criterion depending upon their relative importance and ratings in accordance with the relative magnitude of impact. The results from testing the system using different sites showed the effectiveness of the system in the selection process. A multi-criteria approach was employed in conjunction with GIS-based overlay analysis to identify the most suitable site for landfill development in the Pondicherry region. A set of 17 potential sites were identified. V.R. Sumathi and UshaNatesan et al. (Dec. 2007)

I. Considered all factors and rating criteria, a combination of geographic information systems and analytical hierarchy process (AHP) was used to conclude the best sites for disposal of municipal solid waste (MSW) in Mahshahr County, Iran. In order to the verdict for landfill siting a structural hierarchy formed and the most important criteria surface water, sensitive ecosystems, land cover, urban and rural areas, land uses, distance to roads, slope and land type were chosen according to standards and regulations. Each criterion was evaluated by rating methods and the relative importance of criteria to each other was determined by AHP. They have been found six site location for visiting. The result of this research revealed that this method is an efficient tool for preliminary screening in a wide area; however, detailed inspections are required to involve the public in the landfill site selection process and to investigate unavailable digital data. The result of field study showed that it is a additional, and necessary, step in finding the best candidate landfill site from land with high suitability. Nadali Alavi1 and GholamrezaGoudarzi

J. Basak&Sener This study have targeted the procedure for evaluation of landfill siting with the help of GIS systems. It included introductory part of solid waste management, landfilling methods, landfill design, landfill siting criteria, multicriteria decision analysis,. They have shown methodology including overlay analysis with GIS software and MCDA approach for optimizing landfill site selection in Ankara in central Anatolia. This study showed that different MCDA techniques, their application in siting location of landfill site by using GIS software, method of overlay analysis, buffering of all maps for selected criterion.

V. OBJECTIVES OF STUDY

The aim of this research is to develop model including GIS analysis for evaluation of optimal siting of landfill in Mumbai also it includes the planning of construction of multistoried building for waste disposal purpose to overcome the land problem in Mumbai city .

The principal objectives of this study are:

 To understand the concept of SWM and GIS by literature survey such as research articles, books, journals, papers etc.

 To collect data and analyze existing status of generation, collection, storage, transportation, treatment, and disposal activities of MSW of selected study area.

 To provide site selection criteria for solid waste disposal by identifying an effective parameters and providing optimal solution by using a geographic information system (GIS).

 To prepare a new ISWM system for selectedarea & proposed it to municipal corporation & compare it with current situation.

 To provide suggestion, and recommendations for integrated solid waste management for representative study area.

VI. METHODOLOGY ADOPTED FOR PRESENT STUDY

To collect the maps and attribute data for the project to develop model for effective management of solid waste by using GIS technology.

- Select the case study area.

- Identify the set of key criteria for landfill siting
- Collect spatial and attribute dataregarding different chosen factors from several categories. (Toposheets& available paper maps).
- The attribute data which is generated through data entry process is to be linked with the study area map using ARC-GIS software.
- Development of GIS database for municipal landfill siting comprising of different layers prepared for different criteria.
- Overlay the generated buffer maps to identify the sites where the constraintsparameterization may beemployed – sites where thesiting of landfill is 'notpermissible' thus Identify optimized site forland use siting.
- Conclusions are made based on the models.

VII. 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 applicability for the siting area from related legislation, restrictions, rules, experiences, and expertise in various aspects. Criteria are rules that prohibit a landfill from being placed within a specific area ; factors are important attributes that should be used to evaluate the suitability of a site. Other than assessing and comparing the suitability of a candidate site, the foregoing criteria and factors are used to screen out unsuitable areas and define a model objective for implementing the spatial analysis model described later in this section.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 cited reference may be used as a broad frame of reference to develop perceptions and simulations 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.

VIII. FUTURE SCOPE

The contributions of this study will expect to be relevant to both researchers and practitioners.To researchers, the findings should help to decide the criteria for site selection of landfill to attain the required optimal solution considering various economical, environmental and social factors by using GIS software. As for practitioners, the findings will be helpful to utilize the suggested landfill site location for disposal of MSW in forthcoming future.

REFERENCES

[1] Jehng-Jung Kao, Hung-Vue Lin, "multifactor spatial analysis for landfill siting" Journal of environmental Engineering, October 1996.

[2] Tamara ZelenovicVasiljevic, ZoricaSrdjevic, RatkoBajcetic, "GIS and the Analytic Hierarchy Process for Regional Landfill Site Selection in Transitional Countries: A Case Study From Serbia," Environmental Management (2012) 49:445–458 DOI 10.1007/s00267-011-9792-3, December 2011.

[3] Ferretti V. "A Multicriteria- Spatial Decision Support System (MC-SDSS) development for siting a landfill in the Province of Torino (Italy)". Journal of Multi-criteria Decision Analysis, Vol. 18, pp. 231-252.- ISSN 1057-9214, October 2013.

[4] M. IrfanYesilnacar , M. LütfiSüzen , BaşakŞener Kaya &VedatDoyuran , " Municipal solid waste landfill site selection for the city of Şanliurfa-Turkey: an example using MCDA integrated with GIS," International Journal of Digital Earth, 5:2, 147-164, DOI: 10.1080/17538947.2011.583993, June 2011.

[5] SenerBasak, Suzen ML, Doyuran V (2006) Landfill site selection by using geographic information systems. Environmental Geology 49:376–388.

[6] Jess W. Everett, Baxter E Vieux, "Landfill Siting Using Geographic Information Systems: A Demonstration", Journal of Environmental Engineering. DOI: 10.1061/(ASCE)0733 9372(1996)122:6(515) .June 1996

[7] Wang Guiqin, Qin Li, Chen Lijun, "Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China" Journal of Environmental Management, April 2009.

[8] MontserratZamoranoa, Emilio Molero, "Evaluation of a municipal landfill site in Southern Spain with GIS-aided methodology" Journal of hazardous materials, April 2008.

[9] George Tchobanoglous, HilaryTheisen, Samuel Vigil "Integrated solid waste management Engineering Principles and Management Issues", Mc Graw Hill education

[10] NadaliAlavi, Ali Akbar Babaei, Municipal solid waste landfill site selection with geographic information systems and analytical hierarchy process: a case study in Mahshahr County, Iran" Waste Management and Research31(1) 98–105. DOI: 10.1177/0734242X12456092, December 2012.

[11] JacekMalczewski, "GIS-based land-use suitability analysis: a critical overview" Progress in Planning 62 (2004) 3–65, 2003.

[12] O.E. Demesouka, A.P. Vavatsikos, "Suitability analysis for siting MSW landfills and its multi-criteria spatial decision support system: Method, implementation and case study", Waste Management 33 (2013) 1190–1206, February 2013.

[13] Katerina R. Donevska, Joseph P. Frizado, Cvetko D. Mitrovski, "Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average" Waste Management 32 (2012) 287–296, October 2011.

[14] Mehdi Rezaeimahmoudi, AbdolrezaEsmaeli, Hassan Shabanian, "Application of geographical information system in disposal site selection for hazardous wastes" journal of environmental health science & engineering, 2014.

BOOKS:

[1] P.R. White, M. Franke, and P. Hindle, "Integrated solid waste Management A lifecycle inventory," Aspen Publishers, Inc. Gaithersburg, Maryland 1999.