A Combined Model of GIS and Fuzzy Multi Criteria Decision Analysis (FMCDA) for Suitable Evaluation/Selection of Industrial Areas, (Birjand, Iran)

MEHDI ZIAEI[1], FATEMEH HAJIZADEH[2], SEID SAID REZA AHMADIZADEH[3],

KOMEIL JAHANIFAR[4]

1- Department of Civil and Environment Engineering, University of Birjand, Birjand ,IRAN
Email: Meh.Ziaei@yahoo.com

2- Department of Civil and Environment Engineering, University of Birjand, Birjand ,IRAN
Email: Hajizadeh_najmeh@yahoo.com

3- Department of Civil and Environment Engineering, University of Birjand, Birjand ,IRAN
Email: Ssahmadizadeh@yahoo.com

4- Department of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, IRAN Email: K_Jahanifar@yahoo.com

Abstract: - Suitable site analysis is a key factor in urban planning and a wide range of decision making and management situation. One of the issues that has recently been taken into consideration is site selection for installing industries to prevent from probable environmental crises and also to appropriately utilize all resources.

In recent years, the integration of multi criteria decision analysis (MCDA) techniques with geographic information system (GIS) has considerably advanced the map overlay approaches to site suitability analysis. The main objective of this paper is to incorporate the concept of fuzzy set theory into the GIS-based MCDA. MCDA is utilized for assigning weights of the criteria for site selection and fuzzy is used to determine the most suitable alternative using these criteria weights. In this paper, first effective criteria were recognized for site selection of industrial areas such as slop, landuse, agriculture, fault, soil type and etc, then they were prepared in the form of information layers in the GIS environment. In the next phase, using expert opinions, for each criterion according to its importance, weight was assigned and weight layers were consolidated by conducting fuzzy Logic in GIS environment and finally the best places were chosen for establishing industrial areas. Results show that a creative methodology and a new tool has been developed and designed to help in the process to facilitate decision making at urban and regional planning.

Key-Words: - Site Selection, GIS, Industrial Areas, Fuzzy Multi Criteria Decision Analysis (FMCDA)

1 Introduction

The location of industrial areas is a key factor in regional planning due to the socio-economic benefits and environmental sustainability [1] and also it is one of the most important decision issues for government departments and industrial organizations[2] .

Identifying an optimal site for industrial areas is an extremely difficult and complicated process

ISBN: 978-1-61804-090-9

because it requires data from diverse social and environmental fields and a number of conflicting qualitative and quantitative criteria existed for evaluation/selection.

To solve this problem, various researchers proposed many methods. GIS and MCDA are currently the two most common decision support tools employed to solve spatial decision-making problems [3]. GIS is a computer-based technology and methodology for collecting, managing, modeling and presenting geospatial data for a wide range of applications and the MCDA techniques are decision support tools designed to analyze decision problems, generate useful alternative solutions and evaluate alternatives based on the decision maker's values and preferences[1].

The general objective of these methods is to assist the decision-maker in selecting the best alternative. The MCDA is mainly used in nearly all crisp decision applications. It does not take into account the uncertainty associated with the mapping of people's judgment to an evaluation scale [3, 4] . Hence, in this research, the authors used the Fuzzy Logic, which is one of the most common used approaches to these kinds of problems.

In recent years, the integration of Fuzzy MCDA techniques with GIS have considerably been advanced to evaluate/select the optimum alternative[5,6,7]. The research of M. C. Ruize Puente et al. presented a new model of industrial areas location based on sustainable criteria using GIS and fuzzy logic. It defined three complementary evaluation levels related of the geographical scale in which the analysis takes place [8]. Tangestani used also fuzzy logic in order to help the planners for selecting suitable locations to implement development projects landslide susceptibility [9]. Research of Akbari and et al. has been done about Fuzzy MCDA alongside with a geospatial analysis for selection of landfill sites [10]. It employs a two stage analysis synergistically to form a spatial decision support system for waste management in a fast-growing urban region, south Texas.

This paper proposes the approach of fuzzy multi criteria decision making (FMCDM) methodology based On GIS-MCDA for Industrial site selection. The remainder of this paper is organized as follows: The theoretic descriptions for the FMCDA methods are presented in section 2. In section 3, a real world case study is presented, the results are discussed and a sensitivity analysis is conducted. Finally, the paper is concluded in section 4.

2 Theoretical principles

The goal of a site selection/evaluation exercise is to find the optimum location that satisfies a number of predefined criteria [11].The decision makers consider the existing alternatives which have different attributes and characteristics and the final job is to choose the best among them [12]. It is a complicated process and a number of conflicting qualitative and quantitative criteria existed for evaluation/selection. MCDA for structuring decision problem and evaluation/selection alternatives provides the management team has already a rich collection of methods [13]. Although many techniques have been applied to MCDA, the target of conventional MCDA based on GIS research principally involved application to field around the spatial data and spatial analysis [14].

2.1 GIS-MCDA and Site selection/Evaluation

GIS has been found to play key role in the domain of site selection. The potential advantage of a GIS-based approach is reductions time and cost of site selection, but also provides a digital data base for long-term monitoring of the site [15].

A decision maker frequently faces the problem of identifying a solution from a finite set of alternatives. GIS-MADA deals with the problem of site selecting an alternative from a set of alternatives characterized by multiple attributes.

In such a situation, a number of tools are available to determine the best site [16]. These tools consist Expert Systems (ES) and Decision Support System (DSS). But, combining a GIS with MCDA techniques can help site selection in cases where the problem is ill-structured, meaning that decision-makers do not have complete and reliable information regarding specifications, alternatives and outcomes [16, 17, 18].

GIS-MCDA is a process that combines and transforms criteria map (the input) into a decision (the output). This process consists of procedures that involve the utilization of geographical data, the

ISBN: 978-1-61804-090-9

decision maker's preferences and the manipulation of data and preferences according to specified be transformed into final ranking of alternatives [19].

2.2 GIS-FMCDA

Also the GIS and MCDA can benefit from each other as two area of research, the limitation incorporating whit GIS and MCDA are still existed. In order to overcome the shortcomings, fuzzy set principle is used to integrate MCDA to determine the best alternative [20]. As the foundation of fuzzy theory put forward by Professor Zadeh[5], was also the extension of traditional aggregation conception[20]. This idea is to consider the spatial object on a map as members of a set. In classical set theory, an object is a member of a set if it has a membership value of 1, or not a member if it has a membership value of 0. In fuzzy set theory, membership can take on any value between 0 and 1 reflecting the degree of certainty of membership. Fuzzy set theory employs the idea of a membership function that expresses the degree of membership with respect to same attribute of interest. With maps, generally the attribute of interest is measured over discrete intervals, and the membership function can be expressed as a table relating map classes to membership values [21].

There are various types of Fuzzy numbers and its nomenclature is, in general, associated with its format, such as: sine numbers, bell shape, polygonal, triangular, trapezoids and so on [22]. See more on[14,23]. Fig. 1 illustrated a schema of GIS-fuzzy multicriteria decision analysis.

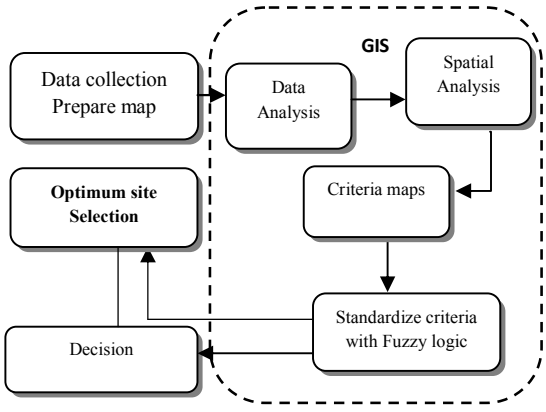


Figure. 1: Integrated GIS/ FMCDA approach

3 Materials and Methods

3.1 Study Area

The Study area is Birjand city, a fast growing center located in the South Khorasan province with a fast growing population of approximately 270000, thus becoming one of the major centers in the east of Iran. The center of this state is 59′ 13″ of east longitude and 32′ 53″ of north latitude (Fig. 2) .The city is located at an elevation of about 1400 meters above sea level and it has a dry climate with significant difference between day and night temperatures. The annual predominant wind direction in Birjand is northeast. The city's northeastern side area is occasionally subjected to soil erosion, fault line and the city's southern side area is subjected to heavy flashfloods. Hence from a perspective of urban development, the location of facilities and especially industrial areas is of utmost importance.

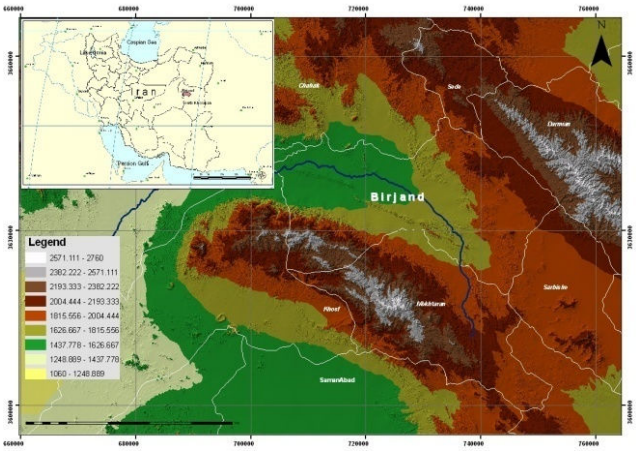


Figure. 2: Location map of the study area.

3.1 Discussion

This section presents an application of how a combined GIS-FMCDA can assist the design of alternative solutions for Suitable evaluation/selection of industrial areas. Using of spatial data and the abilities of geographical information system are important for industrial site selection. As is usual in many countries, spatially georefrenced data and its attribute data are rarely available in direct way. Therefore, the authors have chosen a built-in database from the Birjand Municipality GIS center library. Several spatial map that as criteria map have been considered for industrial areas ,are as indicated: water resources , faults, land use, slop, residential areas , existing transport facilities(road, railroads,

airport) , agriculture, historical and tourism centers, Protected areas , etc. Furthermore, it is necessary the criteria maps have same scale, therefore they be standardized before combination. A linear scaling method is applied in this research with using the minimum and maximum values as scaling points for standardization. Two kinds of equations can be expressed as follows:

$$Yij = (Xij-Xj\ min)/(Xj\ max- Xj\ min) \quad (1)$$

$$Yij = (Xj\ max - Xij)/(Xj\ max- Xj\ min) \quad (2)$$

Where:

Yij = Standardized value for ith criterion and jth option

Xij = Raw score for ith criterion and jth option

Xj min = Minimum score for ith criterion and jth option Xj max = Maximum score for ith criterion and jth option[24].

After that, it is necessary to determine the appropriate combination function in the design and implementation of practical GIS for finding the proper place. Combination functions are one of the GIS spatial analysis functions that choose appropriate places with using of input maps and combination operators. These functions are including different kinds, such as Boolean, analysis hierarchical process (AHP), index overlap, Fuzzy logic, genetic, weight of evidence [25].

In classical set theory, membership in a set or a class is crisp and defined only as either non-complete (=0) or complete (=1). In fuzzy set theory, membership in a set or a class can range from non-complete (=0) to complete (=1) [26]. In a universal set of discourse X, a fuzzy subset A of X is defined by a membership function fA(x) which maps each element x in A to a real number in the interval {0, 1}. The function value fA(x) represents the grade of membership of x in A. The larger the fA(x), the stronger is the grade of membership for x in A [27].

Fuzzy operators, such as fuzzy AND, fuzzy OR, fuzzy algebraic product, fuzzy algebraic sum and fuzzy gamma operator can be used to integrate spatial information layers. These operators are as follows:

$$AND:\ \mu\ AND = MIN(\mu A, \mu B, \mu C,\ldots) \quad (3)$$

$$OR:\ \mu\ OR = MAX(\mu A, \mu B, \mu C,\ldots) \quad (4)$$

$$Product:\ \mu\ Product = \prod_{i=1}^{n} \mu i \quad (5)$$

$$Gamma:\ \mu\ \gamma_{i=1}^{n} = 1-(\prod_{i=1}^{n}(1-\mu i)) \ y\ *\ (\prod \mu i)1-y \quad (6)$$

In this research, proper factors and criteria were determined for finding industrial areas and then were prepared for interring fuzzy function in the ArcGIS (ArcSdm) environment; afterwards the precision of obtained results was evaluated. Finally site suitability has been determined for industrial area using fuzzy model in the GIS environment. The research procedures are as follows:

- Determining criteria by experts.
- Standardizing the map layers in a GIS environment by Fuzzy functions.
- Applying the MCDA method for preparing the land suitability map layer of the targeted lands at the industrial areas in the GIS environment.

Fig.3 shows the result of the standardized criteria with fuzzy logic in the GIS environment. Standardization in the 0-1 range was performed with 0 as the minimum and 1 as the maximum suitability rate at each criterion

According to this method, there would be a limited number of places with dark color whose evaluation is very favorable. Consequently, after gathering fuzzy maps evaluation by Fuzzy operation, generally suitable site for industrial area is generated and presented in Fig. 4.

4 Conclusion

Location of an industrial area is an extremely relevant decision that affects to the future sustainability of the industrial activities in the surrounding area and the whole sustainable development in the region. In this paper, GIS and fuzzy multi criteria decision-making (FMCDM) are integrated to solve the industrial site selection problem and to develop a ranking of the potential industrial areas based on a variety of criteria.

ISBN: 978-1-61804-090-9

The study was based upon a set of key criteria. Nine criteria were evaluated in the present study, including historical and tourism centers, protected areas, slop, roads, railroads, airport, residential areas, land use, faults, water resources. The areas that were unsuitable for industrial area were initially determined and masked. To derive the final suitability map, GIS was then used to generate the criteria maps. These sites are adjacent to highly populated residential. This study has shown that FMCDA approach correctly determines the priorities. It is also the most beneficial method for estimating the weights of the alternatives.

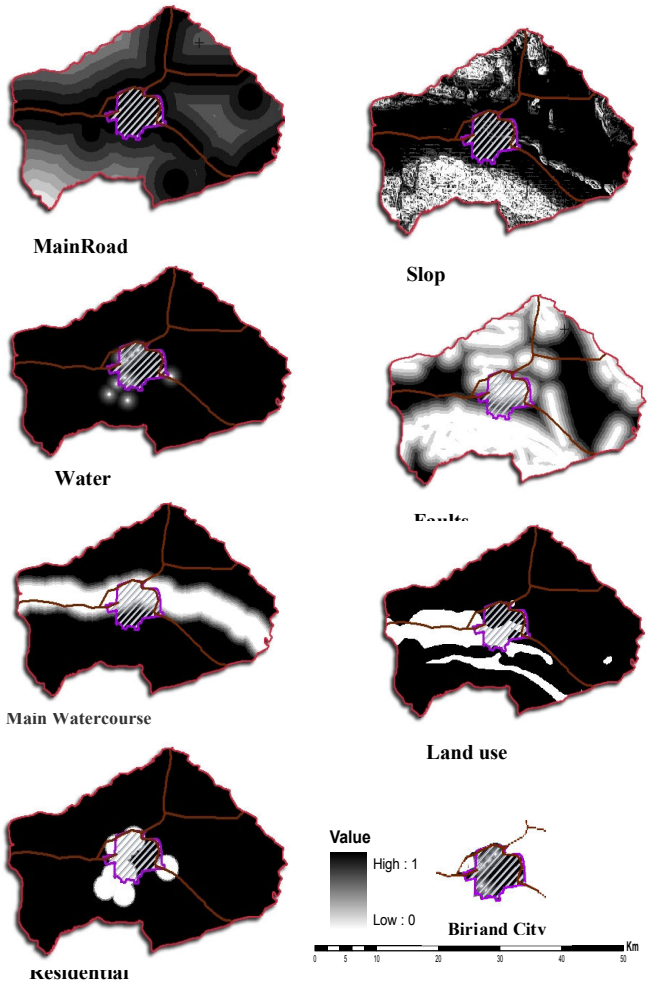


Figure 3. Thematic maps of the standardize criteria with Fuzzy logic.

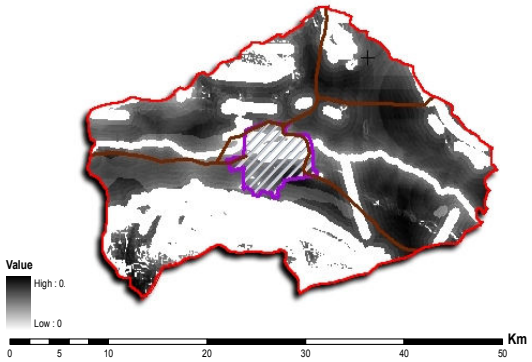


Figure 4. Industrial area suitability map by GIS/FMCDA

References:

[1] C.m. Ruiz Puente, D. Fernández and et al, The Development of a New Methodology Based on GIS and Fuzzy Logic to Locate Sustainable Industrial Areas, 10th AGILE International Conference on Geographic Information Science, Aalborg University, Denmark, 2007.

[2] T. Chou, Ch. Hsu, M. Chen, A fuzzy multi-criteria decision model for international tourist hotels location selection, International Journal of Hospitality Management, Vol.27, 2008, pp. 293–301.

[3] Kh. ldrandaly, N. Eldin, D. Sui, M. Shouman, G. Nawara, Integrating GIS and MCDM Using COM Technology, The International Arab Journal of Information Technology, Vol. 2, No. 2, April 2005.

[4] S. M. Chen, Evaluating weapon systems using fuzzy arithmetic operations, Fuzzy Sets and Systems ,Vol.77, No.3, 1996, pp.265–276.

[5] R. Banai, Fuzziness in Geographical Information Systems: contributions from the analytic hierarchy process, International Journal of Geographical Information Science,Vol.7,No. 4, 1993, pp.315 - 329.

[6] J. Malczewski, GIS and Multicriteria Desision Analysis, new York, 1999.

[7] M. Ziaei, and F. Hajizadeh, Fuzzy Analytical Hierarchy Process (FAHP): A GIS-based multicriteria evaluation/selection Analysis, The

19th International Conference on GeoInformatics, Shanghai, China, 2011.

[8] C.m. Ruiz Puente, D. Fernández and et al, The Development of a New Methodology Based on GIS and Fuzzy Logic to Locate Sustainable Industrial Areas, 10th AGILE International Conference on Geographic Information Science, Aalborg University, Denmark, 2007.

[9] M.H. Tangestani, Landslide susceptibility mapping using the fuzzy gamma operation in a GIS, Kakan catchment area, Iran, Map India Conference, 2003.

[10] V.Akbari, M.A. Rajabi, S.H. Chavoshi and R.Shams, Landfill site selection by combining GIS and fuzzy Multicriteria decision analysis, Case study:Bandar Abbas,Iran, World Application Sciences Journal, Vol.3, 2008,pp.39-47.

[11] M.H. Vahidnia, A.A.A. Alimohammadi, Hospital site selection using fuzzy AHP and its derivatives, Journal of Environmental Management,Vol. 90,NO. 8, 2009.

[12] M. Kordi, Comparison of fuzzy and crisp analytic hierarchy process (AHP) methods for spatial multi criteria decision analysis in GIS, Msc Thesis in Geomatics University of Gavle, 2008, 60p.

[13] J. Malczewski, GIS-based multicriteria decision analysis: a survey of the literature, International Journal of Geographical Information Science, Vol. 20, No.7, 2006, pp. 703 - 726.

[14] Y. Hanashima and K. Yamazaki, The iterative method in multi-criteria decision analysis: A case study of fuzzy GIS, the10th International Conference on GeoComputation. Sydney, Australia, 2002.

[15] V.R. Sumathi, U.natesan, Ch. Sarkar, GIS based approach for optimized siting of municipal solid waste landfill, Waste Management, Vol.28, 2008, pp.2146-2160.

[16] F. Witlox, Expert systems in land-use planning: an overview, Expert Systems with Applications Vol. 29, 2005,pp. 437–4 45.

[17] A. Zucca, A .M. Sharifi, A .G. Fabbri, Application of spatial multi-criteria analysis to site selection for a local park: a case study in the Bergamo Province, Italy, Journal of Environmental Management, Vol.88, 2008 ,pp.752–769.

[18] N.B. Chang, G. Parvathinathan, J.B. Breeden, Combining GIS with fuzzy multicriteria decision making for landfill siting in a fast growing urban region, Journal of Environmental Management, Vol.87, 2008, pp.139–153.

[19] SM. J. Baban, and W. Y. Kamruzaman, Modelling optimum sites for locating reservoirs in tropical environments, Water Resources Management,Vol. 17, 2003, pp. 1-17.

[20] C. H. Cheng, Evaluating naval tactical missile systems by fuzzy AHP based on the grade value of membership function, European Journal of Operational Research, Vol.96, No.2, 1997, pp.343-350.

[21] V.k. Despotakis, A.P. Economopoulos, A Model For Landfill Sitting, Global NEST Journal, Vol 9, No 1, 2007, pp 29-34.

[22] T. L. Saatya and L. T. Tranb , On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process, Mathematical and Com puter Modelling, Vol. 46, No.7-6, 2007, pp. 962-975.

[23] A. Keufmann and M. M. Gupta, Introduction to Fuzzy Arithmetic: Theory and Application. New York, 1991.

[24] H. Javaheri, T. Nasrabadi, M. H. Jafarian, G. R. Rowshan, H. Khoshnam, Site selecyion of municipal solidwaste landfills using analyticalhirarchy process method in a geographical information technology environment in Giroft, Journal Environmental Health Science Engineering, Vol.3, No.3, 2006, pp. 177-184.

[25] M. H. Vahidnia, A.A . Alesheikh, A. Alimohammadi, Hospital site selection using fuzzy AHP and its derivatives, Journal of Environmental Management, Vol. 90, 2009, pp.3048–3056.

[26] L. A. Zadeh, Fuzzy sets, Information and Control, Vol.8, No.3, 1965, pp. 338-353.

[27] T.yu. Chou, Ch.L.Hsu, M.Ch.Chen, A fuzzy multi criteria decision model for international tourist hotels location selection, International Journal of Hospitality Management, Vol.27, 2008, pp. 293–301.