

**PERSPECTIVES IN REGIONAL
DEVELOPMENT IN NIGERIA.**

**A Festschrift In Honour of
PROFESSOR ADEBISI
FUNSHO ADEDAYO**

EDITED BY:

Raphael Abiodun Olawepo, Ph.D
Lanre Tajudeen Ajibade, Ph.D
Ifatokun Paul Ifabiyi, Ph.D

Institutions	169	
Effects of Market Locations on Traffic Flow in Metropolitan Lagos, Nigeria: Olawepo R.A., Asaju J.A., and Ojo T.K.	183	Per
Pollution Waste and Management		
Analysis of Atmospheric Corrosion Potential of The Marine Environment Of Calabar Port, Cross River State, Nigeria- Evans, U. F and Esin, J. O	195	
Pollution And Management: A Review Of Types, Causes And Management Strategies; Ogunbiyi T. F., Ayeni A. O. And Taiwo J.T.	208	
Trace Elements In Soil Of Obajana Mining Site, Kogi State, Nigeria- Alemonu S.O.	219	
Settlement Studies		
Making Cities Function Through Capacity Building In Urban Environmental Management for Sustainable Urban Development- Afolayan, G. P	232	
Analysis Of Socio-Economic Development Differentials In Kogi State, Nigeria- Balogun, G. F, Adefila, J. O, Yusuf, R. O. & I. J. Musa	240	
Perspectives On Urban-Rural Migration In Nigeria: Implications On Socio-Economic Development Of The Rural Landscape- Olawepo, R. A.	258	
Settlements' Ranking and Infrastructure Provision in Niger State, Nigeria- Sulyman, A. O.	269	
Theoretical Issues		
The Application of Spatial Analysis Approach for the Siting Of MSW Landfills- Ayo Babalola	287	
Application Of Multi-Criteria Decision Model and GIS for Criterio Weight Estimation-Ayo Babalola	295	
Nigeria: Imperative Of Spatial Database In Achieving Intelligence-Led Policing In Nigeria: A Case Study Of Ilorin Metropolis: Ogunfolaji, D. & Orire I. O. (Ph.D.) ... imation	306	

CHAPTER TWENTY TWO

Application of Multi-criteria Decision Model and GIS for Criterion Weight Estimation

By

Ayo Babalola

Surveying and Geo-informatics Department University of Ilorin, Kwara State, Nigeria
babalola.ayo@unilorin.edu.ng

Abstract

This paper presents the application of Geographic Information systems (GIS) and Multi-criteria analysis techniques for criteria weight estimation in an environmental decision making process. The location or siting of landfill in environmental management is based on certain factors or criteria. Criteria such as land use, slope, soil, rainfall, and distance to road, aspects, and groundwater and water body are considered here. The relative importance weightings of the criteria are determined using super decision software.

Keywords: ANP; GIS; Weight estimation; Multi-criteria, Super decision.

Introduction

The ever increasing urbanization, population growth, and municipal solid waste generation with it attendant health hazards contributes to the high demand for proper waste management and disposal. The disposal of municipal solid wastes must be effectively done and at designated sites taking into cognizance environmental, social and economic factors. The siting of an optimum waste dump site will also be influenced by local and national legislations.

Studies have used GIS with MCDM to solve the problem of optimum solid waste disposal site. Multiple criteria decision making process provides decision makers with a broad range of techniques that can handle the complexities of the present day environmental decision making problems. Since these criteria may vary in the degree of importance, the analytic network process (ANP) method is used to prioritize the selection criteria (that is to assign weights to the criteria). The ANP developed by Saaty (1999) is a powerful tool in MCDM currently been used for planning, selection and evaluation. It is a generalized form of the analytic hierarchy process (AHP). The need to evaluate the suitability of land use has led to the use and development of methodologies such as the use of criteria or factors, assigning weights to these factors as well as estimating such weights. Quite a number of techniques have been developed and utilized to estimate weights in decision making problems. For

example, the technique for order preference by similarity to ideal solution (TOPSIS) was first proposed by Hwang and Yoon (1981) for weights estimation. Roy (1991) utilized an outranking method known as elimination and choice translation reality (ELECTRE) which compares two alternatives at the same time. This method builds an outranking relationship in order to eliminate alternatives that are dominated using the outranking relationship. Another method that has received wide patronage is the preference ranking organization method of enrichment evaluation (PROMETHEE) method introduced by Brans et al. (1986) for decision making. This method generates partial ordering on the set of possible alternatives. The analytic hierarchy process (AHP) method first proposed Saaty (1980) is another method that has received wide applications. For example it has been used to determine the relative importance weightings of factors such as in Koksai and Egitman (1998), Chang and Lo (2001), Kuo, et al., (2002), and Hanumaiah et al., (2006). However, this method is observed to be deficient in mitigating the problem of dependency and feedback, and therefore less capable of dealing with complex decision making like the ANP.

This paper is therefore an attempt to illustrate this methodology using a practical approach to ascertain relative importance weight of factors for landfill siting. This technique is very suitable as it provides an opportunity for addressing all forms of dependency and

feedback in a decision making system and in a sequential manner. This study considers the analytic network process to estimate criterion weight using Geographic information systems.

1.1 Geographic Information Systems (GIS)
GIS have been defined differently by various authors but for the purpose of this study, it will be defined as the a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from real world for a particular set of purposes (Burrough, 1986). GIS reckon with positions as well as time their coordinates and spatial relationships with other features or objects. When maps are produced from a GIS environment more data can be added and manipulated to assist planners and researchers, environmentalists and decision makers.

The rest of the paper is structured as follows; Section 2 is the ANP super decision model and its development section 3 is the result and discussion, sections 4&5 is the conclusion.

ANP: Super decision model and its development

The structure of the ANP model as executed in the software super decisions and its application in decision making problems has been well documented. The ANP process basically consists of two stages. The first stage is a control network of criteria and sub-criteria that controls the interactions in the system. The second stage is the network of influences among the elements and clusters (Saaty, 2001). The clusters within the system are seen as a collection of important elements within a network or subnet work (Saaty, 1999). In order to obtain the priorities in the system, pair-wise comparisons and judgment are used. The system allows for the interactions and feedback within the cluster called the inner dependence, while the interactions and feedbacks between clusters are known as the outer dependence (Saaty, 2001). The ANP is capable of handling an organized sequence of all types of dependence as well as feedback in a decision system (Chen, 2001). In this method of MCDM, the importance of the criteria determines the evaluation of the alternatives, and the evaluation of the alternatives determines the importance of the criteria in the model. The ANP method has been used in studies such as; contractor selection (Eddie and Heng, 2004), exam scheduling

(Mujgan and Zehra, 2010), valuation of industrial land (Aragone and Aznar, 2008). In addition, the ANP has been combined with mathematical programming approaches to deal with problems like product planning (Karsark et al., 2002), resource allocation (Saaty et al., 2003), economic and finances (Niemura and Saaty, 2004), project analysis (Meade and Sarkis, 1999) and highway planning (Piantanakulchai, 2005). A variety of the applications of the ANP exemplifies its flexibility and the ease of use.

Concepts of the ANP

This vignette itemizes the concepts of the analytic network process and thereafter explains the steps involved in carrying out the ANP methodology. The following are the concept of ANP as highlighted by Saaty (2001).

- i. Feedback, inner and outer dependence
- ii. Influence with respect to a criterion
- iii. The control hierarchy or system
- iv. The super matrix
- v. The limiting super matrix and limiting priorities
- vi. Primitivity, irreducibility, cyclicity.
- vii. Make the limiting super matrix stochastic; why clusters must be compared
- viii. Synthesis for the criteria of a control hierarchy or a control system
- ix. Synthesis for benefits, costs, opportunities, and risks control hierarchies,
- x. Formulation to compute the limit
- xi. Relation to Neural network firing- the continuous case
- xii. The density of neural firing and distributions and their applications to reproduce visual images and symphonic compositions.

Before discussing the next section it is important to briefly explain the different stages involved in the application of the ANP (Saaty, 2001).

Firstly, the control hierarchies are described and their criteria for which the components of the system and their sub-criteria for comparing the elements of the system are compared. Secondly, the hierarchy or the network of clusters and their elements are determined. Thirdly, the clusters of the general feedback system with their elements are

determined for each control criteria or sub-criteria, and thereafter, connected based on their outer and inner dependence influence. Here, an arrow is drawn beginning from a cluster to any other cluster that its element influences. Fourthly, in this stage a system to analyze each of the cluster or element is determined. In the Fifth stage, a super matrix is constructed for each of the control criterion, by putting down the clusters and all the elements in a sequential order and vertically and horizontally on the left and on top respectively. Thereafter, the priorities obtained from the pair-wise comparisons are entered into their rightful positions in the super matrix. In step six of the ANP process, pair-wise comparisons of the elements that are within the clusters are carried out based on their influence on each element in a different cluster that they are connected to or on the elements in the same cluster. In the seventh stage, a pair-wise comparison of the clusters is carried out in order to ascertain the influence of each cluster to which they are linked based on the given criterion. The weights obtained as a result are used as weights of the elements of the corresponding column clusters which also correspond to the control criterion of the super matrix. In stage eight, the limiting priorities are derived and normalized to one for each of the cluster. The ninth stage is to synthesize the limiting priorities, while sensitivity analysis is carried out in the tenth stage. The most important thing here is the importance of criteria as only a few of the control hierarchies are often used in a model. In ANP the determination of the relative weights is based on the pair-wise comparisons method just like in the AHP. The pair-wise comparisons of the elements in the individual level of hierarchy are carried out based on their relative importance towards their control criterion.

In saaty (1999), four basic control hierarchies were used namely; Benefits, Opportunities, Costs and risks (BOCR). However, the most important thing here is the importance of criteria as only a few of the control hierarchies are often used in a model. In ANP the determination of the relative weights is based on the pair-wise comparisons method just like in the AHP. The pair-wise comparison of the elements in the individual level of hierarchy is carried out based on their relative importance towards their control criterion. A scale of 1-9 was proposed by Saaty (1990) when comparing two items (Table 1 below). The score of 1 means equal importance of two items and 9 stands for extreme importance of one item over the other. The table 1 shows the comparison scale for relative importance in AHP this scale is also applicable in the ANP. This scale enables the user to utilize experience as well as intuitive knowledge to present the amount of times a given element dominates another with respect to the criterion. With this scale the user can explicitly state his preference between each pair of elements verbally as equal, moderate, strong, very strong, and extremely important. These verbal preferences are then translated into numerical values of 1, 3, 5, 7, and 9 respectively with 2, 4, 6 and 8 as intermediate values for comparison between two successive qualitative judgments. And for the purpose of determining the corresponding transpose judgments the reciprocals of these values are utilized.

Table 1: Scale of relative importance (Saaty, 1980)

Scale value	Explanation
1	Equally preferred (or important)
3	Slightly more important (or important)
5	Strongly more preferred (or important)
7	Very strongly more preferred (or important)
9	Extremely more preferred (or important)
2,4,6,8	Used to reflect compromise between scale values

Score a_{ij} represents relative importance in row i and column j respectively.

$$a_{ij} = w_i/w_j$$

If for instance the component j is more important than i component then the reciprocal value of $(1/a_{ij})$ is used.

$$A = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \dots & 1 \end{bmatrix} \quad (1)$$

Relative weight w_i/w_j for each pair of components is determined, and the Priority vector w is computed by;

The final weights obtained are used to form the Super matrix which represents the interrelationships of the elements in the system.

In the super matrix, C_N represents the N th cluster, e_{Nn} represents the n th element in the N th cluster.

W_{ij} = block matrix which comprise of priority weight vector (w) representing the influence of the elements in the i th cluster with respect to j th cluster.

$$Aw = \lambda_{\max} w$$

(2)

Where; $\lambda_{\max}$ = maximum eigenvalue of matrix A

w is normalized by $\alpha = \frac{1}{n} \sum_{i=1}^n w_i$

(3)

A is the matrix of pair-wise comparison, w is eigenvector and $\lambda_{\max}$ is the largest eigenvalue of A

In order to compute the consistency index (CI)

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (4)$$

The Super matrix

The Super matrix comprises of several eigenvectors each of which sum to one. Fig. 1 shows a standard form of a Super matrix as proposed by Saaty (2001). The super matrix has the ability of dealing with interdependent characteristics among elements and components. The super matrix is said to be a column stochastic as its entire columns sum to unity (Wey and Wu, 2008).

	C_1			C_2			C_n		
	e_{11}	e_{12}	...	e_{1n_1}	e_{21}	e_{22}	...	e_{2n_2}	...
C_1	e_{11}	e_{12}	...	e_{1n_1}	e_{21}	e_{22}	...	e_{2n_2}	...
C_2	e_{21}	e_{22}	...	e_{2n_2}	e_{31}	e_{32}	...	e_{3n_3}	...
C_n	e_{n1}	e_{n2}	...	e_{nn_n}	e_{n1}	e_{n2}	...	e_{nn_n}	...

Fig. 1 Super matrix (Saaty, 2001; Wey and Wu, 2008)

In order to determine the global priority vectors and weights, the weighted Super matrix is raised to power to obtain the global priority vectors in equation 5.

$$\lim_{k \rightarrow \infty} w^k \quad (5)$$

The average priority weight can be obtained if there is two or more N limiting Super matrices. That is the cesaro sum is obtained from equation 6.

$$\lim_{k \rightarrow \infty} \left(\frac{1}{N} \right) w_i^k \quad (6)$$

The Criteria used

In this paper, eight criteria are used for this siting problem; aspect, land-use, rainfall, road network, water body, soil, groundwater, and slope. The land use simply refers to settlement areas, agricultural land, waste land, road means distance from road network, soil refers to soil types of the study area, groundwater means distance from water table; slope refers to the elevation range. Water body means distance from pond, and aspect means wind speed and orientation. The traditional analytic hierarchy process has been used to solve similar problem without considering interdependence characteristics among the criteria. This paper however, considers the interdependence

characteristics among the eight parameters in the site selection problem (Fig. 2)

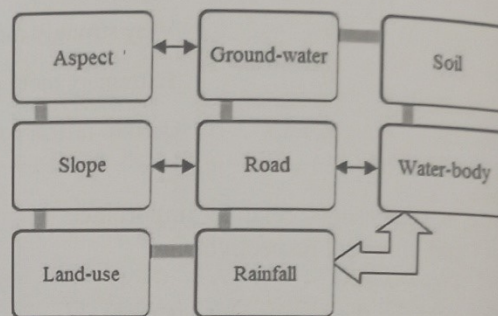


Fig. 2 Interdependent relationships among the criteria.

Site Selection and the ANP decision model

Geographic information system (GIS) has been used in site selection process as this process involved manipulation as well as analysis of a wide range of data. The main aim of site selection is to determine the most appropriate site which fulfils certain criteria from a wide range of options. The combination of GIS with MCDM will facilitate site selection process. Selection of site for the disposal of municipal waste has become an important aspect of waste management system. Sites are located for either of the following waste management techniques; thermal treatment, biological treatment, recycling, and landfilling (Tchobanoglous, et al., 1993). Landfill remains an important part of waste management system even if other options such as waste reduction and reuse are considered (Tchobanoglous et al., 1993). Landfill siting has become increasingly difficult due to the 'NIMBY' (Not in my back yard) syndrome, government regulations as well as cost. Thus siting a landfill entails an extensive evaluation so as to identify the most suitable site for waste disposal (Sumathi et al., 2007). In order to assess a location for the purpose of siting a landfill many factors are considered. The flow chart below represents the process for modeling the landfill site suitability (Fig. 3). The suitability criteria are processed using GIS.

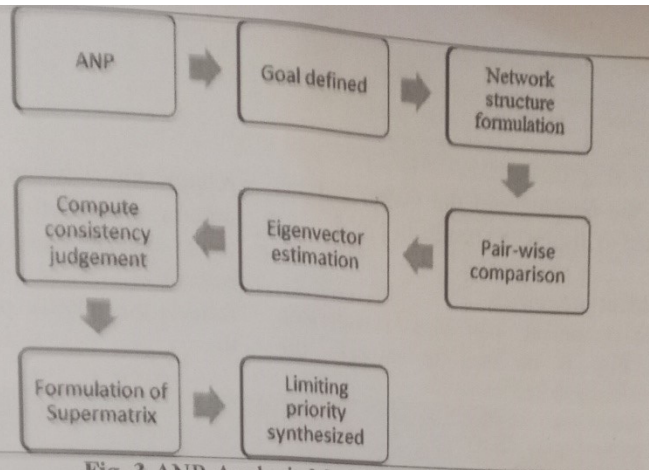


Fig. 3 ANP-Analysis Models

The Questionnaire comparison screen is presented in Fig. 4. Here the clusters that bear any connection to factors are compared to ascertain their impact.

Item	Comparison Matrix	Consistency Ratio	Notes
1. Groundwater	1-9.0	0.0003	No comp.
2. Groundwater	1-0.5	0.0003	No comp.
3. Groundwater	1-0.5	0.0003	No comp.
4. Groundwater	1-0.5	0.0003	No comp.
5. Groundwater	1-0.5	0.0003	No comp.
6. Groundwater	1-0.5	0.0003	No comp.
7. Landuse	1-0.5	0.0003	No comp.
8. Landuse	1-0.5	0.0003	No comp.
9. Landuse	1-0.5	0.0003	No comp.
10. Landuse	1-0.5	0.0003	No comp.

Fig. 4 The Questionnaire comparison screen.

Inconsistency	Landuse	Rainfall	Road	Slope	Soil
Aspect	3.0003	3.0	1.0	2.0	3.0
Landuse		1.0	3.0	2.0	1.0
Rainfall			3.0	2.0	3.0
Road				2.0	2.0
Slope					2.0

Fig. 5 Matrix pair-wise comparison screen

From Fig. 5 above, the number in the matrix is said to be a dominance judgment. The element in blue on the left means dominant i.e. more important or more preferred and so on, from the element shown at the top. The element in red indicates that the element at the top is dominant. If the judgment is 1.0, it means that they are equal, and a judgment of 3.0 signifies moderately or three times as much, while a judgment of 9.0 indicates nine times as much.

After this, the Graphic and the verbal buttons were selected to display the results in Fig. 7.

2.26 Graphical judgments

The graphical pair-wise comparison screen in Fig. 6 is used to express the

relationship between two elements in this case criteria as the ratio of the lengths of two bars (blue and red, representing aspect and land use respectively). The pie chart beneath the bars reflects the relative proportion of the values of the bar charts.

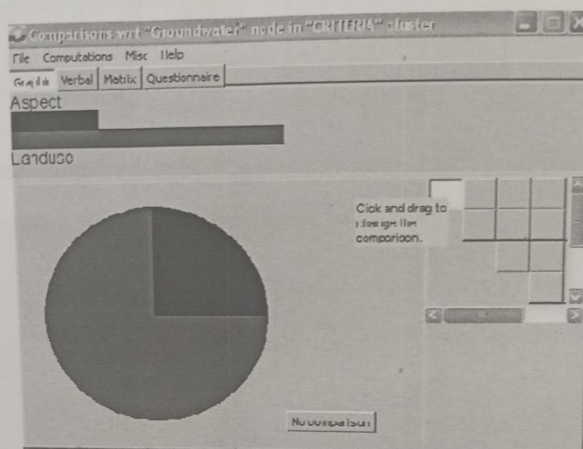


Fig. 6 Graphic pair-wise comparison screen

Relative importance for the alternatives relative to each of these criteria are obtained from pair-wise verbal comparisons, based on the data obtained from the processed data.

2.27 Inconsistency Ratio

The matrix pair-wise comparison

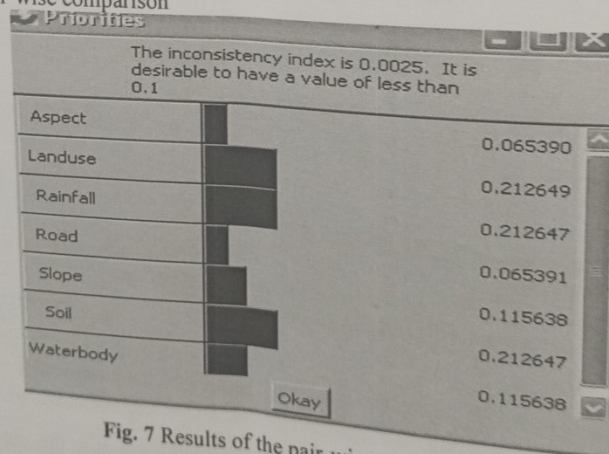


Fig. 7 Results of the pair-wise comparisons

Results and Discussion

The priorities (Fig.7) obtained from the pair-wise comparisons of the cluster are multiplied with the elements on the right in order to obtain the weighted super matrix. Each column in the weighted super matrix has a sum

of 1 (one) which means the matrix is Stochastic. In order to get the limit of the weighted matrix, calculation is done to net out the dominance for all the criteria in the system. The priorities display the results of the pair-wise comparison as shown in Figure 8.

Cluster Node Labels		CRITERIA							
		Aspect	Groundwater	Landuse	Rainfall	Road	Slope	Soil	Waterbody
CRITERIA	Aspect	0.000000	0.065390	0.065392	0.070512	0.057641	0.061770	0.121679	0.061770
	Groundwater	0.186828	0.000000	0.212647	0.203611	0.186828	0.192812	0.207991	0.192812
	Landuse	0.186828	0.212649	0.000000	0.213617	0.186828	0.192812	0.207991	0.192812
	Rainfall	0.186828	0.212647	0.212647	0.000000	0.186828	0.192812	0.165915	0.192812
	Road	0.057641	0.065391	0.065392	0.065696	0.000000	0.061770	0.064314	0.061770
	Slope	0.097523	0.115638	0.115638	0.116473	0.097523	0.000000	0.116054	0.105213
	Soil	0.186828	0.212647	0.212647	0.213617	0.186828	0.192812	0.000000	0.192812
	Waterbody	0.097523	0.115638	0.115638	0.116473	0.097523	0.105213	0.116054	0.000000

Fig. 8 Super Matrix

The outcome of research can be utilized in landfill site selection process as well as prioritize the objectives, and also obtain the priorities of all the criteria in study problem. It can be observed that the normalized values for the factors are depicted in the second column (Table 2). The relative weight for each criterion within the cluster is obtained by normalizing the values in the cluster which has an additive value of one. The first and the third columns of the table represent the factors and their limiting values respectively. Then next step is to utilize the outcome from ANP in the table for the landfill siting process. Landfill has widely been recognized as one of the cheapest form of waste

disposal and as such has attracted more research interest recently. Landfill siting is a complex process as it involves many factors such as environmental, social and technical (Kontos, et al., 2005). It is in view of this conflicting factors or parameters that weights are assigned to each of them to allow for value judgments to be made according to their perceived importance.

The weight for each factor here is in terms of its ANP priorities. Fig. 9 shows the process of utilizing the criteria weights earlier determined using the ANP technique for the landfill suitability analysis. These weights are used in the database and subsequently combined linearly in order to achieve the desired objective.

Table 2: Overall outcome

Name	Normalized by cluster	Limiting
Land-use	0.16877	0.168772
Groundwater	0.16743	0.167428
Rainfall	0.16276	0.162763
Aspect	0.06999	0.069989
Slope	0.10078	0.100784
Road	0.06006	0.060059
Soil	0.16942	0.169422
Water body	0.10078	0.100784

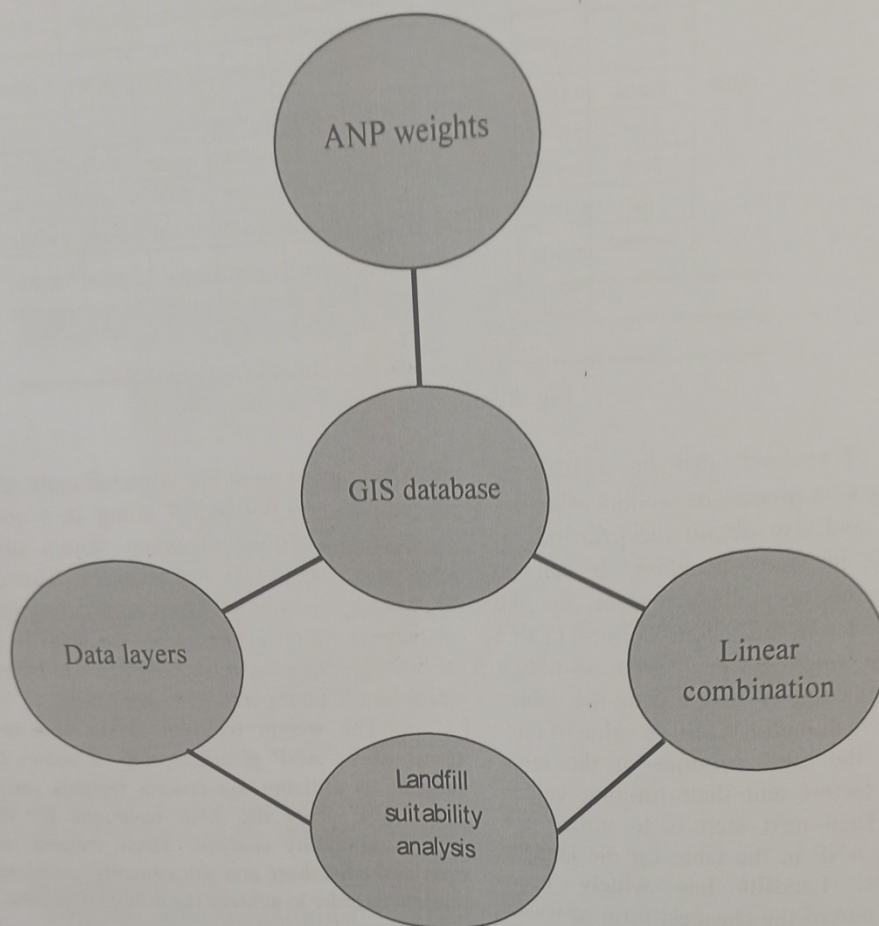


Fig. 9 ANP-Landfill suitability model

Conclusions

Weight estimation is now an important aspect of land suitability analysis and planning and other problems that involves multi-criteria decision making. The quality of the result or model very much depends on the estimated values of the factors or criteria used in the study. In this study an important aspect of waste management referred to as landfill siting problem is considered after estimating weights involved in the siting criteria using the ANP technique. The ANP is a reliable approach to weight estimation as it takes into account both dependence and feed back in the decision making process. The ANP model demonstrated in this study using landfill siting criteria data show that the weight of factors can be produced. Most recent research involving landfill siting considers criteria used here, however judgments in relations to these factors may defer depending on specific considerations and constraints, the ANP technique considered here can be used to ascertain the relative weights of similar problems else where. To present a more sophisticated example for land suitability analysis problems, further study will be directed towards the consideration of more factors or criteria, sensitivity analysis and more data handling. By integrating a range of data, more informed decisions can be made on the suitability of land for landfill.

References

- Aragone, P., Aznar, J. (2008) Valuation of urban industrial land: An analytic network process approach *European Journal Of Operation Research* 185.
- Araz, C., Ozfirat, P.M., Ozkarahan, I. (2006). An integrated multi-criteria decision making methodology for outsourcing Management *Computers and Operational Research*, 34, (12): 3738-3756.
- Bahceci, I., Topkaya, B. (2008) Landfill site selection using GIS methods. *Fresenius Env. Bulletin* 17, (11) A: 1859-1867.
- Brans, J.P., Vincke, P., Mareschal, B. (1986) 'How to select and how to rank projects: the PROMETHEE Method' *European Journal of Operational Research*, 24 (2): 228-238.
- Burrough, P. A (19986) *Principles of Geographic Information Systems for land Resources Assessment* Clarendon Press, Oxford.
- Chang, P.T., Lo, Y.T., (2001). Modeling of Job-shop scheduling with multiple quantitative and qualitative objectives and a GATS mixture approach, *Int. Journal of Computer Integrated Manufacturing*, 14 (4): 367-384.
- Chen, Y. (2001) Formulation of a learning analytical network process. *Proceedings of the Sixth Int. Symposium on the AHP, ISAHP*, Bern-Switzerland, pp. 73-78.
- Eddie, W. L. C., Heng, L. (2004) Contractor selection using the analytic network process *Construction Management and Economic*, (22): 1021-1032.
- Hanumaiah, N., Ravi, B., Mukherjee, N. P. (2006) 'Rapid hard tooling process selection using QFD-AHP Methodology' *Journal of Manufacturing Technology Management*, 17, (3): 332-350.
- Hwang, C.L., Yoon, K. (1981) 'Multiple attribute decision making methods and applications: a state of the art survey' Berlin, Springer-verlag.
- Karsak, E. E., Soner, S., Alptekin, S. E. (2002). 'Product planning in quality function deployment using a combined analytic network process and goal programming approach' *Computers and Industrial Engineering* 44: 171-190.
- Koksal, G., Egitman, A. (1998) Planning and design of industrial engineering education quality *Computers and Industrial Engineering*, 35 (3-4): 639-642.

Kontos, T. D., Dimitrios, P. K., Constantinos, P. H. (2005) Siting MSW landfills with a spatial multiple criteria analysis methodology *Waste Management*, 25: 818-832.

Kuo, R. J., Chi, S. C., Kao, S. S. (2002) A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network. *Computers in Industry*, 47 (2): 199-214.

Meade, L., Sarkis, J. (1999). Analyzing organizational project alternatives for agile manufacturing Processes: an analytic network process approach *International Journal of Production Research*, 37 (2): 241-261.

Mujgan, S., Zehra, K. O. (2010) 'Exam scheduling: Mathematical modeling and parameter estimation with the analytic network process approach' *Mathematical and Computer modeling*, Vol. 52, pp. 930-941.

Niemura, M.P., Saaty, T. (2004) 'Analytic network process model for financial-crisis forecasting' *International Journal of Forecasting*, Vol. 20, No. 4, pp 573-587.

Piantanakulchai, M. (2005) 'An analytic network process model for highway corridor planning' *Proc. Of the International Symposium on the Analytic Hierarchy process (ISAHP)*, Hawaii.

Roy, B. (1991) The outranking approach and the foundation of ELECTRE methods, decision theory, *Math Sci. Net.* 31: 49-72.

Saaty, T., Vargas, L. G., Dellmann, K. (2003) 'The allocation of intangible resources: the analytic hierarchy process and linear programming' *Socio-Economic Planning Sciences* Vol. 37, pp 169-184

Saaty, T., (1980.) *The Analytic Hierarchy Process* McGraw-Hill, New York, USA.

Saaty, T., (2005). *Theory and application of analytic network process* RWS Publication, 4922 Ellsworth Avenue, P.A 15213.

Saaty, T., (1999). *Fundamentals of the analytic network process*, *Proceedings of ISAHP*, Kobe, Japanpp. 48-63.

Saaty, T., (2001). *Decision making with dependence and feedback: the analytic network process* Second ed. Rws Publications, Pittsburgh, USA.

Saaty, R.W., (2003) *Decision making in complex environment AHP and ANP for decision making with dependence and feedback super decision tutorials*, creative decision foundation 4922 Ellsworth Avenue Pittsburgh,

PA 15213.

Sumathi, V. R., Natesan, U., Sarkar, C. (2007). 'GIS-based approach for optimized siting of municipal solid waste landfill,' *Waste Management*, doi: 10.1016/j.wasman. 2007.09.032.

Tchobanoglous, G., Theisen, H., Vigil, S. A. (1993). *'Integrated solid waste management': Engineering principles and management issues*. Mc Grow-Hill, New York, USA.

Wang, G., Qin, L., Li, G., Chen, L. (2009) 'Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. *Journal of Env. Management* Vol. 90, No.8, pp. 2414-2421.

Wey, W., Wu, K., (2008). Interdependent urban renewal project selection under the consideration of resource constraints *Environment Planning and Design*, Vol. 35, pp. 122-147.