INTEGRATION OF GIS BASED SUITABILITY ANALYSIS AND MULTI CRITERIA EVALUATION FOR URBAN LAND USE PLANNING; CONTRIBUTION FROM THE ANALYTIC HIERACHY PROCESS

K.G.P.K. Weerakoon
Senior Lecturer
Department of Estate Management and Valuation
University of Sri Jayawardenepura
Nugegoda,
Sri Lanka
Email: kgpk@sjp.ac.lk

ABSTRACT

Rapid urbanization is proceeding and pushing up the demand for various land uses mainly residential, commercial, industrial etc. Indeed land is the essential ingredient in this process as in all urban growth. This growth has been associated with increasing pressure on land for human settlements and related urban services. The problem in Sri Lanka like more developing countries, is not a shortage of developable land, but the in effective and unplanned mechanisms the use to ensure supply of suitable land for urban expansion. The trend of the development of this nature bears a heavy impact on the urban land development as evident from the horizontal expansion of urban centers. As a result of that increased development pressure on agricultural lands in immediate surroundings of urban centers as further aggravated the problem of conservation of the natural environment. In present urbanization paid insufficient attention for the environment in developing countries. As a result of that ecologically valuable lands are converting to urban development without consideration of the environment. Hence there should be pay more attention for multi-criteria land evaluation for avoiding these facts.

A GIS is a powerful tool for land use planners in their effort to make land development processes more efficient and attractive. In recently fuzzy logic screen as the basic for representing and manipulating in exactness in a relational geographic database and multi-criteria methodology was connected with these recent models. Saaty's analytic hierarchy process (AHP) (1980) is compatible with both these research directions.

This paper demonstrates the application at fuzzy set theory in GIS for urban land use planning. The results indicate the future land directions and present land evaluation compatible with multiple criteria methodology. Present land evaluation is most useful for planners for there sound judgment on land allocation.

1. INTRODUCTION

Sustainable development is a more recent concept of linking environmental, economic and social use values. The concept of land use change management screens the balance of these three values for land use planning. Land use management and policy decisions are almost always based on the analysis of the factors pertaining to each particular issue. When considering the sustainable development of land, land use change management is an important phenomenon.. The content of land use change

management can be described in terms of three value sets (ecological, social and market values) that must be brought into balance by land planning.

. In this context a Geographic Information System is one of the best tools to analyze land uses. Since urban land use is complex, multiple land uses need to be taken into consideration when analyzing the urban land.

2. APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN LAND USE PLANNING

Geographic data have been traditionally presented in map form. Land analysis is commonly done with map overlay and it used to be done manually. McHarg (1969) describes how using manual map overlaying can do systematic land use planning. As the use of computer technology has grown, the more efficient digital form has progressively replaced manual map preparation. This rapidly evolving technology is known as Geographic Information System (GIS). GIS is a computer-based system that is used to store and manipulate geographic information. This technology has developed so rapidly over the past two decades and it is now accepted as an essential tool for the effective use of geographic information.

A GIS can provide better information to support this type of complex decision-making. With the rapid advancements taking place in computer hardware and GIS software, more complex models are being developed. These models help researchers and planners to simplify complex systems and to develop theory to understand the process at work better. Present analytical functions and conventional cartographic modeling techniques in GIS are based on Boolean logic, which implicitly assumes that objects in a spatial database and their attributes can be uniquely defined (Sui, 1992). In the land evaluation process, with Boolean classification, all land units with values that exceed the given threshold may be defined as the class or set of acceptable land units which are to be rejected (Banai, 1993). These uncertain boundary definitions create some problems with loss of information.

The deficiencies of the traditional Boolean logic for the design of spatial databases have been recognized in recent years (Borrough, 1986; 1989, quoted in Sui, 1992). As an alternative to Boolean logic, Zadeh's fuzzy set theory has been proposed as a new logical foundation for GIS design (Robinson, 1988; Leung, 1989 quoted in Sui, 1992).

3 FUZZY SET THEORY

Fuzzy logic methodologies may provide a scheme for the representation and manipulation of the uncertainty, which is related to the classification of individual locations according to their attribute values**.** It implements classes or groupings of data with boundaries that are not sharply defined.
Fuzzy set theory suggests that the inclusion of an element with in a set is a matter of determination of the degree of belonging

The central idea of fuzzy sets can be aided by the Analytic Hierarchy Process (AHP) to achieve operational economy of application in the evaluation of land suitability. For multi-criteria evaluation, Saaty's Analytic Hierarchy Process (AHP) is used to determine the weights of each individual criteria. (Saaty, 1990). AHP is a mathematical method to determine priority of the criteria in the decision making process. It is a popular tool used by decision makers in multi-attribute decisions.

4 MULTI-CRITERIA EVALUATION

Mc Harg (1968) introduced a systematic land use planning by using the concept of compatibility of multiple land uses. He mentioned that the factors affecting land and its relative values are different and therefore it is difficult to think of optimizing them for a single use. It can be optimized for multiple compatible uses. He introduced simple matrix system for determining the degree of compatibility. The idea of multi-criteria decision-making was based on this concept. Recent developments in geographical Information Systems have drawn upon concepts of the multi-criteria methodology.

5. ANALYTIC HIERARCHY PROCESS (AHP)

AHP is a multi-criteria decision method that uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgment of the user (Saaty, 1980). Saaty has shown that weighting activities in multi-criteria decision-making can be effectively dealt with via hierarchical structuring and pairwise comparisons. Pair wise comparisons are based on forming judgments between two particular elements rather than attempting to prioritize an entire list of elements (Saaty, 1980). The AHP scales of pair wise comparisons are as follows.

Table 1: The AHP scales for paired comparisons.

Intensity of importance	Definition and explanation
1* 3 5 7 9 2,4,6,8 Reciprocal of above numbers Rationals	Equal importance-two activities contribute equally to the objective. Moderate importance - Experience and judgment slightly favor one activity over another. Essential or strong importance - Experience and judgment strongly favor one activity over another. Demonstrated importance - An activity is strongly favored and its dominance is demonstrated in practice Extreme importance - The evidence favoring one activity over another is of the highest possible order of affirmation. Intermediate values between the two adjacent judgments when compromise is needed. If an activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with I. Ratios arising from the scale - If consistency were to be maintained by obtaining n numerical values to span the matrix.
* The scale 1.1, 1.2,.....1.9, or even a finer one, can be used to compare elements that are close together, or near equal in importance. Similarly for 2,.....,9	

(Source: Adapted from Saaty (1987)

Based on this AHP method, design a spreadsheet package called EXPERT CHOICE and it is use in calculating weight for each layer. It has an ability to calculate weights, for multiple criteria with pair wise comparisons. Hence, created fuzzy set maps, providing that the AHP process could cope with fuzziness factor diversity and problem complexity,

although the calculation weights were done outside of GIS. This paper also concern about this method for defining land evaluation.

6. AN APPLICATION: SUB URBAN AREA - SRI LANKA

6.1 Background

The development of market-oriented economy in Sri Lanka has led to an urgent need for urban land evaluation because of the rapid conversion of the agricultural lands into urban uses. Therefore there is an urgent need for identifying lands for future development. The author believes that the fuzzy GIS modeling technique, outlined above, can be used to achieve these objectives.

This is a one of sub urban area in Colombo It located in 7km from Colombo, called Maharagama. According to the development plan, the general profile of the study area stated that projected total population in the year 2011 would be 144,924. It indicates that the whole area will have to accommodate 38,000 additional people in the next 15 years. As a result of close proximity to the city of Colombo and good surrounding environment, demand for land will increase. In the recent past, the land values in the area have increased at an alarming rate. This is partly due to present unplanned development and misuses of the land. As a consequence valuable agricultural land have been converted to urban uses without proper planning. If land use is planned the supply of land for various uses can be increased because at present the problem is not really one of scarcity of land. Planners therefore, have a responsibility to identify and regulate suitable land for development.

Urban land is a scarce resource, therefore need to get highest and best use of land. In this case development of land, as well as conservation of land are important because most developments undermined the ecological balances of the land. Therefore development and conservation is a combined process in land development. Therefore while considering developable land for development environmental sustainability should be taken into consideration, for maintain the ecological balance. Conservation of certain land is, therefore, vital.

6.2 Identification of Land for Future Development

When considering lands for future development the suitability depends on developability and road accessibility to a great extent. In the study area the road accessibility is reasonably good. All lands are not more than 500 meters away from a major or a minor road. As a result when lands are buffered it always falls outside the area. This indicates that road access is not a constraint in determining developable suitability. Hence developability is considered as the main suitability factor. Developable land can be grouped into five sub categories. These sub-categories of land cannot be given equal importance and therefore the necessity arises to attach weights according to their level of importance.

Taken into consideration of soil condition, field observations and public opinion scores were given to various land uses. To determine the weights these scores need to be converted to AHP scales. (Table 1 describes in them AHP scales.) After converting to AHP scales, a matrix was prepared as shown in Table 2. Expert choice computer package used for convert the AHP scales.

Table 2: Relative weights of the suitability factors for development

	OA	RU	CO	M	P	Weight
OA	1	2	2	8	9	0.411
RU	1/2	1	1	7	8	0.255
CO	1/2	1	1	7	8	0.255
M	1/8	1/7	1/7	1	2	0.046
P	1/9	1/8	1/8	1/2	1	0.032

OA = other agriculture, RU = rubber, CO = coconut, M = marshy land, P = paddy

Based on these weights suitability ranges were identified as shown in Table 3. The maps 1 showing the land suitability for future development was prepared by feeding these weight categories into the GIS environment.

Table 3 Suitability Classification

Suitability ratings	**Range of weights**
Highly suitable	More than 0.3
Moderately suitable	0.1 - 0.3
Least suitable	Less than 0.1

6.3 Identification of Land for Conservation

The rapid land development that has occurred due to high demand during the last several years has led to an unplanned development trend. If this continues it may affect the environment of the human settlements. General terrain of this area is flat and this unplanned development will cause environmental imbalance due to lack of natural drainage. Therefore, it is imperative to conserve some land to sustain the natural drainage system. The marshy lands and water bodies at present serve this purpose. These lands, therefore, should not be developed for urban activities and instead should remain as conserved land. The paddy lands also should be earmarked for preservation. When suitability of land is considered slope and soil type also should be taken into consideration. The slope variations in the study area are minimal. Thus the effect of omitting the slope factor will not be marginal.

Therefore, considering the conservation, only five factors were identified. Such as, paddy land, all other agricultural land , marshy land, water bodies and quarry land. But each type of land use cannot be given equal weight. Hence the Contribution made to maintain the ecological balance and scenic beauty were taken as the criterion for determining the land for conservation. The weights calculated on the basis of the scores given are presented in Table 4

Table 4: Relative weights of the suitability factors for conservation

	W	Q	P	M	OA	Weights
W	1	1	1	3	9	0.285
Q	1	1	1	3	9	0.285
P	1	1	1	1	9	0.285
M	1/3	1/3	1	1	7	0.117
OA	1/9	1/9	1/9	1/7	1	0.027

W = water bodies Q = quarry land P = paddy M = marshy OA = other agriculture
The weights thus obtained were then categorized into three classes (Table 5).

Table 5 Suitability classification

Level of suitability	**Range of scores**
Highly suitable	more than 0.2
Moderately Suitable	0.1 - 0.2
Not suitable	less than 0.1

Following this grouping the land in the study area was classified using GIS facilities. (Map 1, map2) Final result was obtained after overlaying the two maps. Final map (map 3) shows highly and moderately suitable areas for future development and highly and moderately suitable areas for conservation.
Identification of highly suitable land for development and conservation are significant to planners, for decision-making process. Also planner should be concern the other areas, and wants to take exert judgment to decide weather land should be developed or conserve. Therefore this GIS application helps to describe the future development trends.

7. CONCLUSION

The Analytic Hierarchy Process (AHP) method commonly used in multi-criteria decision making exercises was found to be a useful method to determine the weights. Compared with other methods used for determining weights, e.g. Delphi method, the AHP method is superior because it can deal with inconsistent judgments and provides a measure of the inconsistency of the judgment of the respondents.

The GIS is found to be a technique that provides greater flexibility and accuracy for land use planning in urban areas. Although urban planners have conducted similar exercises in the past using manual methods, the GIS can perform these tasks much faster. The combination of AHP method with GIS is a new trend in land use planning exercises and this study confirms that the findings of other researchers could be a powerful combination to apply for land use planning.

This evaluation is useful for planners for their future urban expansions. Least suitable areas for development and conservation is important to decision making, when making a planning decision it should be considered. These combinations are difficult areas for decision-making process. At that time planner want to exert judgment to decide weather land should be developed or conserve.

References

BANAI, R. 1993, Fuzziness in Geographic Information Systems: contributions from the Analytic Hierarchy Process, *International Journal of Geographic Information Systems*, Vol 7, No4; 315-329

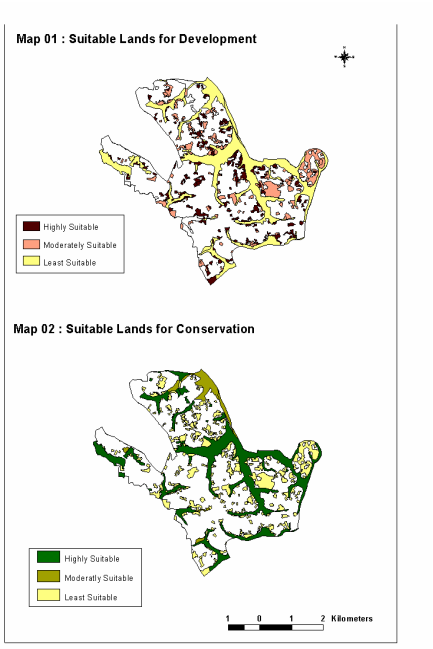
EXPERT CHOICE, 1988, Decision Support Software, Inc., McLean, Virginia.

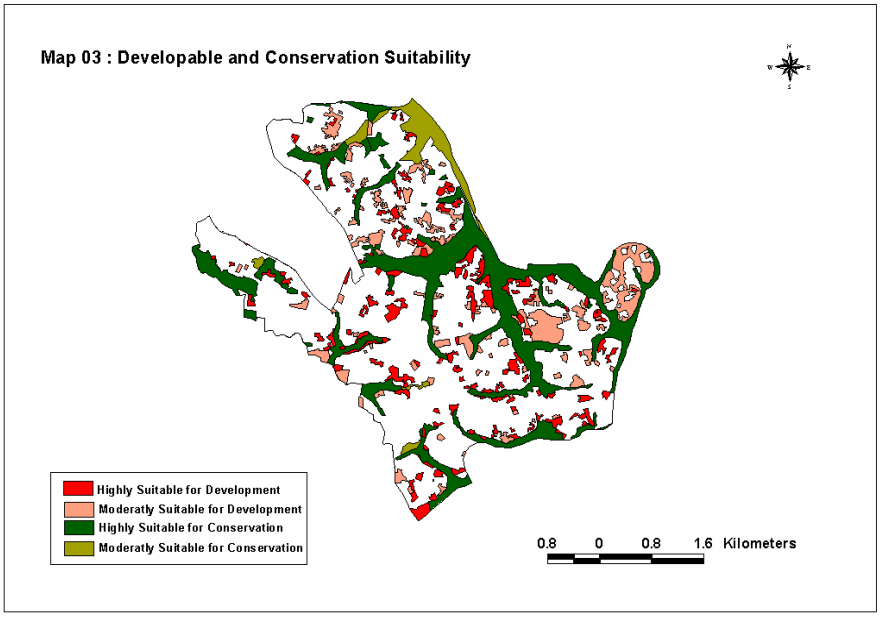
KAISER ET, AL. 1995, Urban Land Use Planning (forth edition), University of illinos, U.S.A.

MCHARG, I. 1969 Design with Nature, National History Press, New York.

SUI, D.Z, 1992, A Fuzzy GIS Modeling Approach for urban Land Evaluation, *Computer Environment and Urban Systems*, Vol. 16, pp, 101-115,

SAATY, T.L.1980, The Analytic Hierarchy Process, McGraw-Hill, New York.


Map 01 : Suitable Lands for Development
Highly Suitable
Moderately Suitable
Least Suitable
Map 02 : Suitable Lands for Conservation
Highly Suitable
Moderatly Suitable
Least Suitable
1 0 1 2 Kilometers


Map 03 : Developable and Conservation Suitability
Highly Suitable for Development
Moderatly Suitable for Development
Highly Suitable for Conservation
Moderatly Suitable for Conservation
0.8 0 0.8 1.6 Kilometers