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New Multicritera Approach for Urban Facility Management by Applying GIS

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Abstract: The increasing level of urbanization growth has created many environmental problems which threaten urban life in the most of developing countries. Many different spatial models are used world wide for urban facility site selection. The most common models such as fuzzy logic, regression, artificial neural network, index overlay and taxonomy which each has its advantages and weaknesses. Today urban authorities are eager to find the right ways to increase the efficiency of the urban facilities with less environmental cost. This paper tries to integrate some of the models to propose a new integrated model by using GIS. The intent here is to design a model which could be generalized to many developing world. The method is practiced by selecting an example like waste disposal to realize the model. The fuzzy logic and analytical hierarchy process (AHP) model were integrated with many socio-economic and environmental factors to select the best location for the solid waste disposal with least negative environmental impact on urban areas. The results revealed that the multi criteria models have the potential to be generalized to the all cities of the world. Moreover the model used multi factors to evaluate the different alternatives to find the most appropriated option. The present model has a high accuracy than the traditional methods which are common in developing countries.

Key words: Fuzzy Logic · AHP · Solid waste management · GIS · Iran

INTRODUCTION

The unprecedented population growth and the application of technology with the change of living style in one hand and the limitation of natural resources in other hand created many complicated situation in most of the developing countries and led to socio-economic disintegration which ultimately resulted severe environmental problems [1-2]. One of the main problems in modern urban life is the production of a large scale solid waste in different quality and quantity. The increasing rate of urban population growth in Iran and the lack of comprehensive policy led to an inappropriate monitoring of national and urban comprehensive plans. So, the continuous pouring of waste and sewers to public places has threatened the health quality of urban residents and their environment [3-4].

The capability of GIS as a set of soft and hardware has proved to be suitable world-wide to site selection for solid waste management [5-6] .A study by Shrivastava and Nathawat [7] using GIS and RS showed that the pair comparison of different indices is quite useful to determine an appropriate site for waste disposal. The APA states that proper site selection is the main principal of approaching sustainability in the 21st centaury [8]. Today, the management of urban waste is the main challenge of most urban authorities and planners. Solid waste management is a serious crisis in urban areas of the country. One of the common methods for solid waste disposal is deposing them in the different layers of the ground in empty lands of the cities. Evidences show that most of the solid waste disposal sites are not appropriated for dumping.

MATERIALS AND METHODS

Different Types of Integrated Information Models for Site Selections: One of the main capabilities of GIS as an exclusive system is its potential of integration, modeling, and site selecting through land evaluation [9]. By integrating and compositing the different criteria, the most appropriated location can be selected. There are different methods for criteria composition which some of them include as follow:

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Boolean Logic: This logic originated from the name of an English mathematician Gorge Boolean who by valuating each unit of information layer on the base zero and one value. The model was used by Warns in 1947 and then was extended by Robino in 1989 . The logical composite of values is in two ways; yes or no. Each place examined by valuating as true or false and so there is not another option [9]. In the end the model introduces a location which is appropriated or inappropriate for a given activity. The main shortcomings of the model are:

- It can not be applied to the real world because the results of the model are 100% true or false.
- If the criteria become inappropriate in the process of sitting, that location will be omitted.
- Also when the criteria are many, the model has no capability to find an appropriate location for site selection.

Index Overlay: In this model the different factors and classes are given different values and then a set of flexible maps will be produced which have a range of numbers. For example, gradient has different degrees for different purposes which may change from 3 to 10% or more. Here, an appropriate gradient for urban development is between 3 to 8%. The process of weighting will be done for fault line, gradient direction, soil and etc. Then by two variable analyses the layers composite and each location with higher values would be selected.

Probability Logic: In this model by using coincident coefficient model, Kappa indicator, entropy, Moran indicator and Cramer and so on the different information layers would be integrated and then analyzed in two or multi layers.

Coefficient Correlation: Two layers will be analyzed on the base of their relationship. For instance, the relationship between height and temperature, disease distribution and population density. The aim is to find the degree of association which may be high or low. The weighting of the layers is on the base of highest correlation coefficient.

Artificial Neural Networks: This is a kind of modeling on the nature of human mind, which is simulated by using mathematical models. Application of this model for integrating layers and variables is in its initial stage.

Analytical Hierarchy Process (AHP): It is one of the most efficient techniques in decision taking. This technique is based on pair comparison and gives the possibility to study different options by the urban managers. Many researches show that AHP technique has proved to be quite useful when is integrated with GIS for site selection. Eldin and Eldradaly [4] applied AHP and GIS to select the best place for some urban utilities. They tried by using these two tools to reduce the users intervention and skills level. Sung et al.[10] used AHP technique to site selection for rail way lines. They tried to avoid some of intimate problems of the AHP such as dependency of questionnaire to each other or the dependency of results to the given groups which may bias the whole work; they used fuzzy logic and sensibility analysis for the different value of weighting.

Fuzzy Logic or the Logic of Black and Uncertainty: Fuzzy logic was first developed by author in order to provide mathematical rules and functions which permit natural language queries. Fuzzy logic provides means of calculating. It enables many concepts, variables and systems to be illustrated mathematically and provided a background for reasoning, control and decision making in the uncertain conditions. Membership degree, combination, joint, similarity, complement, multiple, plus, gamma are the basic powers of this integrated model. For creating layers and fuzzy set the mathematical functions of linear threshold, sigmoidal, S shape, hyperbolic and etc can be applied. For example, sitting for urban utilities such as power station several variables like distance from transport network or a fault line must be studied. Membership degree would be determined as follow (Eq.1):

$$F(x) \begin{cases} \dfrac{X_{max} - X}{\Delta x} = \text{value} & \text{If } x < 1000 \text{ m} \quad (1) \\ & \text{If } 4000 < x < 1000 \text{ m} \\ & \text{If } x > 4000 \text{ m} \quad (0) \end{cases} \tag{1}$$

Here, the fuzzy amount of 1000 points from transport network equals 1, and the fuzzy amount for 4000 points from even transport network is 0, and this amount would be 0.46 for 1600 point from transport net work which all have been resulted from linear threshold function. For all of the other layers these procedures could be set up and the space of the area would be weighted. The only weakness of the model is the substandard weighting in connection with different attitudes of users. Nonetheless this model is one of the most applied integrated models in urban planning.

Applying the Integrated Model by Selecting the Example of Solid Waste: There is not a standard definition of factors for site selection of solid waste disposal, however, but four important variations consist from: *Gradient*; in

this model gradient is a physical parameter, in high slopes waste disposal is impossible as in the rainy season the waste leakage pollutes the area and the establishment of needed utilities like road is high costing. So the best degree of the gradient is 3-6%. *Precipitation*; rain with soil erosion accelerates the leakage of the waste and transfers the chemical and organic pollutants into main water channels. This condition leads to diffusion of insects and other animals which can threat the nearby communities. *Wind direction*; one of the obvious problems of waste minefield is the bad smell which causes discomforts for the near settlements. Clearly wind direction can make the condition worst. *The average disposal duration;* waste disposal land must cover 20 to 40 years due to population growth which usually each damping field is. According to the American Planning Association (APA) research, the area of land determined by using following formula:

$$V = R/D\ (1-P/100) + VC \qquad (2)$$

Where; V = needed space for a year
R = per capita production
VC = the needed cover soil
P = the % of decreased waste volume due to compression
D = the average density of waste

The Municipality Organization of the Interior Ministry of Iran has determined some criteria in 2000 which seems inappropriate to be generalized to all parts of the country. These Criteria are:

- About 300 m from drinking water well.
- About 100 m from surface water resources.
- Displacing from the heavy rain area.
- At least 10 m clay soil under the surface.
- Away from dominated wind direction.
- At least 80 to 100m from fault line.
- At least 30 years of return flooding period.
- Silt clay of surface soil and sand silt in next stage.
- Less than 40% gradient.
- 300 m from population centre like schools and public parks.
- At least 2 to 3 and maximum 20 km from cities.
- 6 to 7 width for adjacent transport lines.
- Away from agricultural, forest, wetland and rangeland.
- At least 8 km from airport.
- At least 700 m from historical sites.
- Land price should be 50% lesser then the most expensive land in the area.

As mentioned already the above factors need to be altered with respect to each region for more accuracy and generalization. In order to applying the model two main stages will be followed. In the first stage by using fuzzy logic and with respect to the different criteria several sites will be selected as alternatives for waste disposal. And in the second stage by using AHP model the alternative sites will be analyzed. Then with the special attention to the socio-economic and political considerations the best place for the disposal will be recommended. Fist stage: The fuzzy theory is able to answer many of imprecise and ambiguous variables, concepts and systems through matematication. So, it provides a good ground for reasoning, control and decision making in an uncertain condition. Therefore the membership degree of variables will be obtained with respect to the selected criteria and informational layers of the research as follow:

For example distance from the urban utilities and fuel station, slaughterhouse would be (Eq. 3):

$$\int_{0}^{600} 1/X + \int_{600}^{2700} 2700 - X/2400 + \int_{2700}^{\partial} 0/X$$

Max distance = 2700 m, Min distance = 600 m,
The number of class = 7 class, Data range = 300 m

First class = 2700-300/2400 = 1,
Second class = 2700-600/2400 = 0.87,
Third class = 2700-900/240 = 0.75

For the all layers these operation were repeated and the value has been obtained with relate maps. Then by using of overlaying functions in the GIS the layers were integrated with their membership degree. In the process the sum of each column value of final maps and their classification in the different classes, some sites which had the highest value selected for the final analysis in the second stage.

Second stage: in order to apply the AHP model on the selected sites, firstly some of the socio-economic and political considerations will be studied. This stage give an opportunity to all the local decision makers to choose the best site for waste disposal one hand and also it regulates the preferences of local authorities to avoid any personal view on the other hand [11-14]. The following steps needs to be taken for the application of. Model.

In the first step knowing the preferences of local decision makers such as socio-economic and political considerations would be a great help to execute the final proposals. Obviously, interview, questionnaires and the study of any old projects considering the issues clarify

Table 1: The pair wise matrix

Consideration	Social	Economic	Political	…..
Social	1	2	3	5
Economic	0.5	1	2	3
Political	0.3333	0.5	1	2
…..	0.2	0.3333	0.5	1

Therefore the amount of above criteria values is as Table 2.

Table 2: Value of the criteria

Criteria	Value
Social	0.4829
Economic	0.2720
Politic	0.1570
etc	0.0881

the situations. In second step after criteria selection the pair wise matrix would determine (Table 1 & 2).

The third step: in this stage with respect to the value calculation in the AHP model, the total value of each alternative would be determined and then the site with the highest advantages will be selected for solid waste disposal.

DISCUSSION AND CONCLUSION

As discussed before the selection of an appropriate site for urban facility is one of the most controversial challenges for urban municipalities and particularly caused many socio-economic and political disputes among the different bodies of local decision makers and the people. In many developing cities of the world, in the case the solid waste management now is a real problem and it needs a huge amount of funds which the cities are lacked already for the major urban infrastructures. So, to find an optimum place for waste disposal the right way to approach the best site is applying of the present model in cities. In this study we tried to evaluate all involved factors by using integrated fuzzy logic and AHP in the GIS environment. The main purpose was to find the most appropriate place for solid waste disposal. The main conclusions are as follow:

- As we saw many diverse and different factors affect the urban facility location that the comprehensive analysis of them is impossible in the traditional methods. So using the means of GIS can analysis a great amount of data and information.
- The integrated fuzzy logic and AHP model provide an efficient and comparative potential for different alternatives by evaluating many factors.
- The model has the capacity to include the preferences and considerations of local authorities and the people which could be quite vital to realize the model in the area.
- The model has the potential to be generalized for other urban areas particularly in the three northern provinces of Iran.

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