Using GIS for Site Selection of Combined-Cycle Power Plants

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Abstract: Concerning the population growth and development of industrial and agricultural sections, the electric power demand is increasing continuously. Therefore, it is necessary to forecast the load of the electric network and expand the power system for supplying reliable electrical energy. A power plant as a power generating station is one of the essential infrastructures of the electric network. The construction of new power plants is an important part of the electric network expansion. The suitability of selected site for power plant affects the amount of generated energy, power plant's productivity, cost of power generation and transmission (loss of energy), economical development and environment. Therefore, in site selection process for a power plant it is necessary to carefully consider not only the technical issues, but also it's impact on

natural environment, economy and near local communities. Since most of the related data to site selection of power plants are geospatial, Geographical Information Systems (GIS) allows for the consideration and combination of various data about geology, topography, water resources, roads, available electric network, fuel supply, land use, etc.
In this paper, the required conditions for the establishment of thermal power plants are comprehensively studied and conceptual model of power plant sitting is designed. Later, conventional models for integrating factor maps have been investigated. For experimental test, the factor maps of studied area have been prepared and integrated. Finally the suitable locations for the construction of power plant are selected using GIS.

Keywords: GIS, Power plant, Site selection, Geospatial data, integrate

1. Introduction

Electrical energy has an important role in development of agricultural, industrial and socio-economical sections. In Iran, as a result of population growth, urbanization, and changes in the life-style of people, the demand for electrical energy has been growing continuously. To respond to this increase in the demand for electrical energy effectively, it is necessary to predict the electricity consumption for the coming years and to plan for the necessary development in the electricity production and transmission network. Power plants as the sources of electricity supply are the most important part of the network. As the first step of network development, existing power plants should be improved and new plants should be established. The construction of a power plant is usually very expensive and time-consuming and has intensive effects on the environment and on all aspects of both people life and socio-economic area. Therefore, comprehensive studies are required before the construction of a power plant.

The most important parameters that should be first defined are the type of the power plant, its capacity and the most suitable location for it. In Iran large volumes of natural gas resources has been found. Therefore the policy of the government is to concentrate on the construction of natural-gas thermal power plants in the development of electricity generation. The location of a power plant has significant effects on the efficiency of electricity generation, the price of electricity production and transmission, its environmental impact etc. therefore the selection of the location for a new power plant should be done very carefully and based on the analysis of many different factors. Many of these factors are essentially spatial, and the data about them are from different sources and in different scales. Therefore GIS along with appropriate models and spatial analysis method should be used to define the suitability of different locations for the construction of power plants.

2. Important Factors in Site Selection for Power Plants

In general, both the construction and operation of a power plant requires the existence of some conditions such as water resources and stable soil type. Still there are other criteria that although not required for the power plant, yet should be considered because they will be affected by either the construction or operation of the plants such as population centers and protected areas. The following list covers most of the factors that should be studied and considered in selection of proper sites for power plant construction. Many of these factors are also used in [3].

- **Transportation network**: Easy and enough access to transportation network is required in both power plant construction and operation periods.
- **Gas pipe network**: Vicinity to the gas pipes reduces the required expenses.
- **Power transmission network**: To transfer the generated electricity to the consumers, the plant should be connected to electrical transmission system. Therefore the nearness to the electric network can play a roll.
- **Geology and soil type**: The power plant should be built in an area with soil and rock layers that could stand the weight and vibrations of the power plant.
- **Earthquake and geological faults**: Even weak and small earthquakes can damage many parts of a power plant intensively. Therefore the site should be away enough from the faults and previous earthquake areas.
- **Topography:** It is proved that high elevation has a negative effect on production efficiency of gas turbines. In addition, changing of a sloping area into a flat site for the construction of the power plant needs extra budget. Therefore, the parameters of elevation and slope should be considered.
- **Rivers and floodways**: Obviously, the power plant should have a reasonable distance from permanent and seasonal rivers and floodways.
- **Water resources:** For the construction and operating of power plant different volumes of water are required. This could be supplied from either rivers or underground water resources. Therefore having enough water supplies in defined vicinity can be a factor in the selection of the site.

- **Environmental resources**: Operation of a power plant has important impacts on environment. Therefore, priority will be given to the locations that are far enough from national parks, wildlife, protected areas, etc.
- **Population centers**: For the same reasons as above, the site should have an enough distance from population centers.
- **Need for power:** In general, the site should be near the areas that there is more need for generation capacity, to decrease the amount of power loss and transmission expenses.
- **Climate**: Parameters such as temperature, humidity, wind direction and speed affect the productivity of a power plant and always should be taken into account.
- **Land cover**: Some land cover types such as forests, orchard, agricultural land, pasture are sensitive to the pollutions caused by a power plant. The effect of the power plant on such land cover types surrounding it should be counted for.
- **Area size**: Before any other consideration, the minimum area size required for the construction of power plant should be defined.
- **Distance from airports**: Usually, a power plant has high towers and chimneys and large volumes of gas. Consequently for security reasons, they should be away from airports.
- **Archeological and historical sites**: Usually historical building …are fragile and at same time very valuable. Therefore the vibration caused by power plant can damage them, and a defined distance should be considered.

3. Data collection and classification of parameters

The study area is Fars province, in the southern part of the country with the area of 122780 Km². Considering the study area size and the diversity of parameters, it was decided that the study should be done in two stages and using data of two different scales. On the basis of available spatial data in the country, using the data of 1:250,000 scale a generally suitable area were selected. Then using 1:25,000 maps more detailed site selection was carried out in the previously selected locations. The Landsat satellite images of year 2002 were used to update the 1:250,000 maps. To be brief, in this paper only site selection based on 1:250,000 maps is discussed. After comprehensive study of selection parameters, all required spatial features are defined and categorized into three main classes of physical, environmental and socio economic features. The three main classes have 13 smaller classes. The classification is presented in table 1.

Table 1: The classification of important features

Main class	Class	Subclass
Physical environment	Topography	Slope
		Elevation
	Geology & Soil type	Stability
		Faults
		Earthquake spots
		Soil type
		Mine
	Climate	Temperature
		Humidity
		Rainfall
		Wind speed
		Wind direction
		Evaporation
Biological environment	Land cover & land use	Forest
		Orchard
		Agricultural land
	Water bodies	Sea
		Lake
		River
		Floodway
		Swamp
		Marsh
	Protected environment	Protected area
	Population centers	City
		Village
		Historical locations

Socio- economic	Accessibility	Free way
		High way
		First class road
		railway
	Electrical consumption points	Industrial town
		Industries
		City/town
		Village
		Agricultural wells
	Fuel supply	Refinery
		Gas pipe
	Water supply	River
		Underground water
		Lake
	Power transmission	Power transmission line
		Power substation
	Power generation	Power plant
		dams

4. Spatial data analysis

The above mentioned features were represented in different layers from these layers two different types of maps were generated, according to the essence of the related factor and its effect on the suitability of the site:

4.1 Limitation maps

Such a map defines the area that cannot be used for the power plant because of a limiting factor. Such a map is binary map, in which the areas with limiting condition (not suitable) are given the value of zero and the allowed (suitable) areas are given the value of one. For example, the area with slope bigger than 10% is represented with zero value (not-suitable) and the areas with less slope are represented as suitable (value one), (Fig. 1). The list and criteria for generation of such maps is presented in table2.

Table 2: Limitation maps and their criteria

Feature	**Description**	**Limitation or Buffer size**
Elevation		>1800 m
Slope		> 10%
Fault	Major& minor	1 Km
	Reverse	2 Km
Earthquake spots	5.5-6 mb	1 Km
	>6 mb	2 Km
City	Shiraz	10 Km
	Center of district	5 Km
	Other cities	3 Km
Village		2 Km
Dam		10 Km
Swamp		1 Km
Sandy land		The whole area
Mine	Unimportant	1 Km
	Important	2 Km
Lake		1 Km
Floodway		2 Km
Marsh		1 Km
Orchard		The whole area
Forest		1 Km
Protected areas	National park	3 Km
	Wild life	2 Km
	Protected area	1 Km

4.2 Factor maps

Some of the parameters do not affect the suitability of a location in absolute manner (e.g. making it absolutely unsuitable), yet has a positive or negative effect on the suitability. The effect of such parameters can be modeled by giving them appropriate weights. For example, areas can be given different weights according to their distances from existing gas pipe lines (Fig. 2).

Fig 1. Limitation map of protected Area

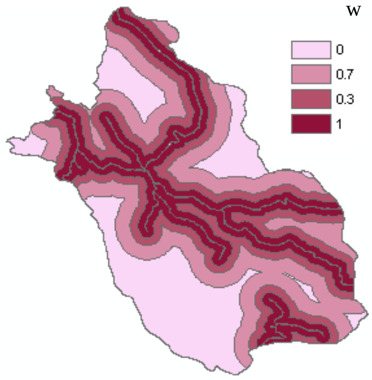

Fig 2. Factor map of road

These parameters and their given weights are listed in table 3. The weights are the result of discussions with experts in the subject.

Table 3: Factor maps and given weights

Factor	Weight of Factor	Class of Factor	Weight of class
Elevation	0.09	0-1000 m	1
		1000-1400 m	0.8
		1400- 1800 m	0.4
		>1800 m	Zero
Slope	0.08	0-6 %	1
		6-10 %	0.7
		>10 %	Zero
Road	0.12	0 – 500 m	Zero
		0.5 - 10 Km	1
		10-20 Km	0.7
		20-40 Km	0.3
		>40 Km	Zero
Demand of consumption center	0.2	High	0.9
		Average	0.6
		Low	0.3
Gas pipe line	0.15	0-500 m	Zero
		0.5- 5 Km	1
		5-10 Km	0.8
		10-20 Km	0.6
		20-40 Km	0.3
		>40 Km	Zero
River	0.07	0- 500 m	Zero
		0.5 – 10 Km	1
		10 – 20 Km	0.5
		>20 Km	Zero
Cultivation	0.06	Yes	0.5
		No	1
Geology & Soil type	0.08	Alluvial fans	0.2
		Alluvium terrace	0.2
		Desert flats	0.2
		Igneous rocks	0.9
		karstic limestone	0.8
		Lagoon & salt bottoms	0.0
		Limestone	0.8
		Lower alluvium terrace	0.2
		Lower plain alluvium	0.2
		Marl	0.4
		Marl, shale, schist	0.4
		Medial plain	0.2
		Evaporaties and Salt domes	0.0
		Sandstone	0.3
		Tuff	0.3
		Tuffeous conglomerate	0.3

Water Discharge	0.09	Excellent	0.9
		Mostly Excellent	0.8
		Very Good	0.7
		Good	0.6
		Relatively Good	0.5
		Medium	0.4
		Small	0.2
		Poor	0.1
		Very Poor	0.0
Lake	0.06	0- 500 m	Zero
		0.5 – 10 Km	1
		10 – 20 Km	0.5
		>20 Km	Zero

5. Data integration and selection of suitable locations

The integration of the data (resulted maps) was carried out in two stages:
1) Limitation maps are overlaid using the Boolean Operation where input maps can be integrated by using logical operators such as AND, OR (Bonham Carter and G.F., 1991). In this research logical 'AND' operator was used, which resulted in the selection of areas that have 'one' value in all limitation maps.
2) Factor maps are integrated with the index overlay method using Eq. (1)

$$S = \frac{\sum W_i S_{ij}}{\sum W_i} \qquad (1)$$

Where:
Wi = The weight of ith factor map
Sij= The ith spatial class weight of jth factor map
S= The spatial unit value in output map

It is resulted in a map with values for every location showing different suitability of locations for power plant construction.
It should be mentioned that the result of index overlay is multiplied by the result of limitation maps overlay. The final integrated map is presented in Fig. 3.

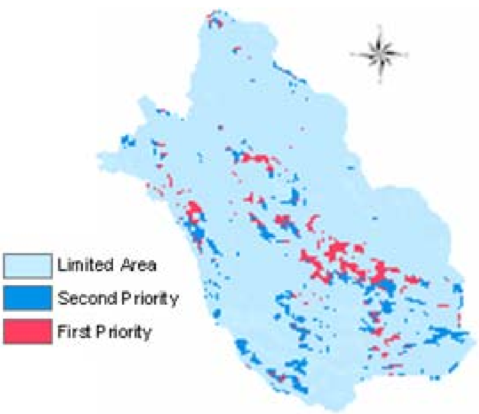

Fig. 3. Final integration map for power plant

6. Conclusion and discussion

Although such methods have been used in many GIS projects, the finalization of this work has shown the following results:

- GIS systems provide us with a rich collection of spatial analytical capabilities. In addition, usually a variety of spatial data might be available. Yet, none of these guide us to a proper spatial decision. Yet there is a strong need for clear thinking, good planning and selection of implemental approaches.
- The most difficult and yet most important part in such projects is the proper selection and evaluation of parameters and criteria. The manipulation and analysis of the data is much more straightforward.
- The accuracy of selection is directly related to the properness of the weights given to the parameters.

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