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LANDFILL SITE SELECTION USING GEOGRAPHICAL INFORMATION SYSTEM AND MULTI CRITERIA DECISION ANALYSIS IN JOHOR BAHRU, MALAYSIA

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By

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LANDFILL SITE SELECTION USING GEOGRAPHICAL INFORMATION SYSTEM AND MULTI CRITERIA DECISION ANALYSIS IN JOHOR BAHRU, MALAYSIA

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October 2015

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Rapid economic growth and urban transformation played a major role to solid waste management problems in Malaysia. Solid waste management is one of the most challenging environmental problems. Despite the enormous amount effort and management strategies the government is applying in recent years, yet the waste management standards in Malaysia did not yield significant impact. Johor Bahru is one of most developing city and also highest of populations in Malaysia. This fact led to increase in waste generation. Instead of using 3Rs which represent reuse, reduce and recycle to diminish waste, the landfill has been identified as the most cost-effective system of solid waste disposal for most urban areas in developing countries. The objectives of this study is to determine the suitable parameters for landfill siting, to delineate and characterized the suitability of various areas and also to optimized the landfill site selection technique using GIS and MCDA methods. Data used in this research were collected from various government agencies. Data such as map were converted into digital map and undergo GIS overlaying process to identify the suitable new landfill sites. Several guidelines from government agencies and local authorities were used to guide in selecting suitable site for new landfill. The final overlay process produces four possible areas for new landfill in Johor Bahru. Furthermore, to enhance these possible sites, MCDA techniques which are Analytical Hierarchy Process and Simple Additive Weighting were used. The method sets the factors clearly and helps experts and NGOs to participate so that the lack of information or any opposition can be discussed, scored and weighted separately. AHP is a tool that has broad applicability in waste management and particularly makes assessments, prioritization and selection among waste management options more readily measurable. Even more, combining GIS and AHP techniques became more effective since this combining techniques mix all possibilities and between technologies and also human logic.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PEMILIHAN TAPAK PELUPUSAN MENGGUNAKAN SISTEM MAKLUMAT GEOGRAFI DAN ANALSIS KEPUTUSAN MULTI KRITERIA DI JOHOR BAHRU, MALAYSIA

Oleh

MUHAMMAD AMAR BIN ZAUDI

Oktober 2015

Pengerusi : Mohammad Firuz Ramli, PhD
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Pertumbuhan ekonomi yang pesat serta transformasi bandar menjadi faktor utama kepada masalah pengurusan sisa pepejal di Malaysia. Pengurusan sisa pepejal adalah salah satu masalah alam sekitar yang boleh dikatakan mencabar. Kebelakangan ini, pelbagai usaha dan pengurusan strategi telah dilakukan oleh kerajaan, namun standard pengurusan sisa di Malaysia masih tidak memberangsangkan. Johor Bahru merupakan salah satu bandar yang semakin membangun dan mempunyai kepadatan penduduk yang tinggi. Hal ini menjadi penyebab peningkatan sisa pepejal di Johor Bharu. Selain menggunakan kaedah 3R (*Reuse, Reduce, Recycle*) untuk mengurangkan bahan buangan, tapak pelupusan telah dikenalpasti antara sistem yang kos efektif untuk melupuskan sisa pepejal bagi kebanyakan negara membangun. Objektif kajian ini adalah untuk menentukan parameter yang sesuai untuk pemilihan tapak pelupusan, menilai ciri-ciri setiap tapak yang dipilih serta dan mengoptimumkan pemilihan tapak pelupusan sampah baharu dengan menggunakan kaedah GIS dan MCDA. Data yang digunakan dalam kajian ini diperolehi daripada pelbagai agensi kerajaan. Data seperti peta telah ditukar ke bentuk digital dan menjalani proses tindanan GIS untuk mengenal pasti tapak pelupusan baru yang sesuai. Garis panduan daripada agensi kerajaan dan pihak berkuasa tempatan juga telah digunapakai sebagai rujukan dalam pemilihan tapak pelupusan yang baru. Proses tindanan akhir menghasilkan empat kawasan yang berkemungkinan sesuai untuk tapak pelupusan baru. Manakala, untuk menambahbaik kawasan-kawasan tersebut, teknik MCDA seperti *Analytical Hierarchy Process* dan *Simple Additive Weighting* telah digunakan. Kaedah ini menetapkan faktor yang jelas dan membolehkan pakar-pakar serta badan bukan kerajaan untuk mengambil bahagian untuk berbincang mengenai kekurangan maklumat atau melakukan sebarang bantahan dengan memberikan pemarkahan secara berasingan. AHP adalah teknik yang mempunyai kebolehgunaan luas dalam pengurusan sisa dan terutamanya membuat penilaian, serta menentukan keutamaan bagi setiap pemilihan. Bahkan menggabungkan GIS dan AHP menjadikan teknik ini lebih berkesan memandangkan ia menggabungkan pelbagai kemungkinan antara teknologi dan logik manusia.

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"BETTER LATE THAN NEVER"

I certify that a Thesis Examination Committee has met on 27th October 2015 to conduct the final examination of Muhammad Amar bin Zaudi on his thesis entitled "Landfill Site Selection using Geographical Information Systems and Multi Criteria Decision Analysis in Johor Bahru, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABREVIATIONS

^0C	Degree Celsius
AHP	Analytical Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
DEM	Digital Elevation Model
DOA	Department of Agriculture
DOE	Department of Environment
DOS	Department of Statistics
dwg	AutoCAD file format
GIS	Geographical Information System
JMG	Jabatan Mineral dan Geosains
JMM	Jabatan Meterologi Malaysia
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
km^2	Kilometer square
m	meter
MCDA	Multi Criteria Decision Analysis
MHLG	Ministry of Housing and Local Government
mm	millimetres
MOH	Ministry of Health
MSW	Municipal Solid Waste
NIABY	Not In Anyone's Backyard
NIMBY	Not In My Backyard
SAW	Simple Additive Weighting
SWM	Solid Waste Management
TCPD	Town and Country Planning Department
WLC	Weight Linear Combination

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Rapid economic growth, especially in the industrial, economic and urban infrastructural sectors, played a significant role in wasting management problems in Malaysia. Besides, the process of development cannot be separated from urbanization thereby increasing more pressure upon the environment through attracting larger number of people within metropolitan areas in search of a job and a better life, which eventually leads to higher waste generation. There are many legal definitions of "waste" which bring about different views as to what should consider as waste. In simplest term, waste is defined as any material, which is unwanted by the holder and intentionally thrown far for disposal. Thus, this does not take in another place the fact that certain waste materials may eventually be reused or become valuable resources to others (Lau, 2004). Solid Waste Management has attracted much attention in recent time due to the growing need to address urban environmental problems, especially in lower income countries (Iscan *et al.*, 2008).

In Malaysia, solid waste is one of the most challenging environmental issues. Despite the enormous amount effort and management strategies the government is applying in recent years, yet the waste management standards did not yield significant improvement. Lau (2004) categorized the following factors as the biggest challenges in waste management which are composition, uneconomic storage and collection systems, disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of wastes and wasteful utilization of dump site space. One of the most widely accepted sustainable waste management techniques is the concept known as 3Rs, which represent as reduce, reuse and recycle (Damgaard *et al.*, 2011). Thus, even with this 3Rs technique, a final disposal element is still required given that no existing method or technology can put a stop to the generation of all waste products, or to eliminate the already accumulated waste. For that reason, sustainable landfill became a necessary component of an efficient and sustainable waste management (Fauziah & Agamuthu, 2012).

Landfill has been identified as the most cost-effective system for disposing of solid waste (Nas *et al.*, 2009). One of the major issues in waste management is choosing the most appropriate site for waste disposal (Iscan *et al.*, 2008). Leakage from landfills usually contains significant amounts of contaminants such as ammonia, nitrate, chloride, and metals. These contaminants may reach aquifers, degrade the water resource, and become hazardous to human health (Berktay, 2008). Landfill site selection is a critical issue in town planning process because of its enormous impact on the economy, ecology and the environment (Akbari et al. 2008). Urban expansion as well as the desire to live in cities, has led to a tremendous amount of waste's generation and, unfortunately, the problem gets bigger day by day (Akbari et al. 2008). The landfill technique is the most common method of the disposal as solid waste (Komilis *et al.*, 1999). Several factors such as distance from community, public health issues and operation cost have been discussed in order to select an appropriate site for the landfill (Komilis *et al.*, 1999; Akbari et al. 2008; Berktay, 2008; Nas *et al.*, 2009). Hence, there is a need to evaluate these factors to identify the most suitable site. The planning and design of a landfill management system involved selection of treatment and disposal

REFERENCES

Agamuthu, P. and Nather, K. (2001), *Effective Solid Waste Management* (pp.12-1 to 12-26). Malaysia, Ecotone Management Sdn. Bhd.

Akbari V., Rajabi M.A., Chavoshi S.H. and Shams R. (2008). Landfill Site Selection by Combining GIS and Fuzzy Multi Criteria Decision Analysis in Bandar Abbas, Iran, World Applied Sciences Journal 3 (Supple 1): 39-47.

Alavi, N., Goudarzi, G., Babaei. A. A., Jaafarzadeh. N. and Hosseinzadeh. M. (2012). Municipal solid waste landfill site selection with geographic information systems and analytical hierarchy process: a case study in Mahshahr County, Iran, Waste Management and Research 31(1) 98-105.

Al-Yaqout, A. F., Koushki, P. A., & Hamoda, M. F. (2002). Public opinion and siting solid waste landfills in Kuwait. *Resources, Conservation and Recycling, 35*(4), 215–227.

Aziz, A. H., Yusoff, M.S., Adlan M.N., Adnan, N.H., Alias, S. (2005), *Physica-Chmical Removal of Iron from s\Semi Aerobic Landfill Leachate by Iimestone Filter*, Journal Waste Management 24 ((2004) 353-358).

Baetz B.W., Pas E., Neebe A., (1989) "Trash management: sizing and timing decision for incineration and landfill facilities" Interfaces Vol. 19 No. 6

Ball, J.M. (2005, October). *Landfill Site Selection*. Paper session presented at the Tenth International Waste Management and Landfill Symposium, Cagliari.

Berktay, A. (2008). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental Monitoring Assess* (2010) 160:491–500.

Buckley, J.J. (1985). Fuzzy hierarchical analysis. Fuzzy Sets and Systems, 17(3), 233-247.

Canada, J.R. and Sullivan, W.G. (1989) "Economic and Multi-attribute Evaluation of Advanced Manufacturing System". New Jersey, USA, Prentice Hall.

Carver, S. J. 1991. "Integrating Multi-criteria Evaluation with Geographic Information System", International Journal of Geographical Information Systems, 5(3), pp.321-339.

Chandrappa, R. & Das, D. B., (2012). *Solid Waste Management: Principles and Practice.* Heidelberg: Springer.

Chang, N., Parvathinathanb, G., & Breden, J. B. 2008. Combining GIS with fuzzy multicriteria decision making for landfill siting in a fast-growing urban region. Journal of Environmental Management, 87, 139–153.

Charnpratheep, K., Zhou, Q., Garner, B., 1997. Preliminary landfill site screening using fuzzygeographical information systems. Waste. Manage. Res., 15 (2): 197-215.

Church, R.L., 2002. Geographic information system and location science. Computers and Operation Research 29, 541–562.

Damgaard, A., Manfredi, S., Merrild, H., Stense, S., Christensen, T.H. LCA and economic evaluation of landfill leachate and gas technologies. Waste Management 31 (2011) 1532–1541.

Daneshvar, N., Oladegaragoze, A. and Djafarzadeh, N. (2005) Decolorization of basic dye solutions by electrocoagulation: an investigation of the effect of operational parameters. *Journal of Hazardous Materials*, B129: 116 – 122.

Dardas, M., Ahmad, R. M., Farjad, B. (2010). Integration of GIS and multi-criteria decision analysis for urban solid waste management and site.

Delgado, B.O., Mendoza, M., Lopez-Granados, E., Geneletti, D., 2008. Analysis of land suitability for the siting of inter-municipal landfills in the Cuitzeo Lake Basin, Mexico. Waste Management 28, 1137–1146.

Demesouka, O.E., Vavatsikos, A.P., Anagnostopoulos, K.P., 2013. Suitability analysis for siting MSW landfills and its multicriteria spatial decision support system: method, implementation and case study. Waste Manage. 33, 1190–1206.

Despotakis, V.K., Economopoulos, A.P. (2006). A GIS Model For Landfill Sitting. *Global NEST Journal*, (9), 29-34. Retrieved from http://www.gnest.org/journal/journal.htm

Donevska, K.R., Gorsevski P.V., Jovanovski, M., Pesevski, I., (2011) Regional non-hazardous landfill site selection by integrating fuzzy logic, AHP and geographic information systems. Environ Earth Sci. DOI 10.1007/s12665-011-1485-y.

Eastman J.R. (1993) IDRISI: a grid based geographic analysis system, version 4.1. Graduate School of Geography, Clark University, Worcester.

Effat, H.A., Hegazy, M.N. (2012) Mapping potential landfill sites for North Sinai cities using spatial multicriteria evaluation. The Egyptian Journal of Remote Sensing and Space Science 12/2012; 15(2):125–133. DOI: 10.1016/j.ejrs.2012.09.002

Erkut, E., & Moran, S. R. 1991. Locating obnoxious facilities in the public sector: An application of the hierarchy process to municipal landfill siting decisions. Socio-Economic Planning Sciences, 25(2), 89–102.

Ersoy, H., Bulut, F. Spatial and multi-criteria decision analysis-based methodology for landfill site selection in growing urban regions. (2009). Waste Management & Research 2009; 27: 489-900.

Farrell M., Jones D.L. (2009) Critical evaluation of municipal solid waste composting and potential compost markets. Bioresource Technology 100 (2009) 4301–4310.

Fauziah S.H., Agamuthu P. (2012). Trends in sustainable landfilling in Malaysia, a developing country. Waste Management & Research 30(7) 656-663.

Fauziah S.H., Izzati M., Agamuthu, P. Toxicity on *Anabas Testudineus*: a case study of sanitary landfill leachate. 2013 International Symposium on Environmental Science and Technology (2013 ISEST). Procedia Environmental Sciences 18 (2013) 14 – 19.

Feo, G. D. & Gisi, S. D., 2014. Using MCDA and GIS for hazardous waste landfill siting considering land scarcity for waste disposal. *Waste Management*, 34(11), p. 2225–2238.

Fotheringham S., Rogerson P. A. (1993) GIS and Spatial analytical problems, International Journal of Geographical Information Systems, 7(1), 3-19.

Fotheringham S., Rogerson P. A. (Eds) (1994) Spatial Analysis and GIS (Taylor & Francis, London, 1994).

Gbanie, S. P. T. P. B. M. J. S. M. J. &. K. V. T. S., 2013. Modelling landfill location using geographic information systems (GIS) and multi-criteria decision analysis (MCDA): Case study Bo, Southern Sierra Leone. *Applied Geography*, Volume 36, pp. 3-12.

Global Environmental Centre, 2002. Solid Waste In Malaysia. http://www.gecnet.info. Accessed on 18 March 2010.

Gorsevski PV, Donevska KR, Mitrovski C, Frizado JP (2012) Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. Waste Management 32 (2):287–296

Graymore, M.L.M., Wallis, A.M., Richards, A.J. (2009) An Index of Regional Sustainability: A GIS-based multiple criteria analysis decision support system for progressing sustainability. Ecological Complexity 6 (2009) 453–462.

Iscan F., Nas B., Cay T. (2008) Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. Environ Monit Assess 160:491–500. doi:10.1007/s10661-008-0713-8.

Jankowski, P., 1995. Spatial decision support system for health practitioners: selecting a location for rural health practice. International Journal of Geographical Information Systems 3, 279–299.

Janssen R. (1992) Multiobjective decision support for environmental management. Kluwer, Dordrecht, 232 p.

Javaheri A, Wysocki R, Jobin-Robitaille O, Altaf M, Cote J, Kron SJ. (2006) Yeast G1 DNA damage checkpoint regulation by H2A phosphorylation is independent of chromatin remodeling.*Proc Natl Acad Sci U S A* 103(37):13771-6

Javaheri, H., Nasrabadi, T., Jafarian, M. H., Rowshan, G. R., Khoshnam, H. (2006). Site Selection of Municipal Solid Waste Landfills Using Analytical Hierarchy Process Method in a Geographical Information Technology Environment in Giroft. *Journal of Environmental, Health and Science 2006*, 3(3). pp. 177-184.

JPBD, 2005. *Garis Panduan Perancangan Tapak Pelupusan Sisa Toksid dan Sisa Pepejal*, Kuala Lumpur: Bahagian Penyelidikan dan Pembangunan.

Kao, J. and Lin, H. (1996). "Spatial models for landfill siting on WWW", *Proceedings of the Air and Waste Management Association Annual Meeting*, pp. 365-78.

Kao, J. J., Lin, H. Y., Chen, W. Y., 1997. Network geographic information system for landfill siting, Waste. Manage. Res., 15 (3): 239-253.

Karkazi, A., Hatzichristos, T., Mavropoulos, A., Emmanouilidou, B., Elseoud, A., (NA). *Landfill Siting Using Gis And Fuzzy Logic*. Retrived from http://www.epem.gr/

Kathirvale, S., Yunus, M.N., Sopian, K., Samsuddin, A.H., (2003) Energy potential from municipal solid waste in Malaysia, Renewable Energy 29 (2003), pp, 559-567.

Komilis, D.P., Ham, R.K., Stegmann, R., 1999. The effect of municipal solid waste pretreatment on landfill behavior: a literature review. Waste Manage. Res. 17, 10–19.

Kontos, T.D., Komilis, D.P., Halvadakis, C.P., 2003. Siting MSW landfills on Lesvos Island with a GIS-based methodology. Waste Management and Research 21 (3), 262–278.

Kura, N. U. et al., 2015. Assessment of groundwater vulnerability to anthropogenic pollution and seawater intrusion in a small tropical island using index-based methods. *Environmental Science and Pollution Research*, 22(2), pp. 1512-1533.

Lau, V. L. (2004). Case Study on the Management of Waste Materials in Malaysia. Geoökol Forum.

Lin, H. and Kao, J.J. (1997). "Spatial models for landfill siting on WWW", *Proceedings of the Air and Waste Management Association Annual Meeting*, pp. 365-78.

Lin, H. and Kao, J.J. (1999). Enhanced spatial model for landfill siting analysis. *Journal of Environmental Engineering*, (125-9), 845-851.

Lober, D.J. (1995) "Resolving the Siting Impasse: Modeling Social and Environmental Locational Criteria with Geo-graphic Information System," *American*

Planning Asso-ciation, Vol. 61, No. 4, 1995, pp.482-495. doi:10.1080/01944369508975659.

Lober, D.J., 1996. Why not here? The importance of context, process, and outcome on public attitudes toward siting of waste facilities. Society and Natural Resources 9, 375–394.

Lunkapis, G. J. (2004). *GIS as decision support tool for landfills siting*. Paper session presented at the Map Asia Conference 2004.

Mahini, S.S., Ronagh, H.R., and Niroomandi, A. 2006. Per-formance Based Assessment of FRP-Retrofitted Existing RC Frames. Proceedings of Fourth International Conference on FRP Composites in Civil Engineering (CICE08) 22-24 July 2006, Zurich, Switzerland Empa, Duebendorf, Paper 6.B.6. p. 6 (CD-ROM).

Malaysian Government. (1995). *Environmental Impact Assessment Guidelines for Municipal Solid Waste and Sewerage Treatment and Disposal projects*. Department of Environment, Ministry of Science, Technology and Environment Malaysia. Government Printing.

Malaysian Government. (2004). The Study On The Safe Closure And Rehabilitation Of Landfill Sites In Malaysia. Ministry Of Housing and Local Government Malaysia.

Malaysian Government. (2004). The Technical Guideline for Sanitary Landfill: Design and Operation. Ministry Of Housing and Local Government Malaysia.

Malaysian Government. (2005). National Strategic Plan for Solid Waste Management. Ministry Of Housing And Local Government Malaysia.

Malaysian Government. (2006). Ninth Malaysia Plan. Economic Planning Unit.

Malczewski J (1997) Propagation of errors in multicriteria location analysis: a case study. In: Fandel G, Gal T (eds) Multiple criteria decision making. Springer, Berlin Heidelberg New York, pp 154–155.

Malczewski J (1999) GIS and multicriteria decision analysis. John Wiley and Sons Inc., 392p.

Malczewski, J., 2004. GIS-based land-use suitability analysis: a critical overview. Progress inPlanning 62 (1), 3–65.

Manaf, L.A., Samah, M.A., Zukki, N.I., 2009. Municipal Solid Waste management in Malaysia: Practices and Challenges. Journal of Waste Management 29 (2009) 2902-2906.

MMD, J. M. M., 2014. *Malaysian Metrological Department.* [Online] Available at: http://www.met.gov.my/[Accessed 13 November 2014].

Moeinaddini, M. et al., 2010. Siting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj). *Waste Management*, Volume 30, pp. 912-920.

Mohan S. and Gandhimathi R. "Solid Waste Characteri-zation and Assessment of the Effect of Dumping Site Leachate on Groundwater Quality: A Case Study," *Inter-national Journal of Environment and Waste Management*, Vol. 3, No. 1-2, 2009, pp. 65-77.

Mokhtar, A. M. D., Wan Zurina, W. J., Markson, O. R., Aminuddin, W. H. (2002). *How GIS Can Be a Useful Tool to Deal with Landfill Site Selection*. Paper session presented at International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2008.

Muckel, G.B., ed (2004). Understanding Soil Risks and Hazards: Using Soil Survey to Identify Areas with Risks and Hazards to Human Lifoe and Property. US Dept. Agric., Nat. Soil Survey Center, Limcoln, Nebraska, 93p. [Includes

discussions on risks posed by various kinds of soils/soil conditions for urban development. Semi-popular publication.]

Nair, M.M., Kumari, P., Vishal, G., 2007. Solid Waste Disposal management System using GIS. http://www.gisdevelopment.net. Accessed on 16 March 2010.

Nas, B., Cay, T., Iscan, F., Berktay, A. (2009). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental Monitoring Assess* (2010) 160:491–500.

Nicolas, J. et al., 2008. Odour annoyance assessments around landfill sites: methods and results. *Chemical Engineering Transactions*, 15(International conference on environmental odour monitoring and control NOSE), pp. 29-37.

Nicolas, J., Craffe, F. & Romain, A. C., 2006. Estimation of odor emission rate from landfill areas using the sniffing team method. *Waste Management*, 26(11), pp. 1259-1269.

Ohman K.V.H., Hettiaratchi J.P.A., Ruwanpura J., Balakrishnan J., Achari G. (2007). Development of a Landfill Model to Prioritize Design and Operating Objectives.

Ouma, Y.O., Emmanuel C.K., Ryutaro T., MCDA-GIS integrated approach for optimized landfill site selection for growing urban regions: an application of neighbourhood proximity analysis. (2011). Annals of GIS 03/2011; 17:43-62. DOI: 10.1080/19475683.2011.558021.

Rao, P.J., Brinda, V., Rao, B.S. and Harikrihna, P. (2007) "Selection of Landfill Sites for Solid Waste Management in and around Visakhapatnam City-A GIS Approach," *Asian Journal of Geoinformatics*, Vol. 7, No. 3, 2007, pp.35-41.

Saaty T.L. (1980) The analytic hierarchy process. McGraw-Hill: New York; 1980.

Saaty, T. L. (2008). Relative measurement and its generalization in decision making: Why pairwise comparisons are central in mathematics for the measurement of intangible factors, the analytic hierarchy/network process. Review of the Royal Spanish Academy of Sciences, Series A, Mathematics, 102(2), 251–318.

Saaty, T. L. and Tran, L. T., (2007). On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process, *Mathematical and Computer Modelling*, 46, 7-8, 962–975.

Saaty, T. L.and Vargas, L. G., (1991). Experiments on Rank Preservation and Reversal in Relative Measurement, *Math. Comput. Modelling*, 17, 4/5, 13–18.

Saeed, M. O., Nasir M. H., and Mujeebu M. A., (2008), Development of Municipal Solid Waste Generation and Recyclable Components Rate of Kuala Lumpur: Perspective Study. Paper presented in International Conference on Environment (ICENV 2008) Penang, Malaysia.

Sener, B. (2004). *Landfill Site Selection by Using Geographic Information Systems*. (Unpublished master's dissertation). Middle East Technical University.

Sener, B., Suzen, L., & Doyuran, V. 2006. Landfill site selection by using geographic Information systems. Environmental Geology, 49, 376–388.

Sener, S., Sener E., Nas B., Karaguzel R. (2010) Combining AHP with GIS for landfill site selection: a case study in the Lake Beysehir catchment area (Konya, Turkey). Waste Management 30:2037–2046

Sharifi, M., Hadidi, M., Vessali, E., Mosstafakhani, P., Taheri, K., Shahoie, S., Khodamoradpour, M., 2009. Integrating multi-criteria decision analysis for a GIS-based hazardous waste landfill sitting in Kurdistan Province, western Iran. Waste Management 29, 2740–2758.

Siddiqui, M.Z., Everett, J.W. and Vieux, B.E., 1996. Landfill siting using geographic information system: a demonstration. Journal of Environmental Engineering, 122, 515-5.

Tagaris, E., Sotiropolou, R., Pilinis, C. & Halvadakis, C., 2003. A methodology to estimate odors around landfill sites: the use of methane as an odor index and its utility in landfill siting. *Journal of the Air and Waste Management Association* , Volume 53, p. 629–634.

Tavares, G. Z. Z. &. S. V., 2011. Multi-criteria GIS-based siting of an incineration plant for municipal solid waste.. *Waste management,* 31(9), pp. 1960-1972.

Tchobanoglous, G., Theisen, H., Vigil, S.A., 1993. Integrated Solid Waste Management, Engineering Principles and Management Issues. McGraw-Hill, NewYork, USA, p. 377.

Themistoklis, D. K., Dimitrios, P. K., Constantinos, P. H. (2005). *Siting MSW landfills with a spatial multiple criteria analysis methodology.* Retrieved from www.aseanenvironment.info/

Ubeda, Y. et al., 2010. *Evaluation of odour impact from a landfill area and a waste treatment facility through the application of two approaches of a Gaussian dispersion model.*. Ottawa, Canada, In International Congress on Environmental Modelling and Software Modelling for Environment's Sake 5th biennal Meeting.

United Nations Environment Programme, Division of Technology, Industry, and Economics. Regional Overviews and Information Services: Asia – Topic f: Special Wastes. (2002). www.unep.or.jp/ietc.asp.

United States Environmental Protection Agency. 2013. Law and Regulations. Site www2.epa.gov/laws-regulations Accessed on January 2014.

Vasiljevic, T. Z., Srdjevic, Z., Bajc˘etic´, R. & Miloradov, M. V., 2012. GIS and the Analytic Hierarchy Process for Regional Landfill Site Selection in Transitional Countries: A Case Study From Serbia. *Environmental Management* , Volume 49, p. 445–458.

Vatalis, K., & Manoliadis, O. 2002. A two-level multicriteria DSS for landfill site selection using GIS: Case study in Western Macedonia, Greece. Journal of Geographic Information and Decision Analysis, 6(1), 49–56.

Wang, T. C., & Chen, Y. H. (2008). Applying fuzzy linguistic preference relations to the improvement of consistency of fuzzy AHP. Information Sciences, 178(19), 3755–3765.

Yesilnacar, M.I., Cetin, H., 2005. Site selection for hazardous wastes: a case study from the GAP area, Turkey. Eng. Geol. 81, 371–388.

Yesilnacar, M.I., Cetin, H., Yazgan, M.S., (2005). Site selection for hazardous wastes: A case study from the GAP area, Turkey, Engineering Geology 81 (2005) 371–388.

Zahedi, F., 1986. The Analytical Hierarchy Process – A Survey of the Method and Its Applications. INTERFACES, 16, 96-108.

Zyma, R., (1990). Siting considerations for resource recovery facilities. In: Public Works (1990), pp. 84–86.