



Optimal Site Selection of Military Bases in Meshginshahr township Using Geographic Information System (GIS) Capabilities and the Analytic Network Process (ANP) Model¹

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Abstract

Background and Objective: Multi-criteria decision-making methods combined with Geographic Information Systems (GIS) enable the simultaneous evaluation of various environmental, infrastructural, and security criteria, assisting in the optimal selection of locations for the establishment of military bases. Accordingly, the aim of this study is to locate military bases in Meshginshahr County using the Analytic Network Process (ANP) model and GIS.

Methodology: To achieve the research objective, a survey method was first employed by designing a questionnaire to collect expert opinions on the factors influencing the siting of military bases in the study area. In the next step, necessary data layers were digitized based on existing maps, and a database was created in the ArcGIS environment. Data weighting was carried out using the ANP method. Finally, the zoning map of the study area was prepared by integrating and overlaying the selected layers.

Findings and Results: The results indicated that 15.67% of the county's area falls within the "highly suitable" class and 17.97% within the "suitable" class, mainly located in the central and eastern parts of the county. In contrast, 25.55% is categorized as "unsuitable" and 21.48% as "highly unsuitable," primarily found in the mountainous and steep western and southern regions. This study demonstrated that integrating multi-criteria decision-making models with GIS spatial analysis can significantly assist in optimizing the site selection of military bases while minimizing environmental and security conflicts.

Extended Abstract

Introduction:

Site selection is a process in which, by considering the specific conditions and requirements of an activity, the most suitable location is chosen based on available resources and facilities. In other words, the goal of site selection is to identify one or more locations with the desired descriptive characteristics through the integrated analysis of spatial data and descriptive information. This process is typically carried out using optimal option selection and various statistical and mathematical procedures. Selecting an appropriate location for regional facilities requires a careful assessment of spatial potentials and descriptive features to ensure that the chosen land use is fully compatible with environmental conditions. In military site selection, access to military resources, supply lines, and logistical capabilities are among the most important factors. In commercial and industrial units, access to labor, raw materials, and

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transportation networks is a top priority. Proximity to the consumer market is one of the most crucial factors in commercial site selection, as it helps reduce transportation costs and increases customer access to products and services. The type of potential threats such as ground, air, naval, or cyber threats also plays a significant role in determining the location of military facilities. Therefore, the geographical position of military bases can have broad implications for national and regional security. Geopolitical features of a region such as proximity to borders, access to natural resources, and strategic location play a decisive role in the selection of military base locations. Military centers and installations are often primary targets during military attacks. Hence, proper spatial organization of armed forces can help reduce a country's vulnerability to enemy attacks. A spatial planning approach, by taking into account various factors such as geographical location, natural features of the region, and potential threats, aims to organize the military forces in a way that maximizes national security and minimizes vulnerability. Analyzing the optimal orientation of military command centers with an emphasis on military and security threats requires understanding the types and sources of threats and ultimately providing site selection strategies based on military and defense considerations.

Methodology:

Meshginshahr County, with an area of over 3,700 square kilometers, is located at 47°30' east longitude and 38°23' north latitude, on the northern slopes of Mount Sabalan and about 20 kilometers from its prominent summit. To the east lies the deep Khiyav-Chay valley, through which the Khiyav-Chay River flows. Two other radial valleys form natural pathways for surface water flow, along which residential neighborhoods have developed. These areas are exposed to flooding and heavy surface runoff. The presence of multiple valleys—most notably the Khiyav-Chay River valley—has given the city a distinct landscape. A portion of Meshginshahr is situated on an alluvial fan, with its sloping landform extending from the Sabalan mountain range to the eastern bank of the Khiyav-Chay River. In this study, the optimal location for military bases in Meshginshahr County was determined using the following data:

- A Digital Elevation Model (DEM) with 30-meter resolution, derived from ASTER satellite data (obtained from the United States Geological Survey – USGS), from which slope, aspect, and drainage network layers were extracted.
- A 1:100,000-scale digital geological map of Ardabil Province.
- Landsat 9 satellite imagery (obtained from the USGS website) used to produce a land use/land cover map for the year 2024 (1403 in the Iranian calendar).
- 1:50,000-scale topographic maps, along with other relevant parameters, all processed and generated in the ArcGIS environment.

To achieve the objectives of the research, relevant criteria for military site selection were first identified through a review of previous studies, library research, and expert interviews (with a sample size of 20 professionals). According to the type of criteria, the required spatial data were then digitized and imported into the GIS environment using appropriate formats. Since not all criteria hold the same level of importance, the Analytic Network Process (ANP) was employed to determine the weight of each criterion using Super Decisions software. In the final stage, the weighted spatial layers were overlaid using standard GIS techniques to identify the most suitable zones for military base construction within the study area. The Analytic Network Process (ANP) views every decision problem as a network of elements—criteria, sub-criteria, and alternatives—grouped into clusters. In such a network, elements may interact in any possible form. In contrast to hierarchical structures, ANP allows for interdependency and feedback both within and between clusters. Hence, ANP consists of two key components: a control hierarchy, which defines the relationship between the goal, criteria, and sub-criteria (impacting the internal structure), and a network of dependencies, which considers the mutual influence of clusters and elements. This ability to account for interrelationships among elements provides a more realistic and comprehensive approach to complex decision-making in fields such as geography, urban planning, and regional development. The influence of each element on others within the network is represented using a supermatrix, enabling robust spatial analysis.

Results and Discussion:

Environmental Layers Used for Military Base Site Selection

In order to determine optimal locations for military bases in Meshginshahr County, seven key environmental layers were analyzed: slope, aspect, elevation, geology, distance from drainage networks, distance from faults, and vegetation cover. Slope is a crucial factor affecting construction safety, cost, and structural stability. Areas with gentle slopes (less than 11 degrees), particularly in the northeastern and central parts of the region, are more suitable for military infrastructure. Aspect also plays a significant role in terms of solar radiation, runoff behavior, and risk reduction from natural hazards. Elevation directly influences climatic conditions such as temperature, precipitation, and evaporation, and also has strategic implications. Mid-altitude areas are generally more favorable both climatically and from a security standpoint. Elevation classes in the region range from 599 to 4,788 meters above sea level. Resistant geological formations like granite and other igneous rocks provide structural stability and are suitable for base construction. In contrast, areas with unconsolidated alluvial deposits, marl, or claystone—due to mechanical instability—are considered unsuitable for military installations. Proximity to watercourses increases the risks of flooding, erosion, and excessive soil moisture. Intermediate distances (approximately 2,752 to 4,128 meters) strike a balance between minimizing hydrological hazards and ensuring access to water resources. Constructing military facilities near active faults poses significant seismic risks. Zones located more than 14 kilometers from fault lines (yellow and green classes) are identified as safer options with lower construction and reinforcement costs. Areas with sparse vegetation—especially in the central and southwestern regions—are less environmentally sensitive and offer better access to infrastructure and strategic advantages. These areas also show lower NDVI values, indicating reduced ecological impact. Overall, analyzing and integrating these environmental layers using the ANP model provided a reliable basis for identifying suitable zones for military base development in Meshginshahr County.

Final Suitability Zoning

The final suitability map for military base location in Meshginshahr County (Figure 13) was produced by integrating weighted layers—slope, aspect, elevation, vegetation cover, land use, geology, distance from faults, drainage, roads, and residential areas—using the ANP model (Table 1) in ArcGIS. The region was classified into five suitability classes: very suitable, suitable, moderately suitable, unsuitable, and very unsuitable.

- Very Suitable Areas (Blue, 580 km²): Located mainly in the central and eastern parts, these zones offer optimal conditions including low environmental conflicts, suitable terrain, and good access to infrastructure.
- Suitable Areas (Green, 665 km²): Also favorable, though potentially with minor constraints such as proximity to agricultural or water-rich zones.
- Moderately Suitable, Unsuitable, and Very Unsuitable Areas (Yellow, Orange, Red): Covering 715 km², 945 km², and 795 km² respectively, these areas are characterized by steep slopes, dense vegetation, residential proximity, or remoteness from infrastructure—making them less appropriate for military base development.

Mountainous and steep regions in the west and south (mainly red and orange zones) pose significant logistical and construction challenges and should be avoided. Therefore, the blue and green zones—primarily in central and eastern Meshginshahr—are recommended for optimal military base placement due to their strategic, environmental, and infrastructural advantages. Figures 13 and Tables 1 and 2 present the final suitability map, criteria weights, area, and percentage of each suitability class.

Conclusion:

In this study, the Analytical Network Process (ANP) model, along with ArcGIS and Super Decision software, was used to weight multiple environmental and infrastructural criteria for optimal military base site selection in Meshgin Shahr County. The final zoning map was generated by overlaying weighted layers such as slope, geology, elevation, land use, vegetation, fault distance, and proximity to roads and waterways. Results indicated that central and eastern parts of the county are most suitable for military bases due to their low slopes, stable geology, moderate elevation, and accessible infrastructure. Areas with steep slopes, dense vegetation, agricultural land, or close proximity to faults, rivers, and residential zones were deemed unsuitable. Notably, the southern and northwestern areas with steep terrain and unstable geological formations showed high construction risks. Conversely, regions with granite or intrusive igneous rocks offered favorable conditions. The study found that areas with moderate vegetation and located 2.7 to 4.1 km from waterways and more than 14 km from faults were optimal. In total, around 37% of the county—comprising "very suitable" (580 km²) and "suitable" (665 km²) zones—was identified as ideal for military base development. These findings can guide strategic planning to ensure security while minimizing environmental and social impacts.

Declarations

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