Environmental Education and Sustainable Development EESD

Available online at www.ap.iauardabil.ac.ir

Islamic Azad University, Ardabil Branch

Anthropogenic Pollution Journal, Vol 6 (1), 2022: 21-25

ISSN: 2783-1736- E-ISSN: 2588-4646

I.A.U Islamic Azad University Ardabil Branch

ORIGINAL RESEARCH PAPER

Assessment of a Spatial Multi-Criteria Evaluation Method to Locate Suitable Industrial Zones in Ardabil, Iran

Farhad Hashemian

Department of Environmental Sciences and Engineering, Ardabil Branch, Islamic Azad University, Ardabil, Iran

ARTICLE INFORMATION

Received: 2020.09.24
Revised: 2021.12.11
Accepted: 2022.01.01
Published online: 2022.05.05

DOI: 10.22034/AP.2022.1910400.1079

KEYWORDS

Adsorption
Ardabil
Site selection
Multi-criteria decision support system
Analytical hierarchy process
ILWIS

ABSTRACT

The global policies concerning the selection of suitable sites for establishing and developing industries aim to prevent potential environmental crises, optimize existing facilities on land, and take the available opportunities in the long run. Located in northwestern Iran, Ardabil is a notable area for such areas. Accordingly, this paper aims to locate suitable sites for industrial parks in Ardabil. To this end, a combination of various systems was used: a multi-criteria decision support system (MCDSS), a spatial decision support system (SDSS), and the geographical information system (GIS). This study was inspired by the SMCE model recently developed into ILWIS software as a non-compensational method. This model considers the objective and spatial priorities of decision-makers. First, the effective criteria for selecting the disposal site were identified based on the analytical hierarchy process (AHP): these criteria were divided into smaller components and surfaces. The present criteria in each component were prioritized using the pair-wise comparisons method. In this method, each element concerning the importance is weighted in a range of one to nine: one for low importance and nine for high importance. The weighting importance level was computed using the Satty method for each surface. After preparing the essential information layers, such as distance from well, fault, and hydraulic slope, the calculated weights were assigned to layers using a tree structure. Finally, four construction scenarios were formulated by overlaying available information layers.

How to Site: Hashemian F., Assessment of a Spatial Multi-Criteria Evaluation Method to Locate Suitable Industrial Zones in Ardabil, Iran, Anthropogenic Pollution Journal, Vol 6 (1), 2022: 21-25, DOI: 10.22034/AP.2022.1910400.1079.

Corresponding author: far55hn@yahoo.com

1. Background

The existing tendency for industrialization in developing countries has significant impacts on natural and artificial environments. Pollution sources increase with the expansion of industrial sites and lead to air, water, and soil contamination. The absence of pro-environment management and viable planning strategies for developing industrial sites has aggravated the concerns for the future expansion of industrial towns (Jamali and Kalkhajeh 2020).

The unprecedented and uncontrolled growth in population worldwide and the increasing need for developing industrial sites have put tremendous stress on local, regional, and global climate. It is necessary to identify the factors that mediate industrialization and environmental quality variations. Land use modification, industrialization, and infrastructure developments can damage natural environments and threaten biodiversity. Site selection for industrial development is a crucial stage in designing an industrial site. Various criteria and factors are involved in selecting an appropriate industry site. They can have several constraints. The final aim of these criteria is to detect the appropriate place with the least harmful environmental repercussions. The contamination of groundwater and surface water resources and the soil around industrial places is a common hazardous phenomenon. Therefore, selecting relevant factors can help protect these resources against the inevitable effects of industrial activities (Zarkesh 2005, Chakhar and Mousseau 2008).

The spatial multi-criteria evaluation (SMCE) method can provide an appropriate solution for defining the value of industrial places and pinpointing industrial construction sites. Many researchers have used multi-criteria decision-aid methods for locating suitable sites for industrial and non-industrial activities, such as dam construction and landfill sites (Sharifi and Retsios 2004, Milani, Shanian et al. 2005, Chezgi, Pourghasemi et al. 2016).

Multi-criteria decision-making methods are known to have several advantages for decision-makers: they can be used to tackle a wide range of challenges by considering multiple quantitative and qualitative factors (Alvarez et al., 2021).

Reisinezhad (2017) studied industrial sites in Isfahan by using GIS techniques and multi-criteria analysis. Similarly, Masoudi and Jokar (2017) employed GIS data and hierarchical analytical process (AHP) method to create industrial units in Expert Choice (Armitage 1995, Fataei, 2009, Ayodele et al., 2018). Fataei (2014) used various environmental and economic criteria and through the method of hierarchical analysis process and similarity method to the ideal option in order to select the most suitable place for the construction of a border industrial town in Ardabil province. The reshalt was shown that there was no significant difference between the use of two methods in site selection of the border industrial towns.

The definition of decision support (DS) is founded on research about organizational decisions introduced in Carnegie Institute by Herbert Simon and Allen Newell during late 1950 and beginning 1960. It was applied using a computer system by Tom Gerrity in Masochist Technology Institute in 1991 (Nguyen and Martin 1994). Furthermore, most GIS models present four analysis functions concerning selection, manipulation, exploration, and confirmation (Fataei 2011; Oliaei & Fataei 2016). Overlaying maps and presenting the spatial analysis results are critical steps in the decision process (Bamber 2002, Jamali, Randhir et al. 2018, Jamali and Kalkhajeh 2020).

The present study used the MADM decision pattern with a value-focused approach and the AHP compensate method. After evaluating potential sites (plan for selecting the solutions) were determined, cities were evaluated based on their economic, social, physical, and environmental characteristics for final selection.

2. Materials and Methods

Study area: Ardabil has a surface area of 4300 hectares located in 47° 48′ to 48° 39′ east length and 37° 56′ to 38° 33′ north width, in the plain with 1340 m height above sea level. (Fig. 1).

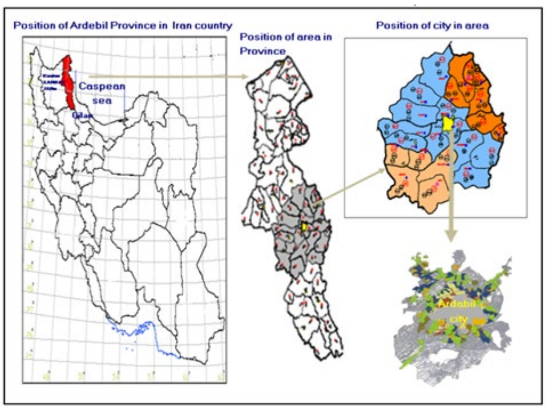

Figure 1. Location of the study area in Iran

The study area consisted of six rural districts and forty-two villages. Land unevenness comprised low and mountainous plains; the higher plains were in the southwest (Sabalan Mountain).

2.1. Decision support system

In this research, evaluation and site selection for developing the Ardabil industrial site were performed using GIS (Arc GIS 10.3) and ILWIS. The SMCE and DSS were used to solve the structural and non-structural problems. As mentioned earlier, the SMCE method is suitable for determining the value of layers. Thus, the criteria were extracted from relevant previous research and credible sources, such as EPA, British Colombia, and the Department of Environment (DOE).

2.2. Preparation of GIS layers

The effective criteria were divided into smaller components and various surfaces based on the multi-attribute decision-making (MADM) method and AHP methods. The Satty method, a pair-wise comparison for criteria, was applied to prioritize each surface's related criteria (Figure 2).

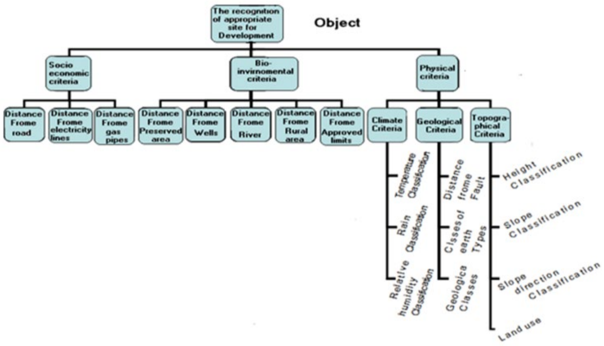

Figure 2. The structure of AHP for site selection of industrial development place

To their significance obtains a value between one and nine (one for low importance and nine for high importance) 9. These comparisons are made in a square matrix to compute the compatible ratio (CR should be less than 0.1) practicability and to specify the effect of each criterion on the other one. This ratio can define the assessment precision. The performed assessment (weighting) was computed using the special vector method for each surface and criterion. In the next stage, raster layers extracted from the mentioned criteria were prepared in GIS. Then, the computed weights of each criterion were assigned to such layers. To manipulate each criterion's values, the suitability index was to which value of each criterion was added to obtain the final value. The principle of this method is the low value of a criterion that is compensated with the high value of another criterion. Regarding some criteria, the elective choice might have a low value, but such a low value is compensated with the high value of other criteria.

2.3. Suitability index (SI)

The suitability index (SI) for each criterion or choice is determined by aggregating the relative importance (RI) of available criteria using Eq. (1). For a four-level of a decision tree, this equation is expressed as:

$$SI = RI.1 \times \sum_{i=1}^{m} RI.Bi \times RI.KBi + RI.A2 \times$$
$$\sum_{y=1}^{L} RICy \times IRKCy + \cdots RIAN \times$$
$$\sum_{z=1}^{1} RIDz \times RIKDz$$

where SI = the suitability index of each cell; N = the number of main criteria A; RIA1, RIA2, and RIAN = the relative importance of the main criteria A1, A2, and AN, respectively; M, L, and J = the number of sub-criteria directly connected to the main criteria A1, A2 and AN, respectively; RIB, RIC and RID = the relative importance of sub-criteria B, C and D directly connected to the main criteria A1, A2 and AN, respectively; RIKB, RIKC, and RIKD = the relative importance of indicators category k of sub-criteria B, C, and D and main criteria A1, A2 and AN, respectively. If a decision hierarchy has more or fewer levels, the equation must be appropriately modified.

After classifying the effective criteria and secondary sub-criteria and computing each level's weight, the secondary criteria in higher levels were prioritized and weighted. To calculate the secondary criteria (Level 3), the Satty method was applied. Expert Choice was used to determine criteria weights. Factors of level one from the model – criteria - were inputs of the matrix counted with computer software. First of all, the criteria weights of the main criteria were determined. If CR was less than 0.1, it was assumed that the expert was consistent in his evaluations. Similarly, weights of sub-criteria were determined for each criteria group. Table 1 shows the weighting of one criterion -distance from the road- in Expert Choice.

In this study, the main criteria are situated in the second level, and they mainly aim to locate perfect sites for industrial. In this stage, the weight of existing criteria, same as the previous stage, was computed using the Satty method. Four scenarios were introduced to determine the weights. Every scenario based on expert judgment and weights of main criteria were different.

3. Results and Discussion

Four scenarios in different parts of the city were employed to determine these weights considering residents' bioenvironmental susceptibility and socio-cultural attitudes. All these scenarios are based on experts' opinions. The main criteria have different weights. In the first three scenarios, the given criteria are given the highest score, and two later criteria are given lower scores. All criteria are given the same score in the fourth scenario (Fig. 9).

3.1. Scenario (I)

In this scenario, physical criteria have more preference. Besides, environmental, economic, and social criteria with the same weight together acquired the lowest weight.

Table 1. Weight of distance from transportation routes in the suggested model

Road map	Map1	Map2	Map3	Map4	Map5	Weight
Map1=0-150	1	9	7	5	3	0.031
Map2=150-500	1.9	1	5	7	8	0.059
Map3=500-1000	1.7	1.5	1	4	5	0.095
Map4=1000-10000	1.5	1.7	1.4	1	2	0.230
Map5=10000-100000	1.3	1.8	1.5	1.2	1	0.585
CR=0.09						

Table 2 and Fig. 3 show the suitable areas for the placement of industries.

Table 2. The first scenario in site selection for the placement of industries

	Parameters	Weight
Suitable area for the placement of industries	Economic and social parameters	0.600
	Environmental parameters	0.200
	Physical parameters	0.200

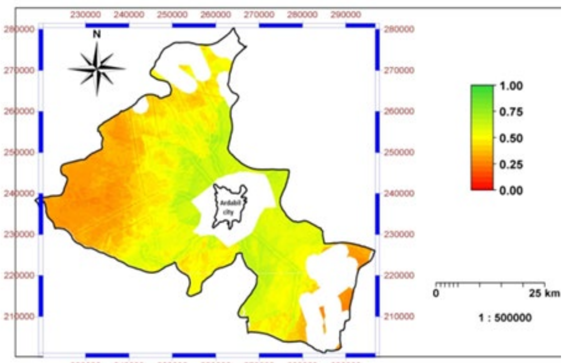

Figure 3. The first scenario in site selection for the placement of industries

3.2. Scenario (II)

In this scenario, environmental parameters have absolute preference relative to the other objectives. This was followed by the importance of physical, economic, and social criteria with the lowest weight. Table 3 and Fig. 4 show the suitable area for the placement of industrial units.

Table 3. The second scenario in site selection for the placement of industries

	Parameters	Weight
Suitable area for the placement of industries	Environmental parameters	0.600
	Physical parameters	0.200
	Economic and social parameters	0.200

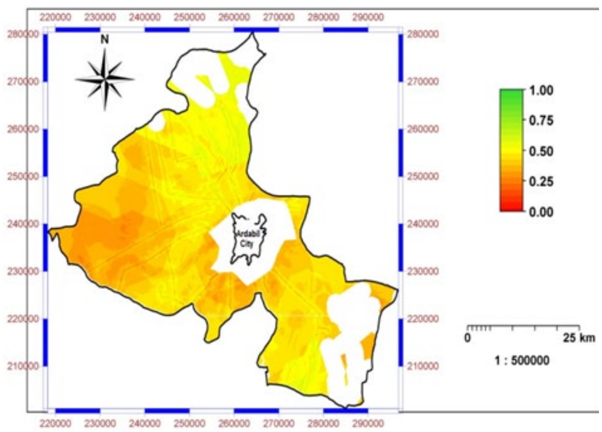

Figure 4. The second scenario in site selection for the placement of industries

3.3. Scenario (III)

In this scenario, absolute preference is given to economic and social criteria where environmental and physical criteria were considered with equal weights successively (Table 4 and Fig. 5).

Table 4. The third scenario in site selection for the placement of industries

	Parameters	Weight
Suitable area for the placement of industries	Economic and social parameters	0.600
	Physical parameters	0.200
	Environmental parameters	0.200

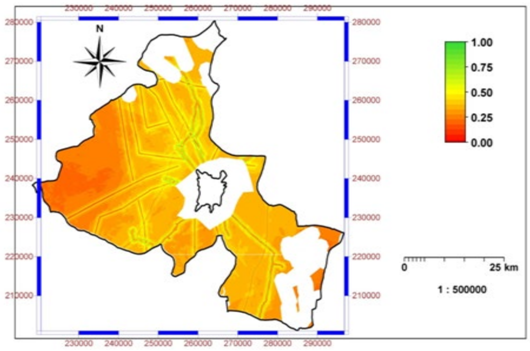

Figure 5. The third scenario in site selection for the placement of industries

3.4. Scenario (IV)

This scenario assumes that four objective criteria have the same preference. It is assumed that all effective criteria have an identical role in selecting suitable land for developing industries (Table 5 and Fig. 6).

Table 5. The fourth scenario in site selection for the placement of industries

	Parameters	Weight
Suitable area for the placement of industries	Physical parameters	0.333
	Environmental parameters	0.333
	Economic and social parameters	0.333

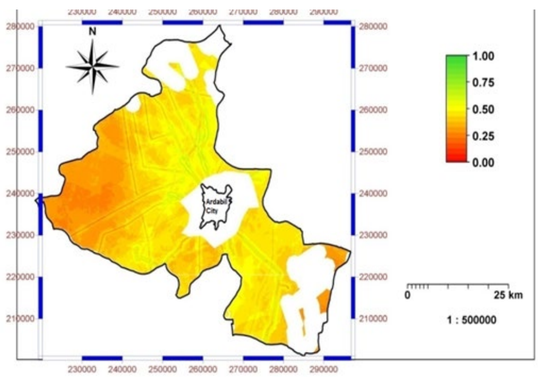

Figure 6. The fourth scenario in site selection for the placement of industries

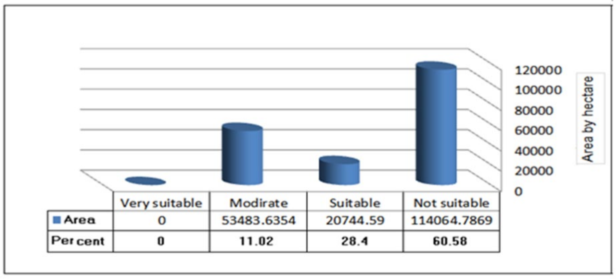

Diagram 1. The area and percentage of categories of the proposed map (second scenario)

In each scenario, suitable sites for the placement of industries were distinct using the SI in the range of 0 and 1. The areas with an SI value of approximately 1 have more preferences than areas with lower values.

4. Conclusion

Locating a suitable site for establishing industries relies on field study and old aerial photo surveys. Hence, technically, the procedure requires more time while, here, the criteria were neglected, and the results were not desirably precise. However, the application of GIS and MCDM in SDSS reduced the required time, allowed for applying more effective criteria, increased result accuracy, and enabled using the knowledge of experts (individual and group) and numerical data. The results indicate that MCDM and GIS are efficient tools for locating suitable areas for industrial parks. The results corroborated the performance of SDSS, given the existence of appropriate geology, geomorphology, pedology, appropriate climate situation, distance from surface and underground water resources limits, distance from a population center, economic justification of selected areas, control, and verification of areas with field study and satellite images. The study findings also showed that MCDM complicated the problems by dividing into small components. The effective criteria can be simplified. Moreover, a combination of the impressive criteria in selecting the location of industries with the numerical data could be performed, making it possible to decide by mathematical computations MCDM.

Concerning codified research methodology for this design, some areas were recognized in GIS to establish industries with four categories: very suitable, suitable, fairly suitable, and unsuitable. This categorization indicates an agreement between the result and hypothesis. It can be concluded that prioritizing the physical criteria will result in the most desired sites for developing industrial parks. There are six hectares of such desired area in the third scenario. However, since human health and environmental protection are critical issues today, the second scenario is preferred. The composite map (Fig. 4-20) indicates that although this scenario does not provide the most desired areas, about 11% of the land (northern and somewhat southern regions) has relative desirability. The fourth scenario has the advantage of considering equal weights in the main parameters. Except for the first choice, there can be interaction about other choices considering managerial priorities.

Furthermore, in the fourth scenario, suitable and fairly suitable regions are in the northern parts of the map, meaning they are prioritized points. Regarding the establishment of major industrial areas, Industrial Park 1 is not located in a suitable region since its situated within the urban zone. Even upon disregarding this drawback, its location is inappropriate based on the mentioned scenarios.

References

1. Armitage, D. (1995). “An integrative methodological approach framework for sustainable environmental planning and management.” Environmental Management 469: 479.
2. Ayodele, T., A. Ogunjuyigbe, O. Odigie and J. Munda (2018). “A multi-criteria GIS based model for wind farm site selection using interval type-2 fuzzy analytic hierarchy process: The case study of Nigeria.” Applied Energy 228: 1853-1869.
3. Bamber, J. L. (2002). “Satellite remote sensing of the environment.” eLS. John Wiley &.
4. Fataei, A., and Al Sheikh, A. (2009). Location of municipal solid waste landfill using GIS and Analytic Hierarchy Process (AHP) (Case study of Givi city). Environmental Sciences, 6 (3), 145-158. https://www.sid.ir/fa/journal/ViewPaper.aspx?id=103156
5. Fataei, E. (2011). Recognition of new habitats of lilium ledebourii baker in northwest ardabil province of iran using GIS technology. Acta Horticulturae, 900(6):65-70.
6. Fataei, E. (2014) Feasibility study of construction of border industrial towns using TOPSIS and AHP Case study: Ardabil province. Geography and Development, 12 (37), 181-193. https://www.sid.ir/fa/journal/ViewPaper.aspx?id=231730 Chakhar, S. and V. Mousseau (2008). “GIS-based multicriteria spatial modeling generic framework.” International Journal of Geographical Information Science 22(11-12): 1159-1196.
7. Chezgi, J., H. R. Pourghasemi, S. A. Naghibi, H. R. Moradi and M. Kheirkhah Zarkesh (2016). “Assessment of a spatial multi-criteria evaluation to site selection underground dams in the Alborz Province, Iran.” Geocarto International 31(6): 628-646.
8. Jamali, A. A. and R. G. Kalkhajeh (2020). “Spatial modeling considering valley’s shape and rural satisfaction in check dams site selection and water harvesting in the watershed.” Water Resources Management 34(10): 3331-3344.
9. Jamali, A. A., T. O. Randhir and J. Nosrati (2018). “Site suitability analysis for subsurface dams using Boolean and fuzzy logic in arid watersheds.” Journal of Water Resources Planning and Management 144(8): 04018047.
10. Masoudi, M. and P. Jokar (2017). “Land Use Planning Using a Quantitative Model and Geographic Information System (GIS) In Sistan Region, Iran.” ECOPERSIA 5(2): 1745-1759.
11. Milani, A., A. Shanian, R. Madoliat and J. Nemes (2005). “The effect of normalization norms in multiple attribute decision making models: a case study in gear material selection.” Structural and multidisciplinary optimization 29(4): 312-318.
12. Nguyen, Q. and J. Martin (1994). Verification and validation of decision support software: Expert Choice {trademark} and PCM {trademark}, Westinghouse Hanford Co., Richland, WA (United States).
13. Oliaei, A.S.B. & Fataei, E. (2016). Breakdown of urban waste repository location using GIS (Case study District 3 Region 1 Tabriz), Iran. Ecology, Environment and Conservation, 22, 2115-2120.
14. Reisinezhad, A. (2017). “Geopolitical Account of Iran’s Ties with Non-State Actors under the Shah: 1958-1979.”
15. Sharifi, M. A. and V. Retsios (2004). “Site selection for waste disposal through spatial multiple criteria decision analysis.” Journal of telecommunications and information technology: 28-38.
16. Zarkesh, M. K. (2005). Decision support system for floodwater spreading site selection in Iran, ITC.