Industrial State Site Selection Using MCDM Method and GIS in Germi, Ardabil, Iran

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***Abstract*—The industrial state site selection for urban and industrial equipment's establishment is tied to some limiting and strengthening factors. Increasingly, the relationships between environmental concerns and industrial, social and political affairs as well as rapid growth of the potential changes rise up regional and local system's complexity. The conditions of different areas in our country indicate that we should consider environmental planning topics more than previous. There are different methods for site selection however using multicriteria methods are more preferred. In this study we investigated about the second industrial area's site selection in Germi where is located in the Ardebil province, in Iran. Totally seven criteria including average annual temperature, slope, water resources, roads, landuse, residential areas and geological fault, were mapped using Arc GIS 9.3. Meanwhile we used Analytical Hierarchical Process (AHP) for map's weighting. The preferred areas were located after field work and software analysis and considering economic, social and environmental conditions such as land ownership value and access. Based on infrastructural facilities existence and short distance to Germi city, the first preference was selected.**

***Index Terms*—geographical information system, multi criteria decision making, Environmental planning, Industrial town, Ardebil, Iran**

I. Introduction

Site selection for industrial areas and states or any developmental activities needs consideration of several limiting factors such as slope, elevation from sea level, protected areas and so on as well as strengthen factors such as road access, roads, suitable lands, and so on [1]. The direct relationships between environmental, industrial, social and political issues and rapid changes increase regional and local system's complexity. Recreation development, protection of natural land scapes, establishing new protected areas and site selection for different land uses such as factories, depositories, industrial units and … are topics that almost all site planners' faces. Environmental planning is essential in industrialization process for every country and consolidation of scattered industrial units as well [2]. Such organizing will be affected by different factors including population growth, employment, landuse, restricted lands, environmental conservation and development. Therefore uncontrolled industrial units growth and environmental pollution will be mitigated [3]-[5]. Present conditions of Iran and new industrial areas construction in different areas indicate that there is no care about environmental planning even after industrial estates institution law approval not the national and regional level. Unfortunately there are some problems in environmental planning process that imposed by those opponents as well. Such problems will affect industrial parks efficiency.

Multi criteria decision making methods as a management science and information analysis is able to solve many difficulties related to the industrial states site selection. There is relatively rich literature about this affair for example [6]-[11]. Fernandez *et al*. [12] used integrated index overlay and weighting method of AHP for facilitating decision making process and industrial state site selection. Karimi [13] surveyed the best sites for industrial state in Qom province using GIS. In recent study all environmental resources were classified in two main categories including ecological and socioeconomic resource and then analyzed and summed up. With regard to necessity of Germi's second industrial park establishment we introduced the best site for this type of land use based on AHP model and validating layers logic with GIS. After that a model was generated for industrial park site selection and applied for Germi's new industrial park.

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II. Materials and Methods

A. Study Area

Germi city is located in the north west of Iran (N38 º 50′ to 39 º and 12 ′ E 48º 20′ to 47 º 30 ′). This city covers more than 1725.2 sq. km in the Ardabil province. This city is located in the vicinity of Bilesavar from the north, Parsabad from the North West, Azerbaijan republic from the east, Meshkinshahr from the south and Eastern Azerbaijan province from the west. Total recorded population in 2011 was 91270 individuals that about 48% were male and about 52% were female [14]. The main occupation of the natives is agriculture and despite of prolific soil the prevailing agricultural system is dryland cropping because of water resources deficiency.

B. Investigated Criteria

Annual average temperature: Different weights were assigned to this parameter different depending on the kind of the industrial activity. For example high temperature will lower turbines efficiency in the powerhouses [15], [16]. In this study we cared more about the higher temperatures because building activities need higher temperatures.

Slope: Topographical features are key factors in building and output flows. Because of landuse, water flowing, drainage, latex infiltration to underground water tables and … this factor was selected. Plain areas have especial importance because of lesser costs during site preparation.

Geological fault: Seismology and faults are very important in the development planning. The fracture resulted from geological faults will affect neighborhood sediments and rocks. Regarding legal buffer from fault lines and avoiding industrial developments in such areas are considerable factors in the industrial park site selection [17].

River basin: Water accessibility is one of the main affecting factors industrial park site selections.

Land use: Land use situation with regard to different environmental effects and the condition of industrial parks is very important. Forest and farming lands shouldn't change to industrial land use and only a negligible damage to the plant cover can be allowed.

Residential areas: A logical distance should be selected between residential areas and industrial parks. A buffer should be defined as well.

Roads: Roads and other infrastructures that facilitate different cities and regions connection are very important in industrial park site selection. Since Germi is located near the country border, so the connection with abroad and custom affairs is necessary.

Different kind of integration models:

The model is the most basic element of the scientific method. Everything done in science is done with models. A model is any simplification, substitute or stand-in for what you are actually studying or trying to predict [18]. A model may include special aims such as predicting, zoning, site selection and so on. The more factors are involved in model construction the model precision will be higher however its complexity will be increased as well. The best model is one that produces the best results. We used seven factors in this study (Fig. 1).

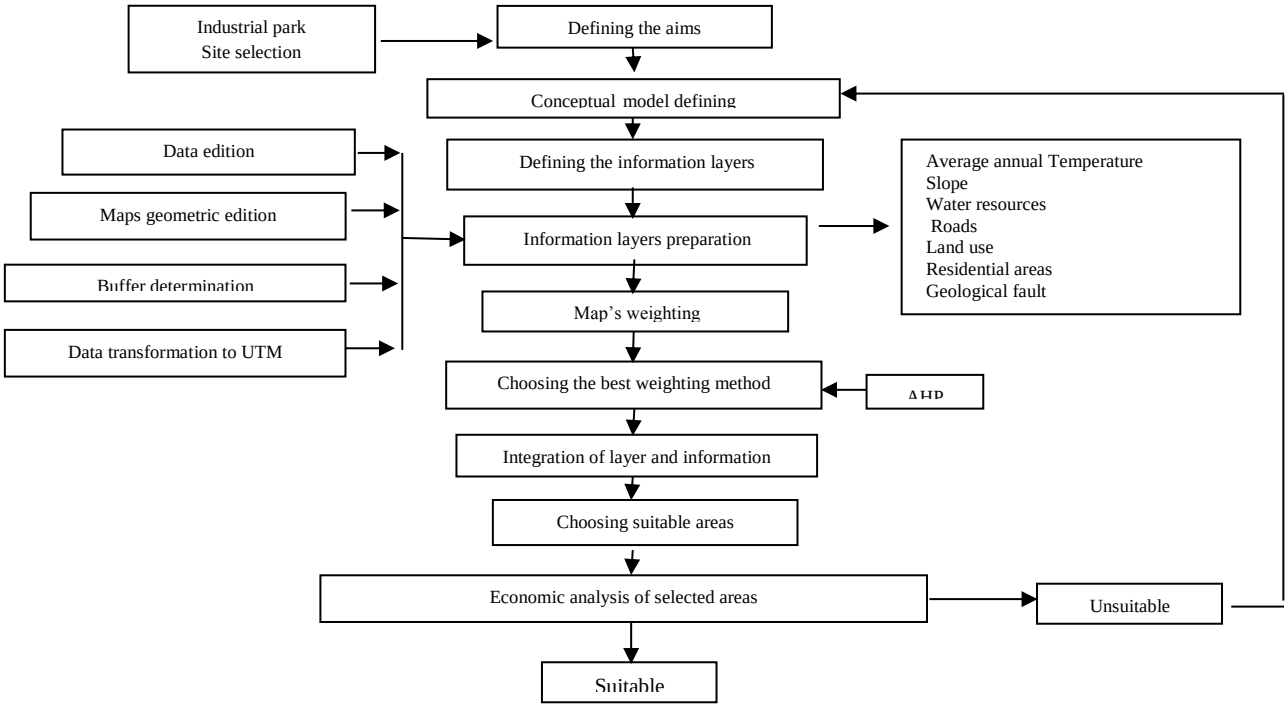

Figure 1. The Steps towards model selection

There are different integration manners for criteria selected for industrial park site selection such as:

Boolean algebra: This method was first suggested by British mathematician, Jeorg Bolee ad is based on

weighting each information layer with 0 and 1.

Index overlay: In this model different weights will be assigned to different classes of topographical features, then flexible combination of maps covering range of figures will be produced. For example different scores were assigned to slope factor for example for the slope lower than 3% we assigned 3 points, between 3% to 8% the 10 points was adopted and finally we adopted the score 3 for the slope range from 8 to 15%. Such scoring or weighting can be applied to geological faults, Azimuth, slope, soil and …. After then the layers were summed up using two variable analysis and the areas with higher score will recorded as preferred

Fuzzy logic: With this logic one can state vague implications with precise mathematical definitions and prepare a background to reasoning, control and decision making in uncertainty conditions.

Probabilities' logic: With using different models such as correspondence coefficient, Cohen capa index, Moran index, Kramer index and … different layers will be summed up and be analyzed as two or more layers.

Regression logic: The correlation between different variables such as population density and diseases distribution, slope and crashes, elevation, temperature and … will be calculated with two layer analysis.

Analytical Hierarchical process: The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. It was developed by Thomas L. Saaty [19] in the 1970s and has been extensively studied and refined since then. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand.

Neural artificial networks: This model is such a kind of Human brain modeling. The mathematical simulating models are used in this method.

In this study correspondence method in a deduction manner was used. Meanwhile we used AHP method in Expert choice software, as well as Arc GIS 9.3 and Spatial Analysis extension. For the better overlay analysis executing, all maps were converted to classified raster one. AHP includes decomposition of the decision problem into elements according to their common characteristics and the formation of a hierarchical model having different levels. Each level in the hierarchy corresponds to the common characteristic of the elements in that level. The topmost level is the 'focus' of the problem. The intermediate levels correspond to criteria and sub-criteria, while the lowest level contains the 'decision alternatives'. Then a judgmental matrix is formed and used for computing the priorities of the corresponding elements. First, criteria are compared pair-wise with respect to the goal. Once the judgmental matrix of comparisons of criteria with respect to the goal is available, the local priorities of criteria is obtained and the consistency of the judgments is determined. It has been generally agreed [19] that priorities of criteria can be estimated by finding the principal eigenvector w of the matrix A. That is:

$$W.w = \begin{bmatrix} 1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & 1 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_1 & \dots & 1 \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{bmatrix} = \lambda.W$$

$$Aw = \lambda_{max}\omega$$

When the vector w is normalized, it becomes the vector of priorities of the criteria with respect to the goal. λ_{max} is the largest eigenvalue of the matrix A and the corresponding eigenvector w contains only positive entries. The consistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

where CI is called the consistency index and RI, the Random Index. CI is defined as:

$$CI = \frac{\lambda max - n}{n - 1}$$

$$IR = \frac{CI}{CRI}$$

RI is the consistency index of a randomly generated reciprocal matrix from the 9-point scale, with reciprocals forced. Saaty [19] has provided an average consistency (RI values) of randomly generated matrices CR of the matrix is higher, it means that the input judgments are not consistent, and hence are not reliable. In general, a consistency ratio of 0_10 or less is considered acceptable. If the value is higher, the judgments may not be reliable and have to be elicited again.

III. Results

A. The Site Selection Steps

Average temperature: The higher this factor the more preferable the area. For mapping this criteria, the average temperature of the all towns were gathered from synoptic stations. Interpolation function was used for extracting annual average temperatures in unknown areas. The average annual temperature recorded for the study area is presented in the following table (Table I):

TABLE I. The Average Annual Temperature and Related Scores

Criteria (Celsius)	Score
0	1
8.8-10	5
>12	9

Slope: The less the slope amount the more suitable will be the area. The slope classes were extracted from topographical map and the following scores were assigned (Table II):

TABLE II. SLOPE AMOUNTS AND RELATED SCORES

Slope (Degree)	Score
0-6	5
6-10	4
10-15	3
15-20	2
>20	1

Distance to geological fault: The more far away from this event the better. The map of fault distribution was constructed from geological maps. The scores will assigned as presented in the following table (Table III).

TABLE III. DISTANCE FROM GEOLOGICAL FAULTS AND RELATED ASSIGNED SCORES

Distance from the fault (m)	Score
0-2000	1
2000-4000	2
40000-10000	3
10000-20000	4
>20000	5

Water resources: At first we defined a 300 meters buffer from the water resources and then assigned the scores as Table IV.

TABLE IV. SCORES FOR WATER RESOURCES

Distance from surface water resources(m)	Score
0-200	1
200-500	2
500-1000	3
1000-10000	4
>10000	5

Access roads such as highways, airports, railroads and … are some important parameters in industrial parks establishment in borderlines. At first we defined a 150 meters buffer from these infrastructures and the scores were assigned as below (Table V).

TABLE V. DISTANCE FROM ACCESS ROADS AND THEIR ASSIGNED SCORES

access road (m)	Score
0-300	1
300-500	2
500-10000	3
>10000	4

Residential areas: these areas are barriers for industries development. The more distance from industrial areas the higher suitability and consistency will be (Table VI).

TABLE VI. DISTANCE FROM RESIDENTIAL AREAS AND ASSIGNED SCORES

Distance from residential areas	Score
0-1500	1
1500-3000	2
3000-6000	3
6000-12000	4
>12000	5

Land uses in the study area: we focused mainly on ranges and dryland cropping with low quality. Weighting and classifying of the landuses are presented in Table VII.

TABLE VII. LAND USE TYPES AND ASSIGNED SCORES

Land use type	Score
Dryland cropping	10
Low density ranges	9
Mid density ranges	8
Scrubland and Bushlands	7
Mid density forest	6
Dense range land	5
Dense forest	4
Horticulture and wet cropping	3
Water zones	2
Residential area	1

B. Criteria Weighting Using AHP

Applying different scientific methods especially different software in project more practicability and utility are essential for accurate resulting. Different methods are developing based on different criteria such as AHP that follow a mathematical logic [20]. This method uses geometric weighting so the related software calculates the final normal weights for each criterion that will be used for final ranking. This method was applied and tested in different georeferenced decision making [21] [22]. We used subjective judgment for getting to the criteria's weights (Table VIII).

TABLE VIII. PAIRWISE CRITERIA COMPARISON MATRIX FOR SECOND INDUSTRIAL PARK SITE SELECTION USING AHP

Criteria	average annual temperature	Slope	Fault	Surface water	Land use	Urban area	Access roads	Normal Weight
average annual temperature	1	$1/7$	$1/9$	$1/5$	$1/5$	$1/3$	$1/3$	0.025
Slope	7	1	1	5	7	5	5	0.314
Fault	9	1	1	7	7	7	7	0.382
Surface water	5	$1/5$	$1/7$	1	3	1	1	0.082
Land use	6	$1/7$	$1/7$	$1/3$	1	$1/3$	$1/3$	0.047
Urban area	3	$1/5$	$1/7$	1	3	1	1	0.075
Pathway	3	$1/5$	$1/7$	1	3	1	1	0.075

Inconsistency coefficient=0.06

Overlaying information layers to generate suitable area's map for industrial park:

The related maps for investigated criteria in industrial park site selection were modified and prepared in Arc GIS software and classified based on Table 1-7. After map's classification we used Index overlay model and the maps were overlayed:

$$C = \frac{\sum W_i S_{ij}}{\sum W_i}$$

In which Wi is equal with its map's weight that was extracted during AHP and Sij is the weight of site classification related to the its map. S is assigned value for each space units in the related criteria for the output map. Each value that assigned to each class in the criteria multiplied by criteria weight and then summed up and divided by criteria's weight to produce its impact factor of that criterion in the final map. All of these values were calculated for each cell in the maps and the final map was produced. Indeed map's overlay model is flexible and has priority for space units' identification in the criterion maps [23]. Based on mentioned formula and weights assignment, we executed overlay in the GIS software and the final suitability map for industrial state were produced (Fig. 2).

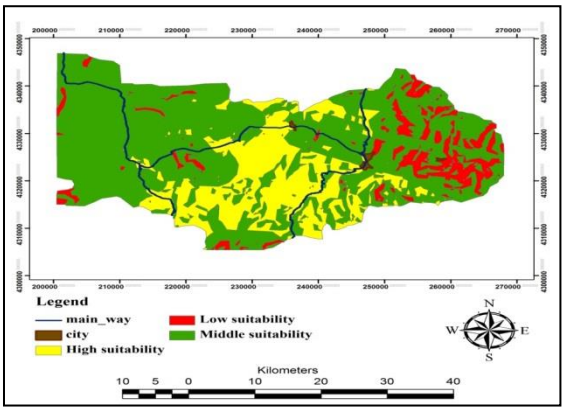

Figure 2. Classification of Germi city different areas for industrial park site selection based on AHP and Index overlay

The final options were determined after field activities and investigation about socio-economic conditions such as land owning, land value, accessibility and so on (Fig. 2). The different resulted priorities are including:

The first priority is located about 7 km to Germi in the line between Germi-Ardebil (E 39 º, 04′ and N 48 º , 01 ′). It accessibility via the road, the least slope and existence of the dryland cropping are some values of the selected areas. This are is close to Germis dam and water will be provided from there.

Tis area as a second priority is located in the west of Germi, close to the Germi-Ilkhchi cross (E 39º, 02′ and N 48 º, 06 ′). This area has different facilities that are essential.

The third priority has located in the Germi-Bilesavar access line, in the Kalasar-Sofla village (E 39º , 08′ and N 48 º , 06 ′) about 12km from Germi. The main problem in this area is water deficiency.

IV. Discussion and Conclusion

Industrial development is essential for multi aspect development of the potential area and the first step toward this end will be site selection, there are many criteria for promoting site selection process that ecological criteria are the most important of them. Because of special ecological and socio-economic characteristics, the establishment of the new industrial park for Germi is essential. Topographical patterns in the study area show high mountains close to the city that affect both of accessibility and suitable slope factors. The existence of borderline between Iran and Azerbaijan, the relative closeness to the province capital (Ardabil) and rich raw material resources in the Germi is some of this city's values. Therefore we also considered these values in the site selection process. As well as ecological factors, we considered economic factors and the suitable areas were identified after field work. The first priority was selected with regard to low slope and closeness to the first industrial park. The two other priorities were selected based on land value and owning as well as its accessibility and closeness to the Germi. In this study we found that the tools such as GIS and multi criteria decision making systems can successfully applied to criteria analysis and can deal with huge data. This study showed that applying AHP model as well as GIS is very effective in industrial parks sites selection and allow different sites comparison and evaluation based on related criteria. Therefore this method can be used through country in the similar studies. Meanwhile the criteria can be modified with regard to local conditions to produce more precise results.

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