Geography and human relationships, supplement1, winter2019

Land potential evaluation to Industrial development with combination the spatial and decision-making techniques (Case study, Kurdistan province)

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Submit date: 21/12/2018 *Accept date:22/04/2019*

ABSTRACT:

In this research, we are present a GIS-based multi-criteria decision analysis approach to evaluating the suitability for industry site selection in the Kurdistan province in Iran. The multi-criteria decision approach considers different criteria which are standardized by fuzzy membership functions and combined by integration of fuzzy analytical hierarchy process (FAHP) and weighted linear combination techniques. The FAHP is used for the elicitation of attribute weights while WLC method weighting layers by use of obtained weights from FAHP and multiply in constraint elements. In preparation the restriction map, we combine different constraint element by union analyst. We used of increase and decreased linear-fuzzy functions to standardization the layers, and the Gamma operator is used for the overlaying these layers. We used of three levels of gamma operator for overlaying the layers, and we compare the three result map, then we recognized that the 0.5 of gamma operator is rational and optimum.in the final stage by overlaying gamma0.5 result map with restriction map we distinguished the suitable place for industry in Kurdistan province. As a result, 0.024 percent of total province area has the best potential to industrialization.

Keywords: industry site selection, GIS, FAHP, WLC, Fuzzy logic, Kurdistan province

INTRODUCTION:

Nowadays, in each country, two factors; economic and sustainable development, are related to industry and mine capacity and type of used technology. Industrialization with optimum concentration is caused more facilities on the human lifeway. Since the the twentieth centuries beginning, industrial constructions in forms of the industrial zone, region and estate have been considered for countries industrial development (Hamid Ebadi. et al.).

In today's society, site selection problems are characterized by their multi-objectives and numerous stakeholders (Keeney R.L. et al., 1980), (*Williams E. A. et al., 1983)*. The location of industrial areas is a critical factor in regional planning due to the socioeconomic and environmental impacts which this kind of decisions has on any territory. A proper location must attend to a wide range of factors to coordinate socio-economic benefits and environmental sustainability. Access to transport and communication infrastructures, workforce availability, proximity to the primary market and the raw materials are nowadays still the main factors (Ruiz Puente et al., 2007). *An optimal site identifying for industrial areas is an arduous and complicated process because it requires data from different social and environmental fields and some conflicting qualitative and quantitative criteria existed for evaluation/selection (MEHDI ZIAEI et al.). The guidelines are applicable for use in the selection of sites for such activities as:*

- *a. New manufacturing or processing industries located within designated industrial estates or in greenfield areas;*
- *b. Expansion of existing manufacturing or processing industries which are located adjacent or close to environmentally sensitive areas or receptors;*
- *c. Facilities for waste management including waste recovery, recycle, treatment and disposal;*
- *d. Extraction and production of natural resources such as minerals and rocks; and*
- *e. Facilities for animal husbandry in feedlots or concentrated animal feeding operations (DOE, MALAYSIA, 2012).*

Some tools were used to determine the proper site for capital improvement facilities. These tools include Expert Systems (ES), geographic information systems (GIS), and Multi-criteria decision-making (MCDM) techniques (MOHAMMED A. AL-AMRI et al., 2009). *GIS-based multi-criteria decision analysis could be a useful process that combines and transforms spatial data into a resultant decision* (*Samo Drobne and Anka Lisec, 2009*). *There are many ways in which decision criteria can be combined in MCDA. A Weighted linear combination (WLC) and its variants (Carver S. J. (1991), Eastman J. R. (1997-2006), Rao M., et al., 1991) require the summation of the weighted criteria.* These tools have played an essential role in solving site selection problems. However, each tool has its limitations in addressing spatial data, which is necessary for spatial-decision issues such as site selection. Many expert systems have attempted to solve various site selection problems that are heavily dependent on human judgment and experience (*Arentz T.A. et al., 1996,2000), (Findikaki I., 1986),(Han S.Y., and Kim T.J., 1990),(Rouhani S., and Kangari R., 1990),(Suh S., et al., 1988),(Witlox F., and Timmermans H., 2000)*. There is now a comprehensive body of literature on integrating ES, GIS and MCE techniques for solving site selection problems*(VahidniaH., Alesheikh A.,et al.,2009),(Siddiqui M.,et al.,1996),(Mak S.,1999),(Kates S.,1997),(Jun C.,1997),(Eldrandaly K.,et al2005),(Eldrandaly K.,2003), (Eldin N., Eldrandaly K.,2005),(Boroushaki S., and Malczewski, J.,2008). Site selection is a type of GIS analysis that is used to determine the best site for land use which also called suitability analysis, Potential sites used in suitability analysis can include businesses such as a store or city facilities like a hospital or school. Site selection can also be used to determine ideal habitat for a specific plant or animal species. When performing site selection analysis in GIS users must set various criteria so that the best or ideal sites can be rated based on this criterion (*Amanda Briney, 2014).

In spite of its popularity, the AHP is often criticized for its inability to incorporate the inherent uncertainty and imprecision associated with mapping the decision-makers perceptions to exact numbers (Deng, 1999). Since fuzziness is a common characteristic of decision-making problems, the FAHP method was developed to address this problem (Mikhailov and Tsvetinov, 2004). Hence, FAHP uses a range of values to express the decision maker's uncertainty (Lee et al., 2008). The decision-maker is free to select a range of values that reflects his confidence. Alternatively, he can specify his attitude in general terms as optimistic, pessimistic or moderate, representing high, low, and middle ranges of values respectively (Jeganathan, 2003).

Fuzzy logic is one type of commonly used form of site selection. It assigns membership values to locations that range from 0 to 1 (ESRI). 0 indicates non-membership or an unsuitable site, while 1 indicates membership or a suitable place. Fuzzy logic site selection is different from other site selection methods because it represents a possibility of an *ideal site, rather than a probability and it is commonly used to find perfect habitat for plants and animals or other places that are not specifically chosen by a user or developer (Amanda Briney, 2014).*

In recent years, many of researchers used GIS, MCDM and fuzzy logic to find an optimum site for industry and many other facilities. Some of this research are as follows: Nazli Yonca Aydin et al. in research introduces a methodology for site selection of hybrid wind-solar–PV renewable energy systems. First, environmental acceptability and economic feasibility objectives are identified through a comprehensive review of the literature, current Turkish laws, and legislation, and interviews with the General Directorate of Electrical Power Resources Survey and Development Administration of Turkey. Second, viable locations regarding environmental acceptability and economic feasibility are determined through a fuzzy decision-making procedure that uses ordered weighted averaging algorithm for multiple aggregating objectives. Then, priority sites are identified separately for wind and solar energy systems by using Geographic Information System (GIS), and finally, associated maps are overlaid to obtain the most feasible locations for hybrid wind-solar–PV systems (Nazli Yonca Aydin et al., 2013). Aleksandar Rikalovic et al. presents a successful solution for spatial decision support in the case of spatial analysis of Vojvodina as a region of interest for industrial site selection. They used GIS-Based Multi-Criteria Analysis for Industrial Site Selection (Aleksandar Rikalovic et al., 2013). DAVID BAILEY et al. in research presents an application of a new fuzzy algorithm for finding and exploring potential solutions to these problems in a raster Geographical Information System (GIS) environment. Linguistic assessments from decision-makers are represented as fuzzy triangular numbers (TFN's), which are adjusted for uncertainty in the source data and its relationship to suitability by using an approach based on type-2 fuzzy sets. The first aggregation of inputs is a compensatory one based on fuzzy multi-attribute decision-making (MADM) theory. An adjusted aggregation then factors in conflicts, risks, and uncertainties to enable a variety of compensatory and non-compensatory outcomes to be generated based on decision-maker preferences. The algorithm was implemented in ArcView GIS as part of an ongoing collaborative project with Brisbane Airport. This paper outlines the fuzzy algorithm and its use in site selection for a recycling facility on the Brisbane Airport site (DAVID BAILEY et al., 2003). MEHDI ZIAEI et al. use of GIS and Fuzzy MCDA for a suitable selection of industrial areas. The first useful criteria were recognized for site selection of the industrial regions such as slop, land use, agriculture, fault, soil type, 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 (Mehdi ziaei et., al). In another study, Hamid Ebadi et al. useful parameters and criteria were defined for industrial estate site location and corresponsive data layers. Finally, we classified and prepared data layers concerning the main criteria and parameters. By checking the executive routines for different kinds of integration models, we evaluated results of Indexing overlay, Fuzzy logic and Genetic algorithm methods that could be implemented in GIS environment based on the processing time and spatial accuracy which presented some interested models for industrial estate site location (Hamid Ebadi et al.).

MATERIALS & METHODS

Study area:

Kurdistan province is located in the West of Iran, bordering Iraq from 34° 442 to 36° 302 North, and, 45° 312 to 48° 162 East(S. Zandsalimi et al.,2011). This province with 1,493,645 inhabitants, make up 1.99% of the total population of Iran (Statistical Center of Iran, 1390).

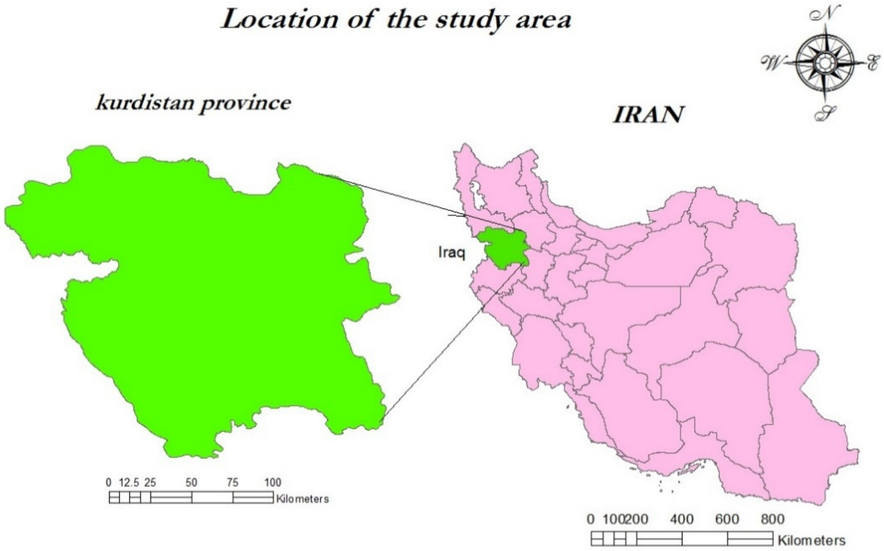
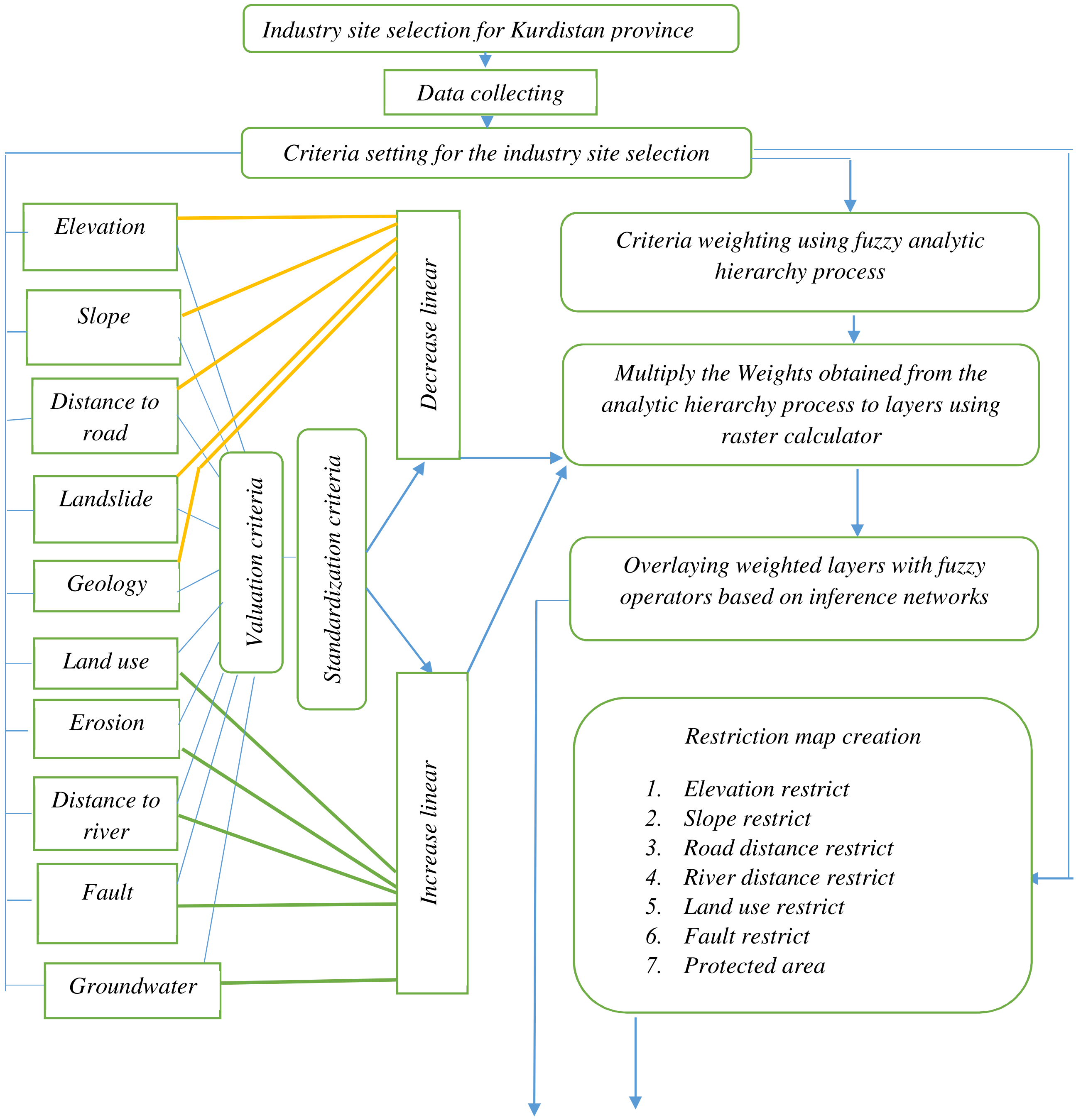


Fig.1: the location of the study area

The province of Kurdistan is 28,817 km² in area, and It is located in the west of Iran and bound by Iraq on the west, the province of West Azerbaijan to its north, Zanjan to the northeast, Hamedan to the east and Kermanshah to the south.

We followed the below model in this research (fig 2). First, we specified and studied site selection and industry and then, the necessary criteria for this research exported and evaluated. Then we collected the data that we need for import to GIS environment for valuation, classification, standardization, and overlay. We used the FAHP technique to criteria prioritization and fuzzification function memberships to deferent layer standardization in a GIS environment. To overlaying patterned layer used of fuzzy gamma operators. Restriction map created by union deferent restrict element layers and finally overlay final capability map exported from gamma operator and restriction map for specifying the areas that have an industry capable.


Industry site selection for Kurdistan province
Data collecting
Criteria setting for the industry site selection
Elevation
Slope
Distance to road
Landslide
Geology
Land use
Erosion
Distance to river
Fault
Groundwater
Valuation criteria
Standardization criteria
Decrease linear
Increase linear
Criteria weighting using fuzzy analytic hierarchy process
Multiply the Weights obtained from the analytic hierarchy process to layers using raster calculator
Overlaying weighted layers with fuzzy operators based on inference networks
Restriction map creation
1. Elevation restrict
2. Slope restrict
3. Road distance restrict
4. River distance restrict
5. Land use restrict
6. Fault restrict
7. Protected area

Final stage

Overlay restriction map with output map of the fuzzy operator that shows the most appropriate sites for industry

Fig.2: The conceptual model of research

Table.1: interaction degree used to fuzzy analytical hierarchy process

ξ	0	$0 < \xi < 0.5$	0.5	$0.5 < \xi < 1$	1
Identify standard	Input numbers standard	All standard	All standard	All standard	Input numbers standard
Fuzzy measure	G(A)=0 (A≠Ø)	Superadditive	Additive	Subadditive	G(A)=1 (A≠X)
Aggregation method	minimum	Intermediate aggregation between the minimum and the weighted sum	Weighted Sum	Intermediate aggregation between the maximum and the weighted sum	Maximum
Kansei words		Complementary		Substitute	
		Balance		Personality	
		Negative		Positive	
		Cautious		Daring	
		Conservative		Progressive	
		Certainty		Possibility	

Table.2: used criteria, fuzzy membership, its min, and max value in this research

Criteria	Used fuzzy function for fuzzification	Minimum	Maximum
Elevation	Decrease linear	718 m	3207 m
Slope	Decrease linear	0 %	100%
Distance to road	Decrease linear	0	25 km
Distance to river	Increase linear	0	8.5 km
Erosion	Decrease linear	1	7
Landslide	Decrease linear	2700001	2700295
Fault	Increase linear	0	74 km
Groundwater	Increase linear	3 m	75 m

Table.3: land use types, used fuzzy membership and its value

Row	Land use type	Value	Used fuzzy function for fuzzification
1	Urban, water, wetland	1	Increase linear function based on the value field used for this criteria fuzzification
2	Watercourse	2	
3	Island	3	
4	Rock	4	
5	4 type forest (dense, mod, low, afforest)	5	
6	Garden	6	
7	Mix (forest, agriculture, garden, etc.)	7	
8	Agriculture-dry farming	8	
9	3 type rangeland(poor, mood, good)	9	
10	Bare land	10	

Table.4: geology classification, sensitivity level, and used fuzzy membership

Row	Geology classification of Kurdistan province	Sensitivity level	Used Fuzzy function for fuzzification
1	Limestone, marl, gypsiferous marl, sandy marl and sandstone (QOM FM)	1	Decrease linear function used for this criteria fuzzification based on the sensitivity level
2	Olivine basalt and basalt related to Bazman Volcanism and partly associated with Taftan Volcanism	1	
3	light red to white, thick bedded quartz arenite with dolomite intercalations and gypsum (PADEHA FM)	1	
4	Dark grey medium-bedded to massive limestone (RUTEH LIMESTONE)	2	
5	Yellowish, thin to thick - bedded, fossiliferous argillaceous limestone, dark grey limestone, greenish marl, and shale, locally including gypsum	2	
6	High-level piedmont fan and valley terrace deposits	2	
7	Low-level piedmont fan and valley terrace deposits	3	
8	Stream channel, braided channel and floodplain deposits	3	

Fuzzy set theory is a mathematical theory designed to model the fuzziness of real-world situations. A fuzzy number is a special fuzzy set F = {(x, μf(x), x ∈ R}, where x takes its values on the real line, R: -∞ ≤ x ≤ 1 and μf (x) is a continuous mapping from R to the closed interval [0, 1] (E. H. Ibrahim et al., 2011).
The fuzzy classes are used to define the transformation or remap of the input values to new values based on a specified function. The transformation process is referred to as fuzzification and establishes the fuzzy membership for each input value. The transformed values range from 0 to 1, defining the possibility of membership to a specified class or set, with one being utterly in the collection. Each fuzzy class defines a continuous function, and each function captures a different type of transformation to achieve the desired effect. For example, one role is more appropriate when the values closer to a specified value have a higher possibility of being a member of the set, while another function might be more appropriate if the higher values are more likely to be members of the set.
The fuzzy logic method of spatial analysis requires that the crisp data be scaled into fuzzy membership values, ranging from zero to one. This process called fuzzification (Tsoukalas and Uhrig, 1997). The algorithms implemented in Fuzzy.ave are the following: Small (Tsoukalas and Uhrig, 1997), Near (Tsoukalas and Uhrig, 1997), Gaussian (Masters, 1993), and Large (Tsoukalas and Uhrig, 1997). These fuzzification algorithms can also be modified, such as very small, with an additional set of algorithms referred to as hedges (Tsoukalas and Uhrig, 1997, Zadeh, 1993).

The Fuzzy Overlay tool allows the analysis of the possibility of a phenomenon belonging to multiple sets in a multi-criteria overlay analysis. Not only does Fuzzy Overlay determine what sets the event is possibly a member of, but it also analyzes the relationships between the memberships of the multiple sets.

Overlay type lists the methods available to combine the data based on set theory analysis. Each method allows the exploration of the membership of each cell belonging to various input criteria. The available methods are Fuzzy And, *Fuzzy Or, Fuzzy Product, Fuzzy Sum, and Fuzzy Gamma. Each approach provides a different aspect of each cell's membership to the multiple input criteria.*

Fuzzy Sum: the *Fuzzy algebraic sum is complementary to the algebraic product which can be defined as:*

$$\mu_{combination} = 1 - \prod_{i=1}^{n}(1 - \mu_i) \quad (1)$$

The result is always larger (or equal to) the largest contributing membership value, and thus it has an 'increasive' effect (Graciela Metternicht and Daavid Malins, 2005).

Fuzzy Gamma: *The Fuzzy Gamma type is an algebraic product of Fuzzy Product and Fuzzy Sum, which are both raised to the power of gamma. The generalize function is as follows:*

$$\mu_{combination} = (FuzzySum)^{\gamma} * (FuzzyProduct)^{1-\gamma} \quad (2)$$

This is the specific function used by Fuzzy Gamma:

*Fuzzy Gamma Value = pow(1 - ((1 - arg1) * (1 - arg2) * ...), Gamma) * Pow (arg1 * arg2 * ..., 1 - Gamma)* (3)

If the specified gamma is 1, the output is the same as Fuzzy Sum; if gamma is 0, the output is the same as Fuzzy Product. Values in between allow you to combine evidence between these two extremes and possibly different than Fuzzy Or or Fuzzy And. Fuzzy Gamma is a compromise of the increasing effect of Fuzzy Sum and the decreasing effect of Fuzzy Product. The following graphic defines the relationship of gamma to the Fuzzy Sum and Fuzzy Product terms:

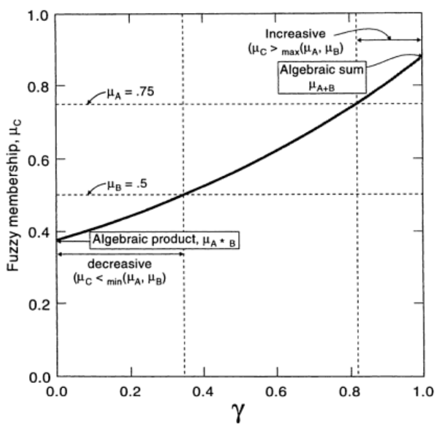


Fig.3; A graph of fuzzy membership, μ_c, obtained by combining two fuzzy memberships, μ_A, and μ_B. (Graeme f. Bonham-carter, 2006).

Fuzzy Gamma establishes the relationships between the multiple input criteria and does not merely return the value of a single membership set as does Fuzzy Or and Fuzzy And.

You can use Fuzzy Gamma when you want values greater than Fuzzy Product but less than Fuzzy Sum.

Table.6: restriction elements

element	This research	Beheshti far, sara., et al. (2008)	Other studies
Elevation	2000m	1800m	2000m
Slope	20%	10%	10%
Dis to road	200m	100m	1km
Dis to river	500m	500m	1km
Fault	2km	-	1km
Cities	5km	5km	2km
Protected area	1km	1km	
Lake	2km	1km	-

RESULT & DISCUSSION

In this research, to assess Kurdistan province capability to industrialization, we decide to perform a study according to different parameters as described above. To achieve this goal, we use some technique as fuzzy logic, WLC, and FAHP. This approach helps to optimization the site selection function. To identify the areas that can't use to industrialization, we produce a restriction map that shown in the table.6, then we produced, reclassified and standardized the layers of parameters in GIS that shown in tables 2, 3 and 4. This functions down according to ecological models and the studies that performed in this field. We use the technique of fuzzy analytic hierarchy process to prioritization the different parameters, result shown in table 5. In the last stage of our research, we overlay the layers in GIS environment by GAMMA fuzzy operator and the result shown in below. In the first map, GAMMA 0.3 applied, and the logarithmic histogram is shown too. This function down with 0.5 and 0.9 coefficients and theirs logarithmic histograms are shown too. Finally, the combined capability and restricted map for three coefficients are shown. As explained above, Fuzzy Gamma establishes the relationships between the multiple input criteria and does not simply return the value of a single membership set as does Fuzzy Or and Fuzzy And. If the specified gamma is 1, the output is the same as Fuzzy Sum; if gamma is 0, the output is the same as Fuzzy Product. Values in between allow you to combine evidence between these two extremes and possibly different than Fuzzy Or or Fuzzy And. As we observed in the map and logarithmic histogram, the rate of capability from 0.3 to 0.9 is raised. This means that with movement from 0.3 to 0.9, the sum operator effect is raised. The SUM operator has an increasing effect; this means that the operator selects the maximum value between corresponding cells of different layers. In contrast, the product operator has a decreasing effect; this means that the operator selects the minimum value between corresponding cells of different layers. To achieve the logical and comparable result, we applied gamma operator with three different coefficients (0.3, 0.5 and 0.9) (Fig.4). As we can detect and recognize on the map, the 0.5 coefficient is more suitable and logical because this coefficient combines the two other operators (sum and product) and decrease the uncertainty and exaggeration.

Table.5: weights identified by pairwise comparison in FAHP

Evaluation items	*Weights*
Slope	*0.0595503*
Elevation	*0.0271119*
Dis to road	*0.0639541*
Dis to river	*0.134929*
Land use	*0.082791*
Dis to fault	*0.250712*
Groundwater	*0.162484*
Geology	*0.0604506*
Landslide	*0.0930803*
Erosion	*0.064937*

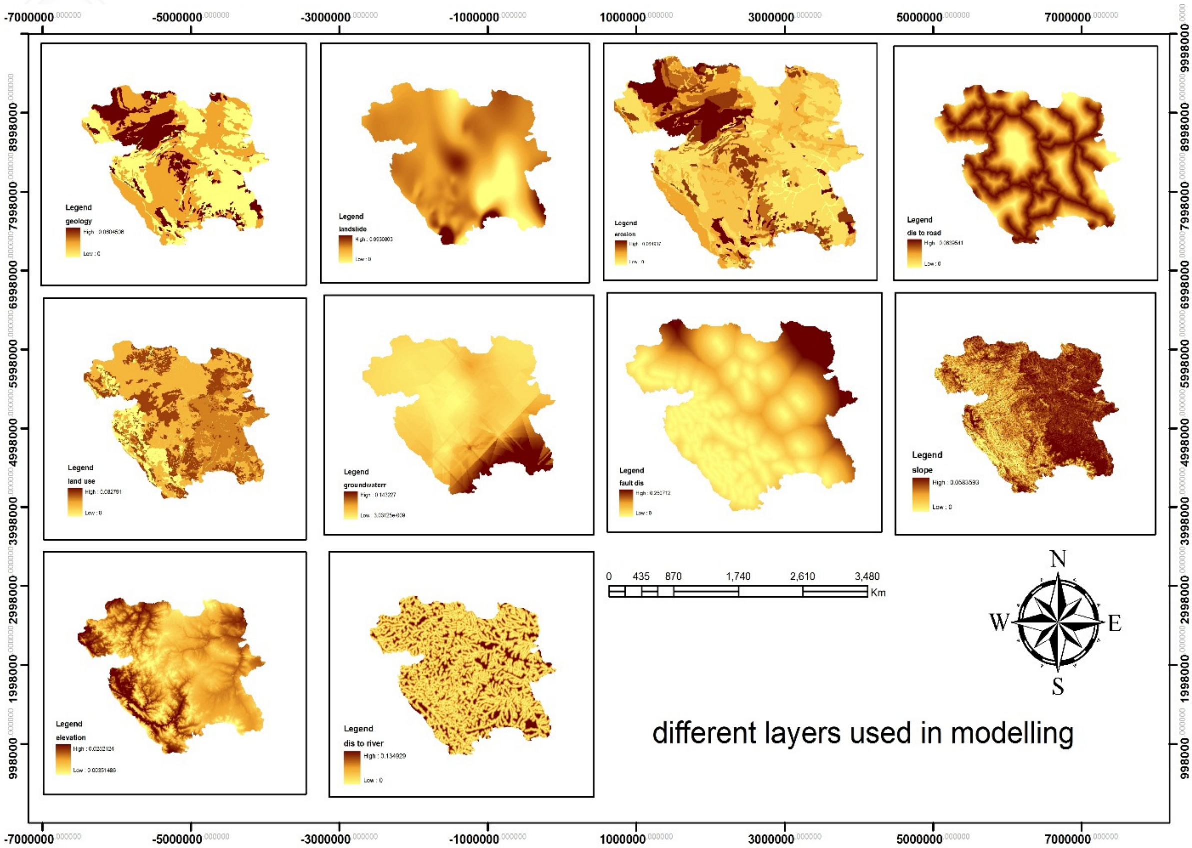


Fig.4: different layers used in modeling

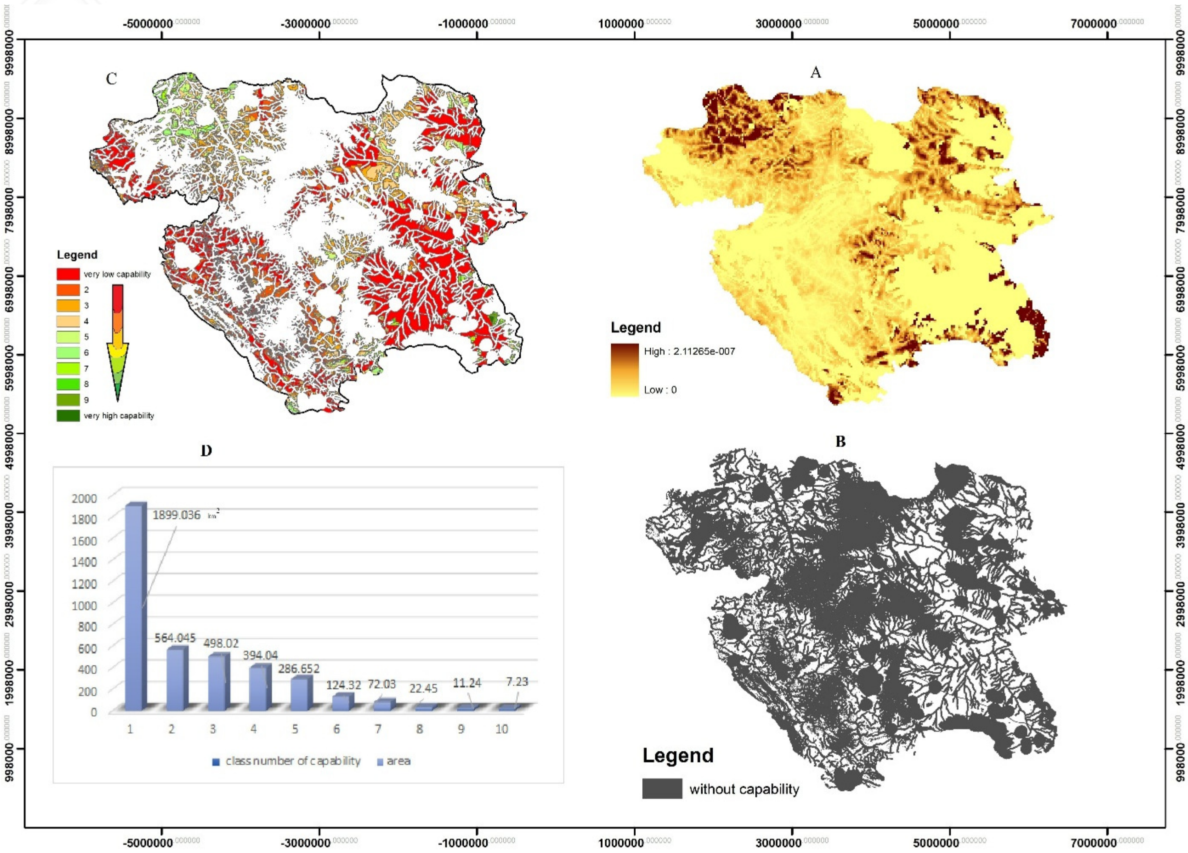


Fig.5: A. fuzzy operator gamma 0.05, B. restriction map for the industry, C, fuzzy map reclassified and erased restriction map of it (source: authors)

Table .7: different classes of capability for the industry in Kurdistan province

Class number of capability	Area (km^2)	Percent of any level to the capable region (3879 km^2)	Percent of any class to total area of territory (29065.02 km^2)
1	1899.036	48.95	6.53
2	564.045	14.54	1.94
3	498.02	12.83	1.71
4	394.04	10.15	1.35
5	286.655	7.38	0.98
6	124.32	3.20	0.42
7	72.03	1.85	0.24

8	22.45	0.57	0.077
9	11.24	0.28	0.038
10	7.23	0.18	0.024
total	3879	100	13.34

CONCLUSION

In this research, we used a new approach to identify and optimization the site selection. In other studies, researchers applied the different method in doing so. The industry is one of the critical factors in the improvement of lifestyle in the world, for doing this important we have applied many parameters to identify a place for implementing this operation known as site selection. Using of geographic information system (GIS) combined with multi-criteria decision making (MCDM) can play an important role. This approach in combination with the weighted linear combination (WLC) can play a more significant role as we used in this research. By use of FAHP we priorities the different parameters to implement in this process. The value of the distance to fault parameter is maximum, and elevation parameter is minimum based on expert opinion. The needed layers evaluated, standardized, multiplied, overlay and exported In ARC GIS software environment and by using different functions. For more detailed implementation work we create a restriction map to eliminate sensitive and vital areas that by industrialization maybe hurt and contaminate. By implement, this removes 87 percent of Kurdistan provinces areas. The 13 percent remnant evaluated by fuzzy set theory between 0 – 1 that 1 shown the more suitable site and zero shown the areas with the minimum value for industry site. The fuzzy operator that used in this research for overlaying the layers is Gamma at the different level (0.3, 0.5 and0.9). This operator is combined with Sum and Product operators and in 0.3 level show sum result and 0.9 show product but 0.5 show combined value of these two operators. As we expected, the 0.5 level shown more reasonable result and at the end of this manuscript, we conclude that Kurdistan province has a good potential for industrialization.

REFERENCES

Aleksandar Rikalovic, Ilija Cosic, and Djordje Lazarevic, 2013, GIS-Based Multi-Criteria Analysis for Industrial Site Selection, 24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013, Procedia Engineering 69 (2014) 1054 – 1063.

Amanda Briney, ESRI. (n.d.). "Using Raster Data for Site Selection." ESRI Virtual Campus. Personal Notes. (Course Taken 2 April 2014).

Arentz T.A., Borgers A.W., and Timmermans H.J., "An efficient search strategy for site selection decisions in an expert system," Geographical Analysis, vol. 28, pp. 126-146, 1996.

Arentz T., Borgers A., and Timmermans H., "A Knowledge-based system for developing retail location strategies," Computers, Environment and Urban Systems, vol. 24, pp. 489-508, 2000.

Bailey, David, Goonetilleke, Ashantha and Campbell, Duncan. (2003), A new fuzzy multi-criteria evaluation method for group site selection in GIS. Journal of Multi-Criteria Decision Analysis 12(6): pp. 1-11

Beheshti far,sara.,mesgari.m.s., voldan ,z,m,j.,and karimi.m. using of fuzzy logic in GIS environment in order to gas power plant site selection, Journal of Civil and Surveying Engineering - Faculty of Engineering, Volume 44, Number 4, pages 583 to 595, January 1389(2008).

Boroushaki S., and Malczewski, J. "Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS," Computers & Geosciences, vol. 34, no. 4, pp. 399-410, 2008.

Carver S. J. (1991). Integrated multi-criteria evaluation with geographical information systems, International Journal Geographical Information Systems, 5(3), pp. 321–339.

Deng, H., 1999. Multicriteria analysis with fuzzy pairwise comparisons. International Journal of Approximate Reasoning 21, 215–231.

Department of environment ministry of natural resources and environment MALAYSIA, guidelines for siting and zoning of industry and residential areas,(2012), Second Revised Edition, October 2012.

Eldin N., Eldrandaly K. "A Computer-Aided Decision-Making System for Siting Capital Investment Projects," ASCAAD's first International Conference on Computer Aided Architectural Design, KFUPM, Saudi Arabia, pp. 3-12, 2005.

Eldrandaly K., Eldin N., and Sui D. "A COMbased Spatial Decision Support System for Industrial Site Selection," JGIDA. Vol. 7, no. 2, pp. 72-92, 2003.

Eldrandaly K., Eldin N., Sui D, Shouman M., and Nawara G. "Integrating GIS and MCDM Using COM Technology," The International Arab Journal of Information Technology, vol. 2, no. 2, pp. 163-168, 2005.

Eastman J. R. (1997). Idrisi for Windows, Version 2.0: Tutorial Exercises, Graduate School of Geography – Clark University, Worcester, MA.

Eastman J. R. (2006). Idrisi Andes – Tutorial, Clark Labs., Clark University, Worcester, MA.

E. H. Ibrahim S. E. Mohamed A. A. Atwan, (2011), Combining fuzzy analytic hierarchy process and GIS to select the best location for a wastewater lift station in ELMAHALLA EL-KUBRA, NORTH EGYPT, International Journal of Engineering & Technology IJET-IJENS Vol: 11 No: 05

Feng, C., 1995. Fuzzy multicriteria decision making in the distribution of factories: an application of approximate reasoning. Fuzzy Sets and Systems 71, 197–205.

Findikaki I., "SISES: An Expert System for Site Selection," In M. L. Maher and C. N. Kosten, "Proceedings of a Symposium of the American Society of Civil Engineers," Expert Systems in Civil Engineering, pp. 182-192, 1986.

Graciela Metternicht and Daavid Malins, (2005), fuzzy modeling of dry land salinity hazard in Western Australia, 160-170 pn

Graeme f. Bonham-carter, 2006, geographic information systems for geoscience.modelling with gis.298pn

S. Zandsalimi, N. Karimi, A. Kohandel, Arsenic in the soil, vegetation and water of a contaminated region, Int. J. Environ. Sci. Tech., 8 (2), 331-338, Spring 2011.

Hamid Ebadi, Roozbeh Shad, Mohamad Javad Valadanzoej, Alireza Vafaeinezhad, Evaluation of Indexing Overlay, Fuzzy Logic and Genetic Algorithm Methods for Industrial Estates Site Selection in GIS Environment, Commission V, WG V/2

Han S.Y., and Kim T.J., "ESSAS: The Expert System for Site Analysis and Selection," In Kim T.J., Wiggins L.L., and Wright J.R. (Eds.), Expert Systems: Applications to Urban Planning, pp. 145-158, Springer-Verlag, Berlin, 1990.

Jun C. Incorporating decision preferences into an expert geographic information system for industrial site selection. Ph.D. Dissertation, Texas A&M University, College Station, USA, 1997.

Jeganathan, C., 2003. Development of Fuzzy Logic Architecture to Access the Sustainability of the Forest Management. MSc. Thesis. Enschede, ITC: 126.

Kates S. Retail site selection using GIS and MCDM: A case study of the Toronto retail jewelry industry. M.A. Thesis, University of Western Ontario, London, Ontario, Canada, 1997.

Keeney R.L., Siting Energy Facilities, Academic Press, New York, 1980.

Lee, A.H.I., Chen, W.C., Chang, C.J., 2008. A fuzzy AHP and BSC approach for evaluating the performance of the IT department in the manufacturing industry in Taiwan. Expert Systems with Applications 34, 96–107.

Lou, X., and Dimitrakopoulos, R., 2003, Data-driven fuzzy analysis in quantitative mineral assessment: Computers and Geosciences, v. 29, p. 3-13

Mikhailov, L., Tsvetinov, P., 2004. Evaluation of services using a fuzzy analytic hierarchy process. Applied Soft Computing 5, 23–33.

Masters, Timothy, 1993, Practical neural network recipes in C++: New York, Academic Press, p. 285.

Tsoukalas, L.H., and Uhrig, R.E., 1997, Fuzzy and neural approaches in engineering: New York, John Wil ey and Sons, Inc., 587 p.
Mak S. "Identify sites for Accommodating Open Storage Uses: A GIS Modeling Approach," Esri International User Conference, 1999. http://proceedings.esri.com/library/userconf/proc 99/proceed/papers/pap168/p168.html
Mohamad A. Al-Amri and Khalid A. eldrandaly, 2009, a proposed GIS-based decision-making framework for tourism development site selection, The International Arab Conference on Information Technology (ACIT),
Mehdi ziaie, Fatemeh hajizadeh, Seid said Reza ahmadizadeh, Komeil jahanifar, A Combined Model of GIS and Fuzzy Multi-Criteria Decision Analysis (FMCDA) for Suitable Evaluation/Selection of Industrial Areas, (Birjand, Iran), Recent Researches in Environmental Science and Landscaping
Nazli Yonca Aydin, Elcin Kentel H. Sebnem Duzgun, 2013, GIS-based site selection methodology for hybrid renewable energy systems: A case study from western Turkey, Energy Conversion and Management 70 (2013) 90–106(2013).
Rouhani S., and Kangari R., "Landfill Site Selection: A Microcomputer Expert System," In Kim T.J., Wiggins L.L., and Wright J.R. (Eds.), Expert Systems: Applications to Urban Planning, pp. 157-169, Springer-Verlag, Berlin, 1990.
Rao M., S. V. C. Sastry, P. D. Yadar, K. Kharod, S. K. Pathan, P. S. Dhinwa, K. L. Majumdar, D. S. Kumar (1991). A Weighted Index Model for Urban Suitability Assessment – A GIS Approach. Bombay Metropolitan Regional Development Authority, Bombay.
Ruiz Puente, C., Diego, M., Ortiz, J., Hernando, M., Hernaez, P. 2007. 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.
Suh S., Kim M.P., and Kim T.J., "ESMAN: An Expert System for Manufacturing Site Selection," Computers, Environment, and Urban Systems, vol. 12, pp. 239-252, 1988.
Siddiqui M., Everett J., and Vieux B. "Landfill Siting using Geographic Information Systems: A Demonstration," Journal of Environmental Engineering, vol. 122, pp. 515- 523, 1996.
Tsoukalas, L.H., and Uhrig, R.E., 1997, Fuzzy and neural approaches in engineering: New York, John Wiley and Sons, Inc., 587p.
VahidniaH., Alesheikh A., and Alimohammadi A. "Hospital site selection using fuzzy AHP and its derivatives," Journal of Environmental Management. Vol. 90, no. 10, pp. 3048-3056, 2009.
Williams E. A., and Massa A. K., Siting of Major Facilities: A Practical Approach, McGraw- Hill Inc, New York, 1983.
Witlox F., and Timmermans H., "MATISSES: A Knowledge-Based System for Industrial Site Selection and Evaluation," Computers, Environment, and Urban Systems, vol. 24, pp. 23-43, 2000.
Zadeh, L.A. A computational approach to fuzzy quantifiers in natural languages: Computers and Mathematics, v.9, p. 149-184.