Hindawi
Advances in Civil Engineering
Volume 2022, Article ID 5144642, 24 pages
https://doi.org/10.1155/2022/5144642

Research Article

Site Selection of Isolation Hospital for Coronavirus Patients in Nile Delta, Egypt, Using GIS Technology

Ashraf A. A. Beshr,[1,2] **Magdy Israil**,[3] **Hameda A. Abden**,[3] **and Magda H. Farhan**[3]

[1]*Public Works Engineering Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt*
[2]*Civil Engineering Department, Delta Higher Institute for Engineering & Technology, Mansoura, Egypt*
[3]*Civil Engineering Department, Faculty of Engineering, Kafr El-Sheikh University, Kafr el-Sheikh, Egypt*

Correspondence should be addressed to Ashraf A. A. Beshr; aaabeshr@mans.edu.eg

Received 25 May 2022; Revised 19 August 2022; Accepted 10 September 2022; Published 30 September 2022

Academic Editor: Romulus Costache

Coronavirus disease (COVID-19) is a viral infection caused by the SARS-CoV-2 virus that first surfaced in December 2019. According to the World Health Organization, most persons infected with this virus suffer from mild to severe respiratory infections and recover without specific treatment or hospitalization. Some people, however, may acquire serious illnesses that need medical attention and isolation facilities. This paper investigates the use of multi-criteria decision analysis (MCDA) based on GIS technology to determine the optimal site selection for isolation hospitals for coronavirus patients in Nile Delta region in Egypt using the fuzzy analytical hierarchy process (F-AHP) and the weighted overlay tool analysis method (WOA). The research of isolation hospital site selection in Nile Delta governorates in Egypt is one of the areas that have received insufficient attention due to the current global coronavirus epidemic. Several criteria are applied to identify and select the isolation hospital location, including World Health Organization regulations, Egyptian Ministry of Health conditions, previous research studies, and field visits. Geodatabase is created using ArcGIS Pro software, and manual digitization is done. As a conclusion of the study, numerous additional optimal sites for isolated hospitals have been found and chosen. There are around 29 proposed ideal sites for isolated hospitals utilizing F-AHP and approximately 24 sites using WOA approach in Nile Delta region. These planned hospital locations might be permanent as a central hospital or temporary, to be relocated after the epidemic is over. The paper emphasizes the need to use the study criteria while selecting and defining the location of coronavirus isolation hospitals.

1. Introduction

Healthcare services are considered a significant indication of a society's growth. Health service research is one of the most effective public services that each society needs since its existence and availability to an acceptable degree through prevention or treatment lead to illness prevention. There are norms for attaining sustainable development in the health professions that prioritize hospitals [1]. The world is now suffering from the coronavirus pandemic. The coronavirus disease (COVID-19) is an infectious disease that is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) novel virus [2]. Coronavirus pandemic has resulted in the collapse of several global health systems and health infrastructure in many countries and a severe scarcity of isolation hospitals due to the increasing number of patients. Therefore, governments have set up field hospitals to ensure that all patients receive the necessary medical treatment due to the development of this virus and the increase in people infected with the coronavirus

Determining the best location for coronavirus isolation hospital (permanent or temporary) is vital and necessary, especially in Nile Delta, Egypt. One of the most significant challenges of the study in Egypt is the lack of an official declaration of isolation hospitals within the official state statistics (Central Agency for Public Mobilization and Statistics) because the census was issued in 2017, before the start of the coronavirus epidemic. This challenge was solved by conducting field trips to determine the rising rates till 2022.

Modern technologies such as remote sensing and geographic information system (GIS) are utilized to locate new hospitals [3, 4]. GIS technology can store, organize, analyze, calculate, and present all types of geographical data for health services [5, 6]. This paper employs two analytical approaches for optimum site selection: F-AHP and WOA. The WOA performs multiple phases in a single tool's typical overlay analysis process, and it only accepts accurate raster data as input. F-AHP is a method for deriving ratio scales from paired comparisons that is preferable for assessing weights for decision criteria used in many decision-making domains [7, 8].

Deveci et al. [9] investigated using GIS by using type-2 fuzzy set-in site selection for public bread factory in Turkey, and their results showed that the technique is effective and can be used in the bakery industry. Mallick et al. [10] examined utilizing GIS through employing fuzzy AHP in landslide susceptibility evaluation in Abha Watershed, Saudi Arabia. Their results revealed that the approach is practical for understanding the watershed's sustainability in terms of land sliding. El Jazouli et al. [11] examined using GIS-multicriteria by applying AHP in landslide susceptibility mapping in the Oum Er-Rbia high basin (Morocco). Their results revealed that the approach is beneficial to obtain a map that gives vital information about current and future landslides, making it feasible. Balusa and Gorai [12] explored the application of fuzzy analytic hierarchical process (F-AHP) in sensitivity analysis for selecting underground metal mining methods. Their findings revealed that the methodology effectively acquires mining method selection using the F-AHP model.

Tripathi et al. [13] made a comparison of GIS-based AHP and fuzzy AHP methods for hospital site selection, and their results showed that the fuzzy AHP method is effective and is the best choice for choosing a new hospital site. Şahin et al. [14] investigated the use of the analytic hierarchy process on the hospitals' site selection, and their results showed that the technique is useful to get the best site selection for the hospital. Mirzahossein et al. [15] investigated using ArcGIS by applying AHP in site selection for emergency centers in Silk Road based in Iran.

For this research, the Nile Delta region in Egypt was chosen as a case study. A high rate of coronavirus infection plagues the delta area. As a result, there is a need for the ideal positioning of coronavirus isolation hospitals to improve access to health services following the advent of the COVID-19 pandemic. This research uses multi-criteria decision analysis (MCDA) based on GIS and remote sensing technologies to identify the optimal isolation hospital sites in the delta area. This paper seeks to achieve the following objectives:

(a) Investigating the selection criteria for coronavirus isolation hospitals.
(b) Developing a GIS framework based on MCDA for the selection of isolation hospital sites in Egypt's study region (Nile Delta). This suggested framework may be used to identify acceptable and safe hospital sites in any country.
(c) Comparing F-AHP with the WOA method as an analytic technique for optimum site selection.

2. Study Area and Health Services

Nile Delta in Egypt is chosen as study area for this paper because it is one of Egypt's most densely inhabited places. The delta region is located between two latitudes 31°30′ 0″ N, 30°30′ 0″N and two longitudes 30°20′ 0″E, 32°0′ 0″. The Mediterranean Sea bounds this region from the north, the Suez Canal from the east, Cairo from the south, and Alexandria from the west. Delta is located in the north of the Arab Republic of Egypt, as shown in Figure 1. The Nile Delta region in Egypt includes 5 governorates, which are Dakahlia, Kafr El-Sheikh, Damietta, Gharbia, and Menoufia, and is located between the two streams of the Nile (Damietta and Rashid). Some governorates' centers may expand beyond these two branches, as Dakahlia Governorate and Menoufia Governorate (Figure 1). These five governorates cover a combined area of 16735.61 km^2 which represents 1.22% of the total area of Egypt. The population, area, and density are depicted in Table 1, with a total population of 2,211,2848 which represents 22.6% of the total population of Egypt (Central Agency for Public Mobilization and Statistics 2021). Therefore, health care must be given to them well to maintain their safety.

There are several types of governmental hospitals (health service centers) in the study area distributed according to Figure 2. The number of hospitals and their distribution in delta governorates are shown in Table 2. The number and position of these hospitals are necessary for this study through using MCDA where each hospital is correlated to route analysis, closest facility analysis, and serviced area. As shown in Table 2, the total number of hospitals in the delta governorates was as follows: 29 central hospitals (A), 24 central hospital (B), 13 general hospitals, 30 quality hospitals, and 18 university hospitals.

In Table 2, general hospital is the hospital located in the governorate's capital or an administrative center and serves a population of more than 500,000 people, but central hospital (A) is the hospital that is located in an administrative center or a city and serves a population of about 200–500 thousand people; central hospital (B) is the hospital located in an administrative center or a city and serves a population of about 100–200 thousand people. Quality hospital is the hospital that provides specialized health care services, including chest hospitals, dermatology hospitals, fever hospitals, children's hospitals, ophthalmology hospitals, sciatica and obstetrics hospitals, and brain and nerves hospitals.

The development of patients in Egypt who have been infected with the coronavirus since the epidemic's beginning till now can be illustrated as follows.

From the start of the pandemic (year 2019) to the end of year 2020, the total number of people infected was 136,644 thousand. By 2021, the total number of individuals afflicted reached 438,728 thousand. As of mid-March 2022, the total number of persons infected with the coronavirus had reached 495,373 thousand, indicating a rise in infection rates (source: Egyptian Ministry of Health, 2022).

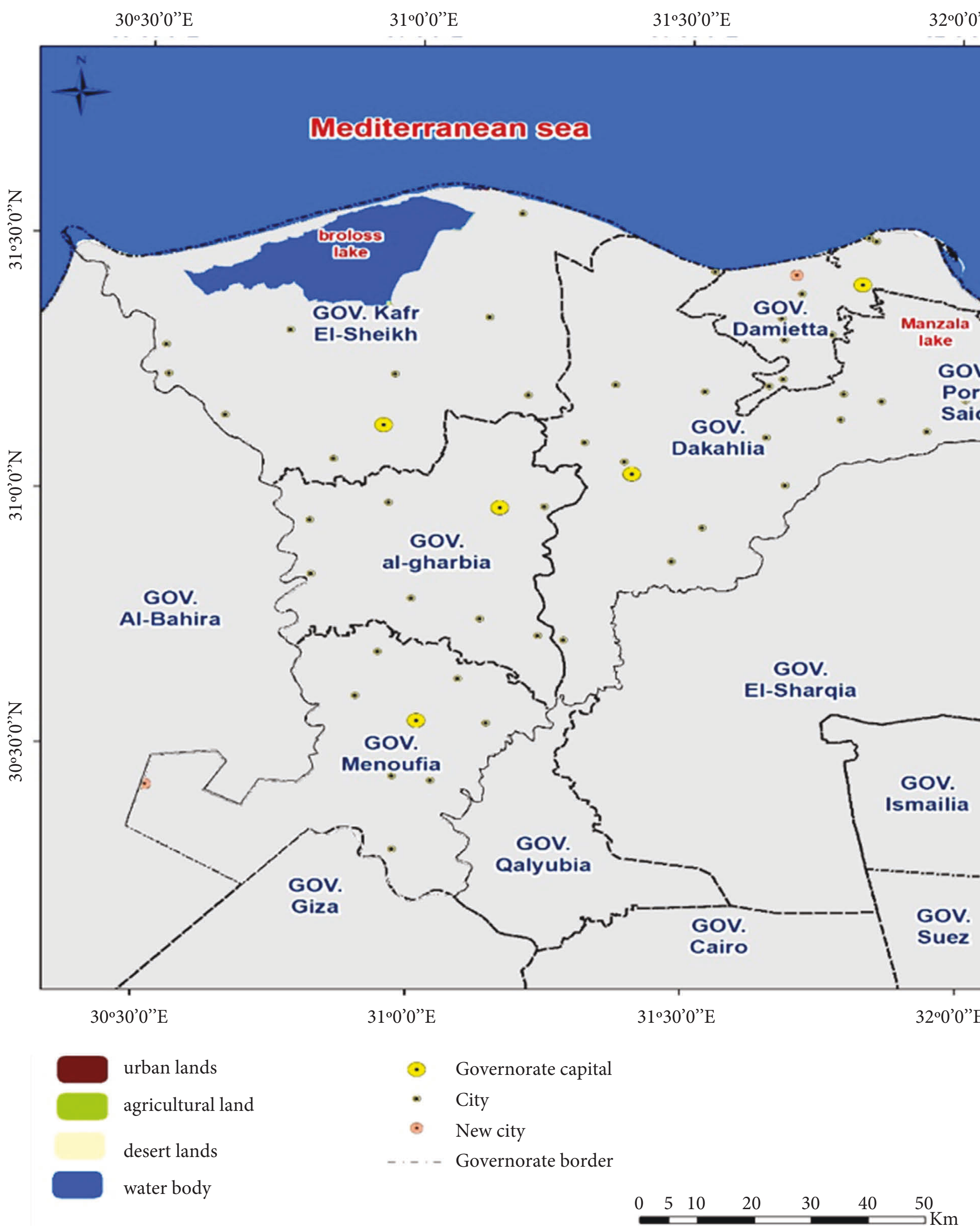


Figure 1: Land cover and governorates of the study area.

Table 1: Areas and population for Nile Delta governorates, Egypt, in the year 2021 (source: Central Agency for Public Mobilization and Statistics, Egypt 2021).

Governorate	Population (people) 2021	Area (km^2)	Density (population/km^2)
El-Dakahlia	6922687	5383.36	1285.94
El-Gharbia	5335280	2648.10	2014.77
El-Menoufia	4632983	3125.41	1482.36
Damietta	1591109	1225.51	1298.37
Kafr El-Sheikh	3630789	4353.23	834.04
Total	**22112848**	**16735.61**	**6915.48**

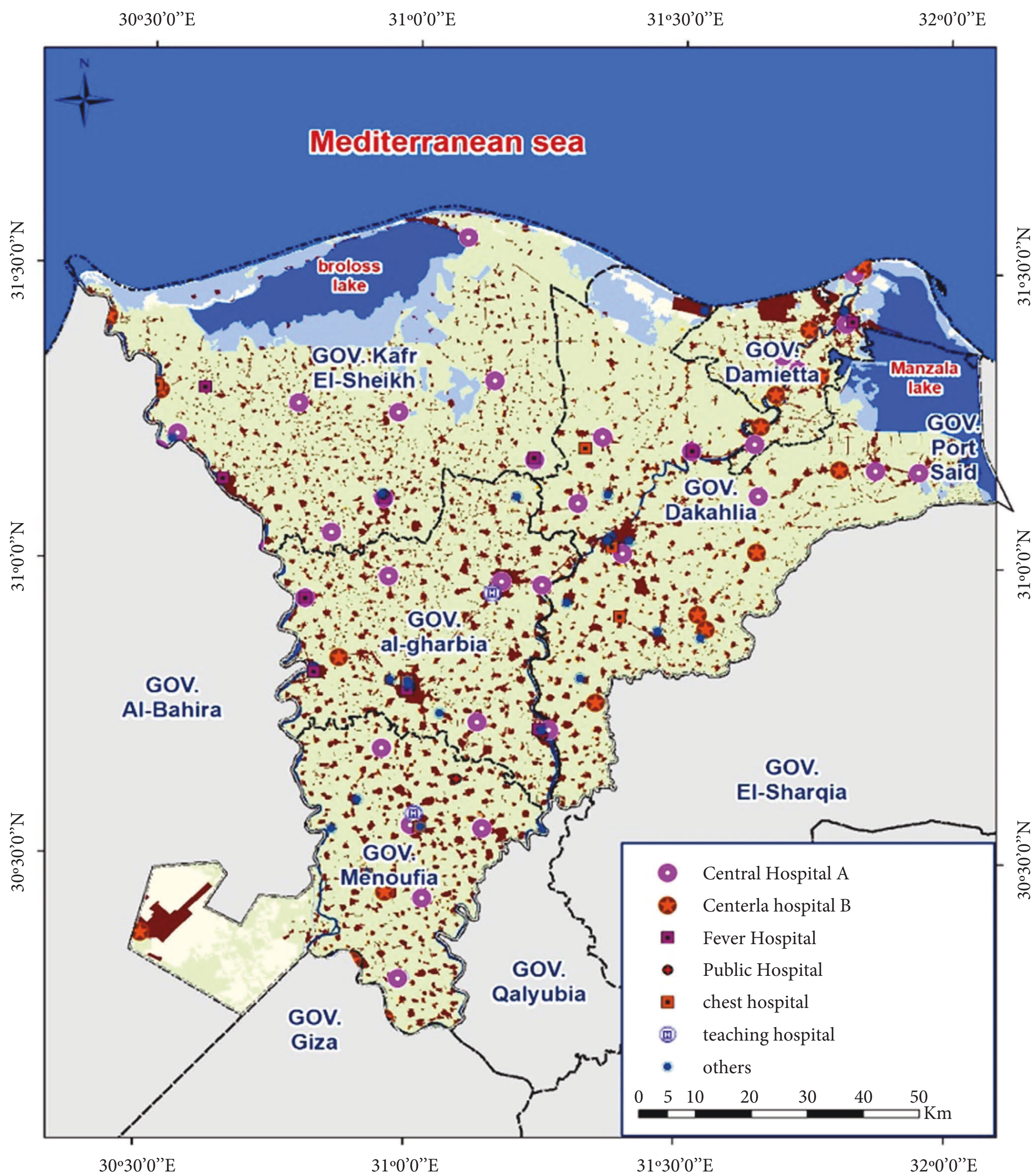


Figure 2: Types and distribution of existing governmental hospitals (health service centers) in the study area.

Table 2: General hospitals, central hospitals, quality hospitals, and university hospitals in the Nile Delta, Egypt (source: Egyptian Ministry of Health, 2021).

Governorate	Types of hospitals					Total
	General hospitals	Central hospitals (A)	Central hospitals (B)	Qualitative hospitals	University hospitals	
El-Dakahlia	2	6	4	5	1	18
El-Gharbia	2	3	6	3	1	15
El-Menoufia	3	11	9	5	7	35
Damietta	2	5	3	9	5	24
Kafr El-Sheikh	4	4	2	8	4	22
Total	**13**	**29**	**24**	**30**	**18**	**114**

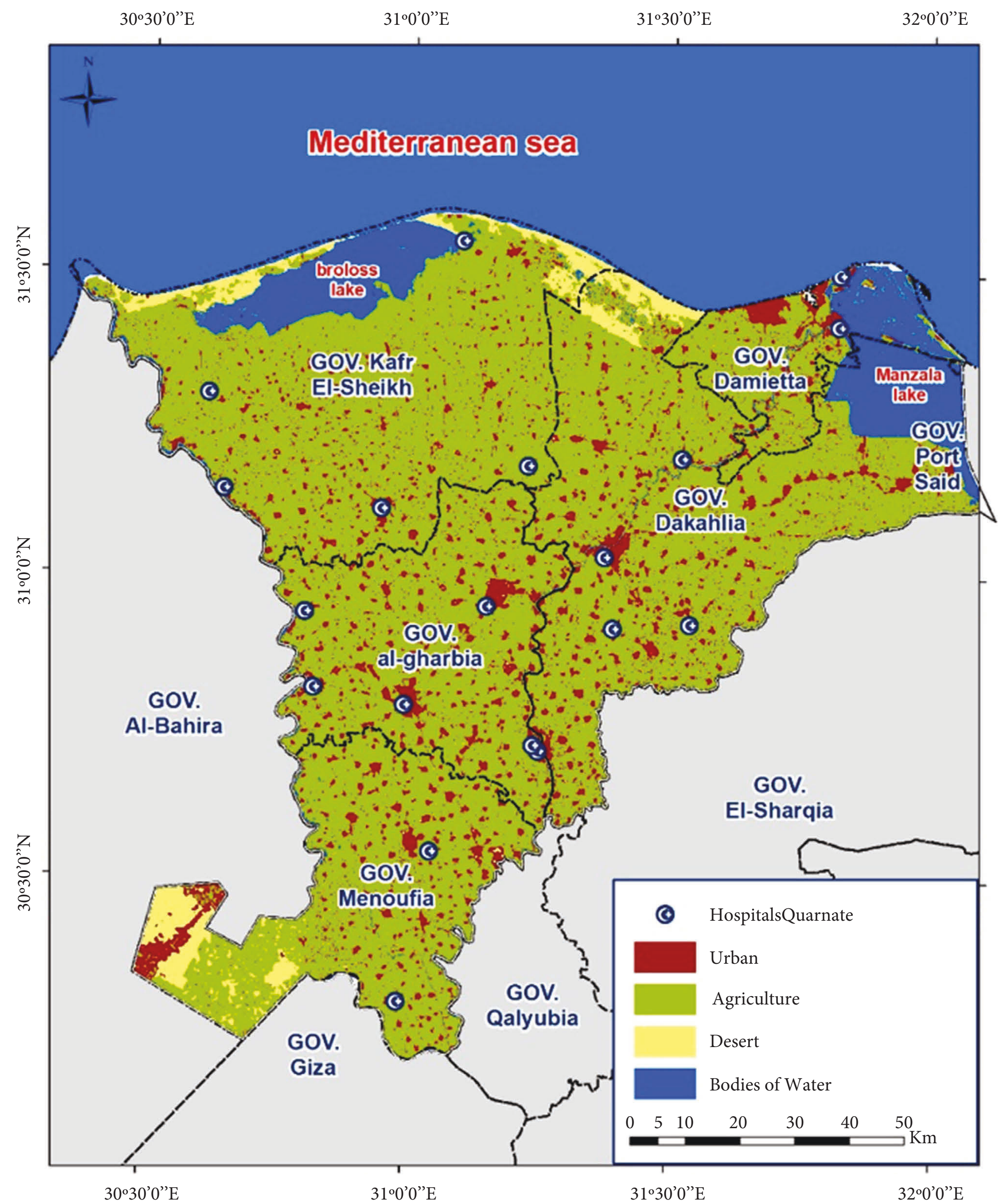


Figure 3: Locations of isolation and existing quarantine hospitals in the Nile Delta, Egypt.

Since the beginning of the epidemic, several public sector hospitals in the study area (Nile Delta, Egypt) have been designated as isolation hospitals for coronavirus patients. Figure 3 and Table 3 depict the distribution of the existing isolation hospitals designated throughout the Egyptian delta governorates in accordance with the Ministry of Health and Population's guideline to isolate persons infected with coronavirus (COVID-19). As stated in Table 3, the total number of isolation hospitals in the delta governorates has reached 19. The number and distribution of these hospitals are vital for the study.

Table 3: Isolation and quarantine hospitals for the delta governorates (source: Egyptian Ministry of Health, 2021).

Governorate	Isolation and quarantine hospitals
El-Dakahlia	4
El-Gharbia	6
El-Menoufia	2
Damietta	2
Kafr El-Sheikh	5
Total	**19**

3. Available Data for the Study

This study utilized more than one data source to get the various necessary information as follows:

(1) Field visits to the health directorates and hospitals in the Nile Delta governorates to know the number and locations of the hospitals selected as isolation hospitals for coronavirus patients in each governorate and to collect the criteria for selecting isolation hospitals positions.

(2) Satellite images for the studied area from Landsat 8 with a resolution of 30 m downloaded from the site https://earthexplorer.usgs.gov/ in October 2021.

(3) The official cadastral map of the urban plan of Nile Delta, Egypt, in 2017 with a scale 1 : 50000.

(4) Annual Statistical Report of population in the year 2021 (Egyptian Ministry of Health).

(5) The road network for the delta governorates in the year 2021 (Central Agency for Public Mobilization and Statistics, Egypt).

(6) The strategic plan for the delta region 2019 (General Authority for Urban Planning, Egypt).

4. Applied Analytic Methodologies for the Study

In this paper, two analytical techniques are applied to select the optimum site selection for isolation hospitals as follows.

4.1. Fuzzy Analytical Hierarchy Process (F-AHP). Fuzzy analytic hierarchy process is a method of analytic hierarchy process (AHP) developed with fuzzy logic theory. The F-AHP method is used similar to the method of AHP. It is just that the F-AHP method sets the AHP scale into the fuzzy triangle scale to be accessed with priority [16].

A main reason for the new approach (F-AHP) is that a traditional AHP is ineffective in dealing with uncertainty when decision makers choose a scale from a given fundamental scale of 1 to 9. To reflect the uncertainty, decision makers require more flexible scales by using fuzzy membership functions and linguistic variables, e.g., good or poor, rather than deterministic or crisp values [17, 18]. This method has been applied to numerous areas of the construction industry with similar purposes as the conventional AHP method. The F-AHP was studied a lot in renewable energy alternatives since it is more advantageous to provide flexible scales from fuzzy membership functions [19]. The F-AHP is considered a sufficient mathematical method for analyzing complex decisional problems [20]. It determines the weights by comparing the relative importance of the criteria in a pairwise manner through a pairwise comparison matrix. After forming the pairwise comparison matrix, computation of the criterion weights is done. The computation involves the following operations [21]:

(i) Evaluating the sum of all values in each column of the pairwise comparison matrix.

(ii) Division of each element in the matrix by its column total (the resulting matrix is a normalized pairwise comparison matrix).

(iii) Computation of the average of elements in each row of the normalized matrix, i.e., dividing the sum of normalized scores by the number of criteria. These averages estimate the relative weights of the criteria being compared.

When performing pairwise comparisons, F-AHP deals with consistency explicitly just as in thinking; people do not always have the intrinsic logical ability to be consistent for estimating consistency; it involves the following operations [22, 23]. Nowadays, humans determine the weighted sum vector by multiplying the matrix of comparisons on the right by the vector of priorities to get a new column vector. Then, divide the first component of the new column vector by the first component of the priority vector and the second component of the new column vector by the second component of the priority vector. Finally, sum these values over the rows.

GIS and MCDA are used to determine the optimal sites for isolation hospitals after entering weights to ArcGIS program. MCDA is used to measure the relative importance weights for individual evaluation criteria as shown in Table 4 [24].

4.2. Weighted Overlay Analysis Tool (WOA) Method. The weighted overlay tool is one of the most widely used techniques for solving multi-criteria problems such as site selection models [25, 26]. ArcGIS uses the weighted overlay tool, which is the sum of a variable's value of a distribution unit multiplied by the weight of the variable. In WOA, you must define the problem, break the model into sub-models, and identify the input layers [27]. Since the input criteria layers will be indifferent numbering systems with different ranges, to combine them in a single analysis, each cell for each criterion must be reclassified into a standard preference scale such as 1 to 10, with 10 being the most favorable. An assigned preference on the ordinary scale implies the phenomenon's preference for the criterion. The preference values are relative [28, 29].

A preference of 10 is twice as preferred as a preference of 5. The preference values should not only be assigned relative to each other within the layer but should have the same meaning between the layers. Each of the weighted overlay analysis criteria may not be equal in importance. You can weigh the important criteria more than the other criteria. The input criteria are multiplied by the weights and then added together. The final step of the overlay analysis process is to validate the model to make sure that the model indicates that it is at a site. Once the model is validated, a site is selected, and the house is built [30, 31].

The WOA combines the following steps:

(i) Reclassifies values in the input raster into a common evaluation scale of suitability.

Table 4: Intensity of importance for used criteria (source: [24]).

Intensity of importance	Description	Suitability class
1	Equal importance	Lowest suitability
2	Equal to moderate importance	Very low suitability
3	Moderate importance	Low suitability
4	Moderate to strong importance	Moderately low suitability
5	Strong importance	Moderate suitability
6	Strong to very strong importance	Moderately high suitability
7	Very strong importance	High suitability
8	Very to extremely strong importance	Very high suitability
9	Extreme importance	Highest suitability

Table 5: The deduced criteria used to select coronavirus patient isolation hospitals.

Description	Criteria
The population of the Nile Delta Egypt governorates that occupies the study area	Population density
The spacing rate between urban areas (buffer: 20 km)	Urban shops (list cities)
Delta governorate roads, whether main or secondary roads	Road network
Electricity lines, sewage, phone, and water lines	Infrastructure
Factories, quarries, and workshops in the delta governorates	Industrial zones
Existing hospitals and medical centers in the delta governorates	Current hospital sites
The railways in the delta	Railways
The output of use of medical instruments and materials used in coronavirus (COVID-19)	Landfill sites

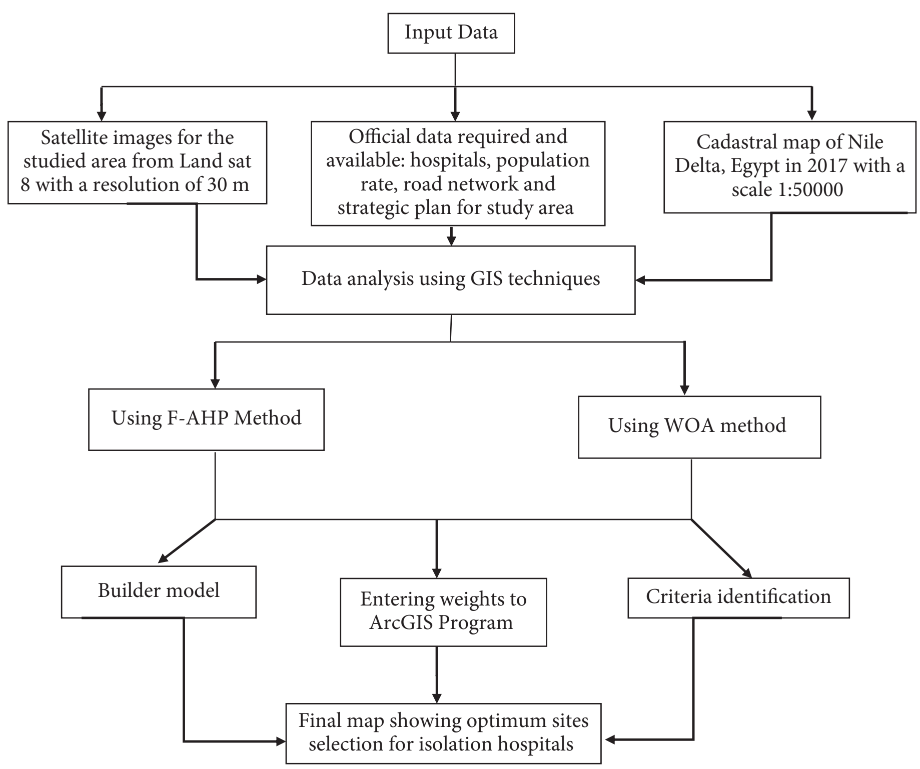


Figure 4: Flowchart of the research methodology.

(ii) Multiplies the cell values of each input raster by the raster's weight of importance.

(iii) Adds the resulting cell values together to produce the output raster.

The tool only accepts integer raster as input, such as a raster of land use or soil types. Continuous rasters must be reclassified to integers before they can be used. The values of continuous rasters are grouped into ranges. Each range must be assigned a single value before being used in the weighted overlay tool. The Reclassify tool allows for such rasters to be reclassified. Assign weights at the time of reclassifying. With the correct evaluation scale chosen, simply add the raster to the weighted overlay. WOA is used for suitability modeling

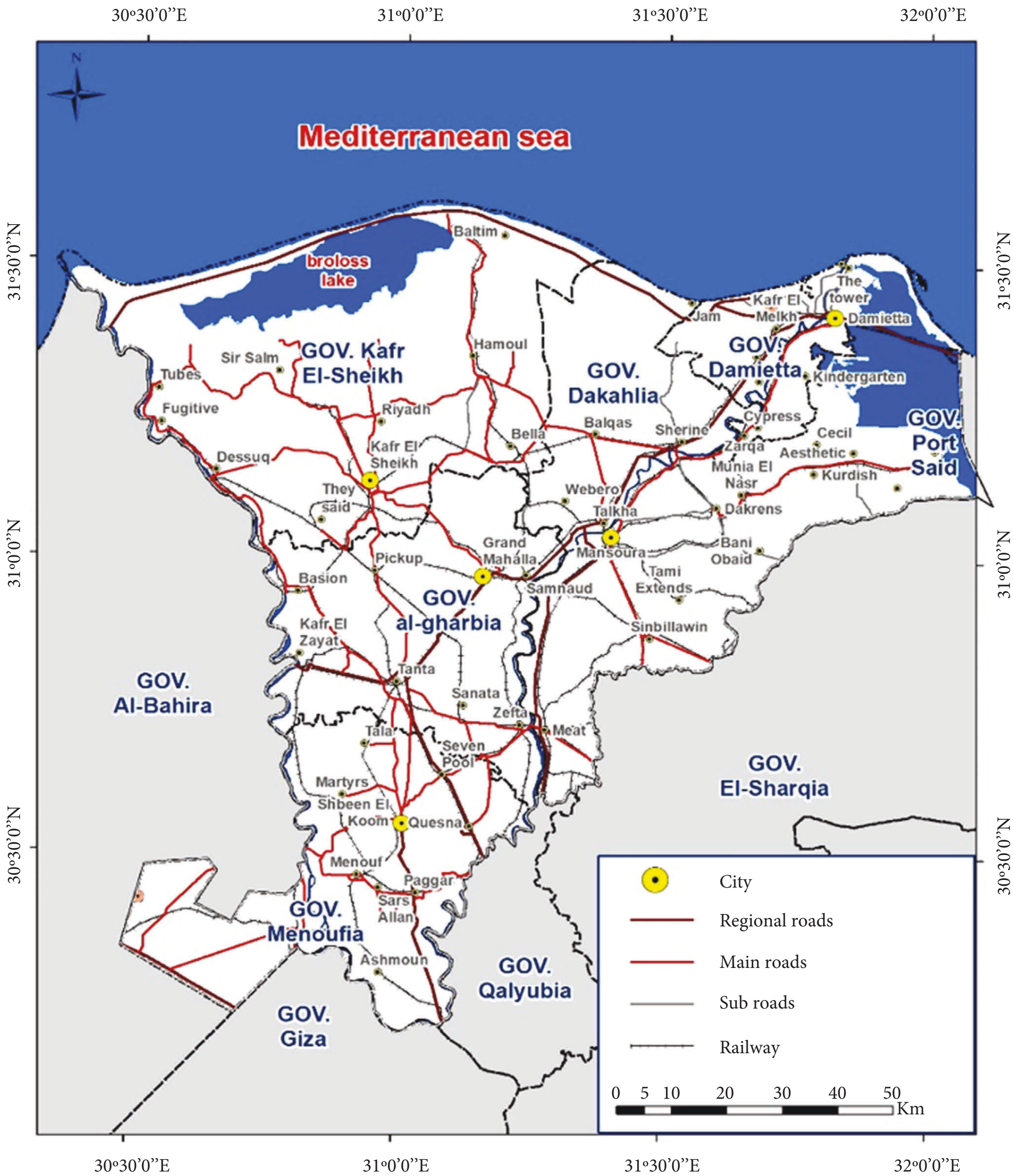


Figure 5: The main and secondary road networks and the railway network of the study area.

(to locate suitable areas), and therefore higher values generally indicate that a location is more suitable.

5. The Used Criteria Applied for the Study

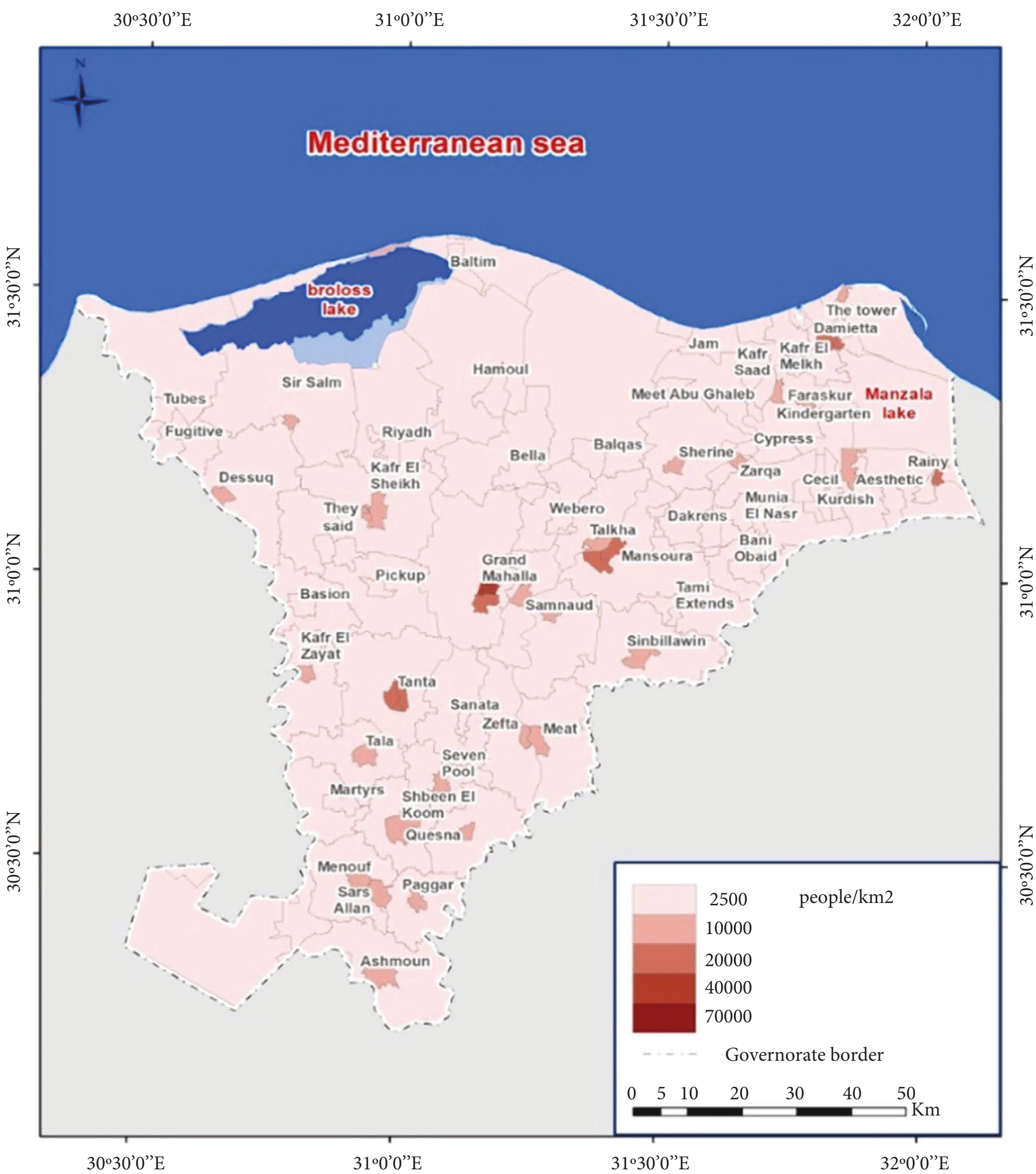
Depending on the World Health Organization regulations, Egyptian Ministry of Health conditions, review of previous research studies, and field visits to various hospitals and by asking specialist doctors, several criteria (eight criteria) can be identified for selecting optimal site selection for isolation hospitals for coronavirus patients as shown in Table 5. Each criterion is clarified and described and gives a clear indication for choosing the locations of health services.

6. Research Methodology and Procedure Steps

This section explains the applied methodology of research using GIS tools and multi-criteria decision analysis to determine the optimum site selection for new isolation hospitals in Nile Delta. Figure 4 shows a flowchart of research methodology for identifying new site selection for isolation hospitals for coronavirus patients in the study area using two different analytic techniques which are F-AHP method and WOA method.

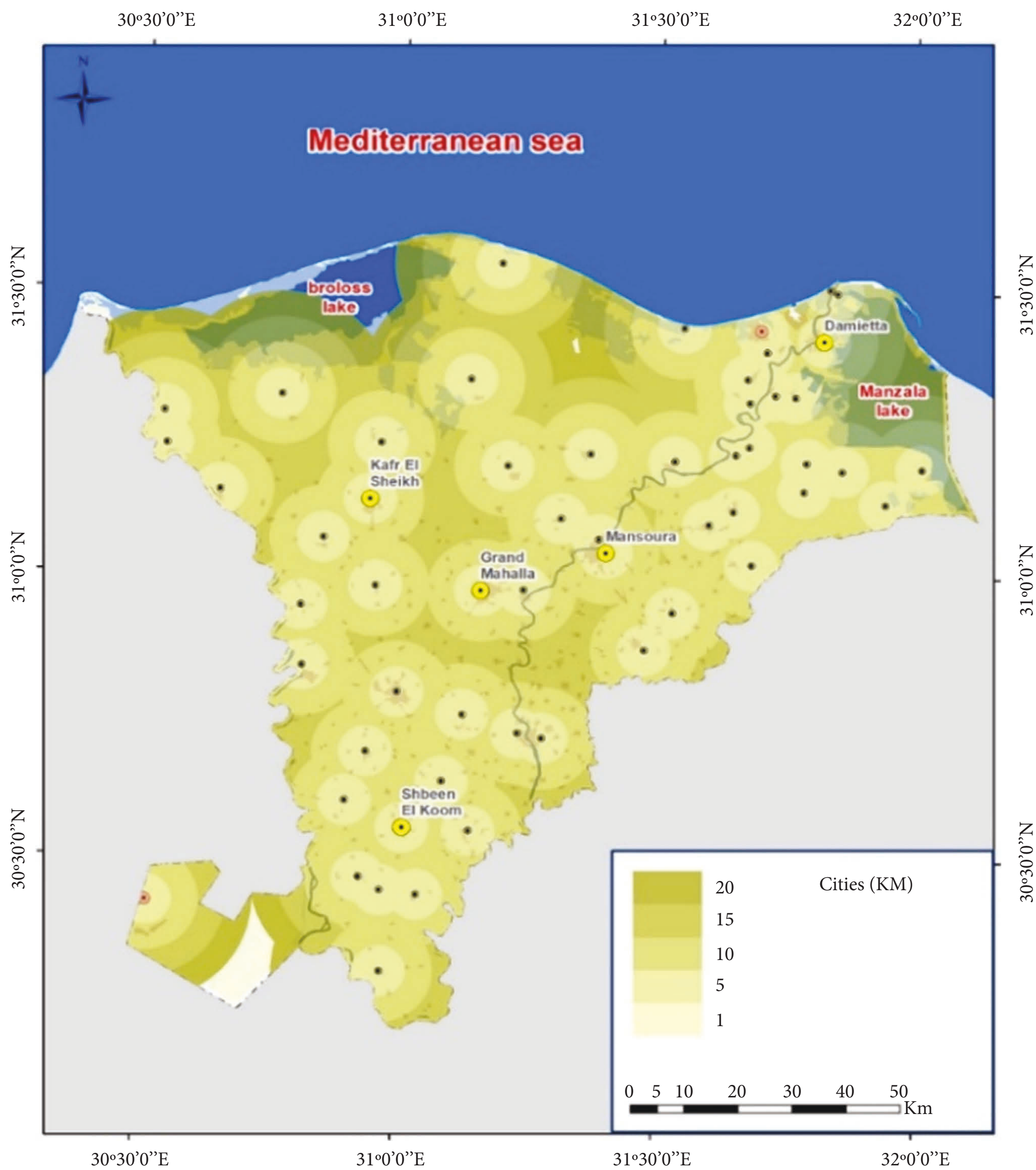
The model was built using the following steps.

6.1. First Step: Preparation of a Base Map. A base map was prepared for delta governorates in order to perform the site



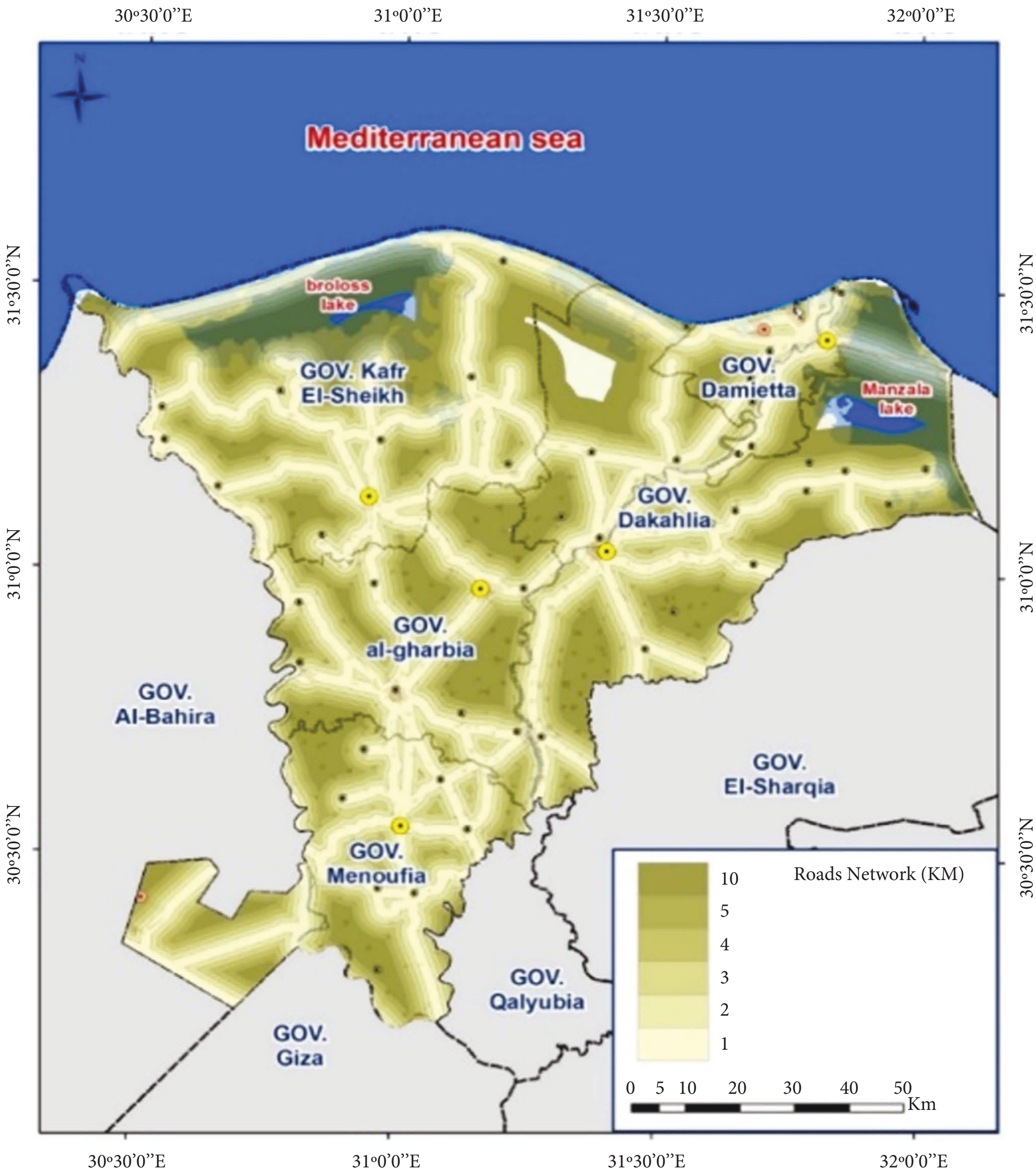
(a)

Figure 6: Continued.



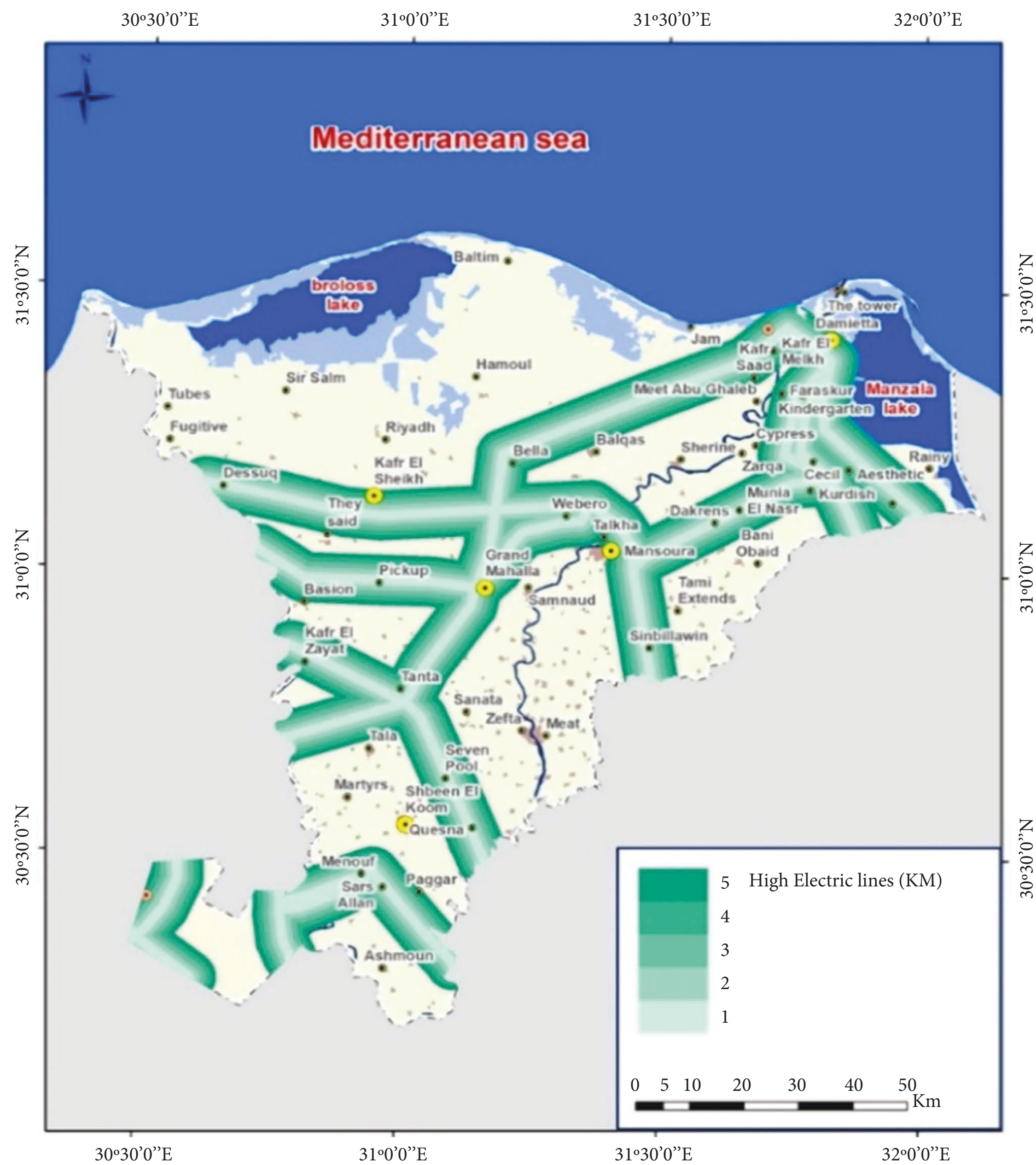
(b)

Figure 6: Continued.



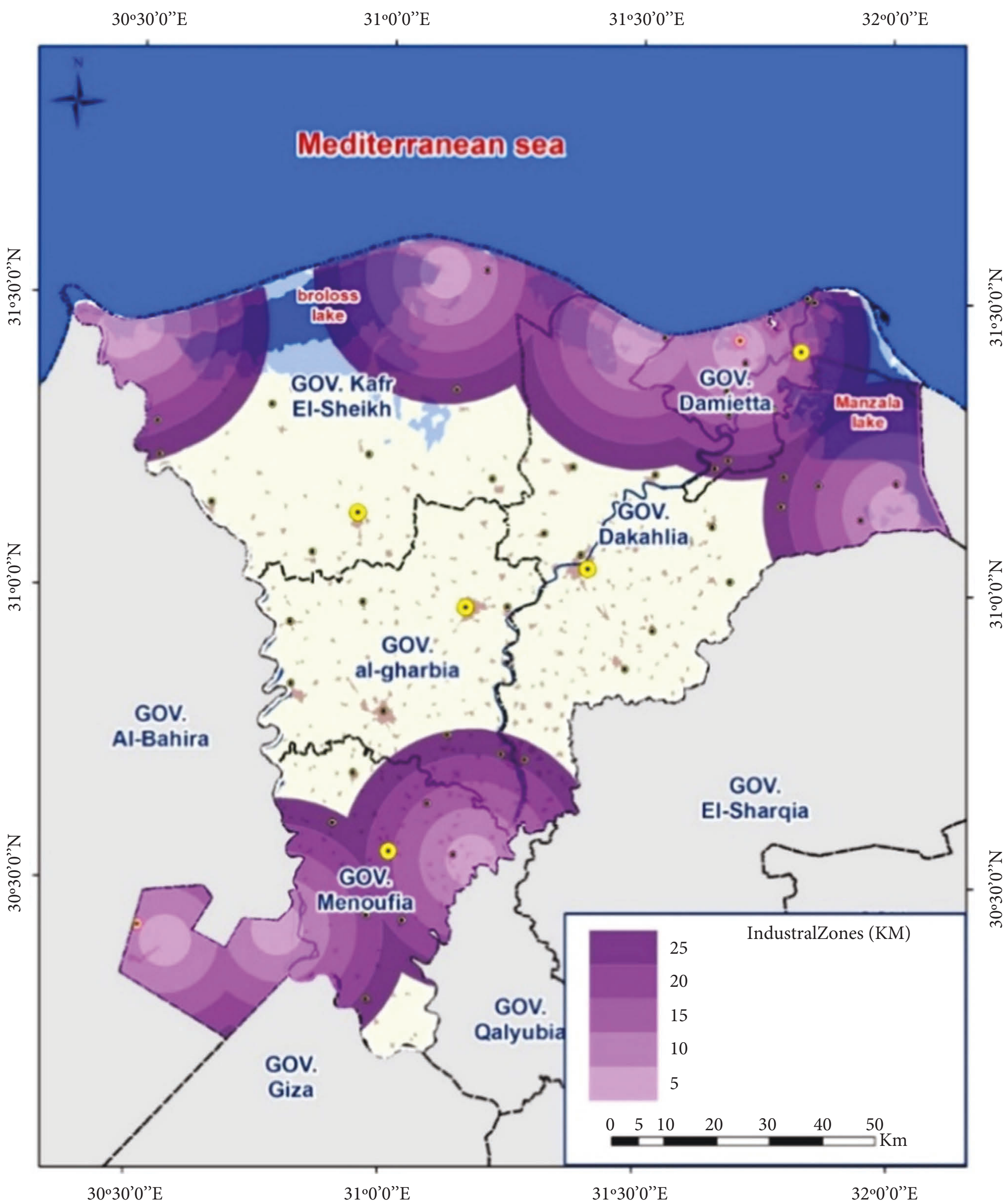
(c)

Figure 6: Continued.



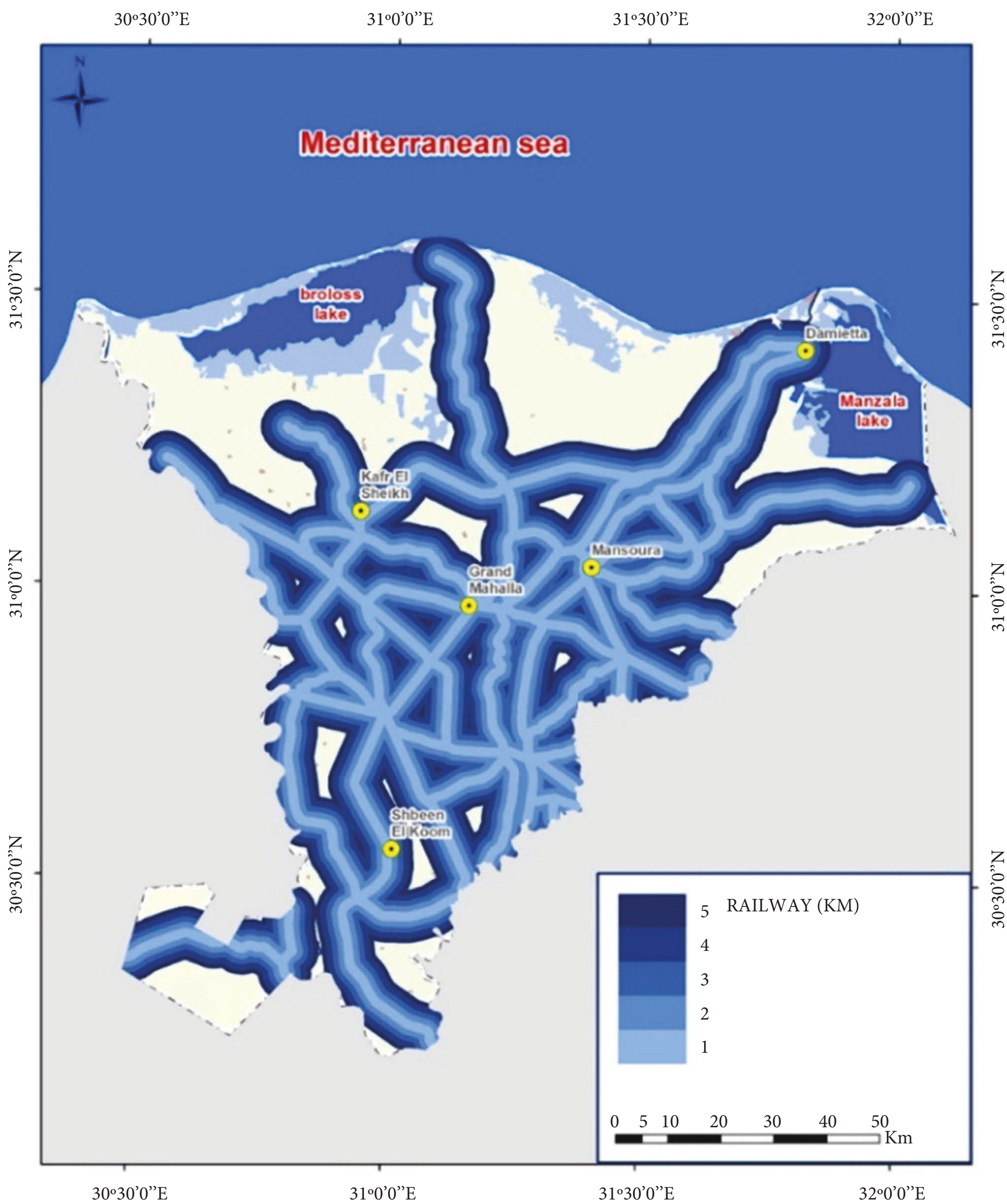
(d)

Figure 6: Continued.



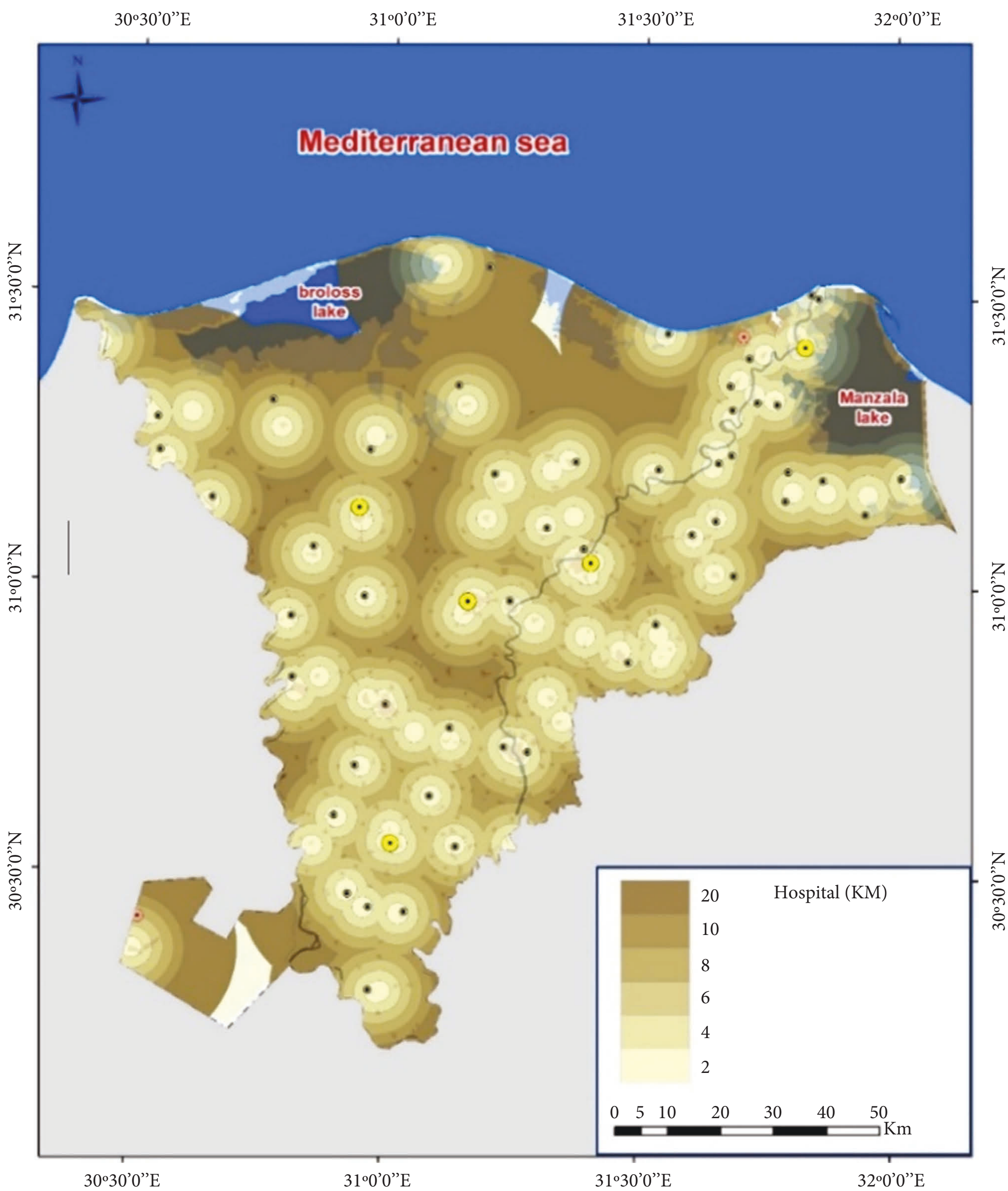
(e)

Figure 6: Continued.



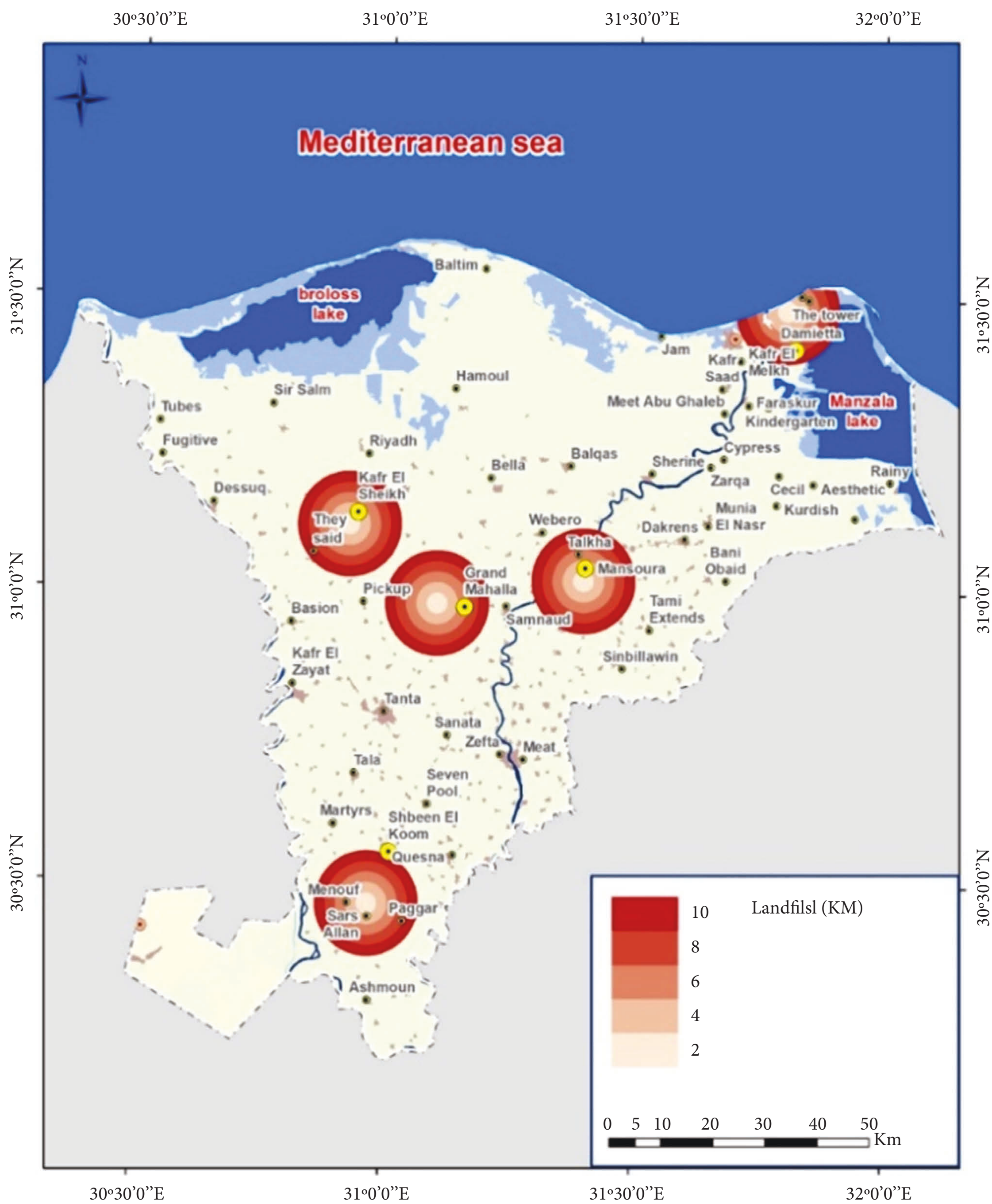
(f)

Figure 6: Continued.



(g)

Figure 6: Continued.



(h)

Figure 6: A model for the method of entering the criteria used in the study. (a) Population density. (b) List cities. (c) The road network. (d) Electricity lines. (e) Industrial areas. (f) Railways. (g) Existing hospitals. (h) Landfill sites.

assignment analysis in the network analyzer in (ArcMap10.7.1), WGS 84 UTM Zone 36 N coordinate system, where the following layers appear on it: the administrative boundaries layer for each delta in the form of an area (Polygon). The public sector hospitals layer in the form of points (Points); the population layer in the form of points (Points) includes the population field.

6.2. Second Step: Preparing the Road Network Map. As shown in Figure 5, a road map was prepared for the study area in the form of polyline, and it was obtained from the Ministry of Public Works and Housing using the Muscat Mercator coordinate system (UTM). When preparing the road network map, four main things were represented: making spatial relationships for network resources, defining network

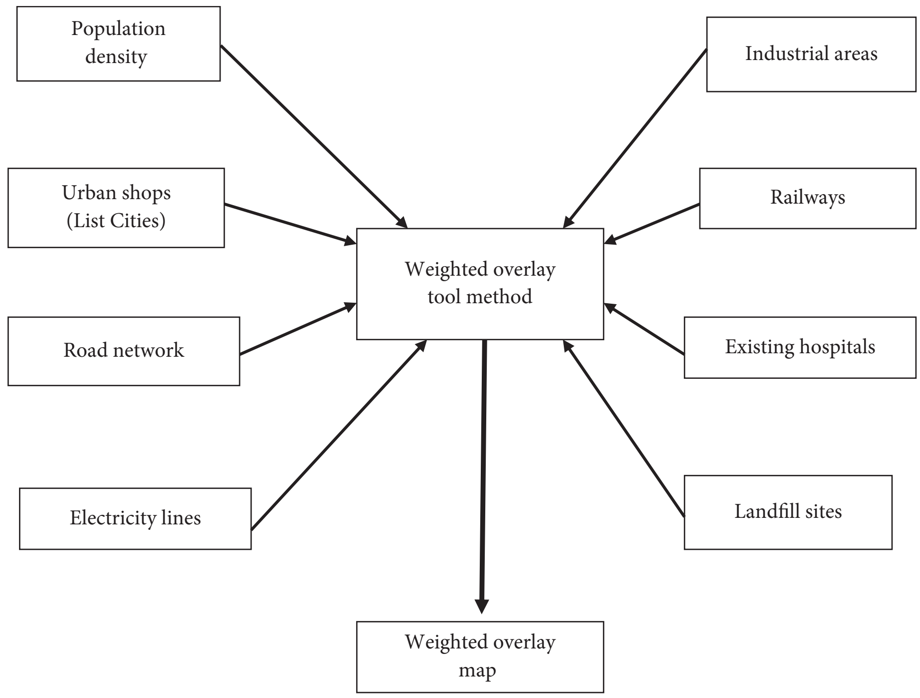


Figure 7: Weighted overlay tool model for the criteria of the study.

Table 6: Arrangement of the applied criteria for a pairwise comparison matrix for isolation hospital site selection.

Criteria	Population density	Urban shops (buffer: 20 km)	Road network	Infrastructure	Industrial zones	Current hospital sites	Railways	Landfill sites
Population density	1	2	2	3	4	3	4	5
Urban shops (buffer: 20 km)	0.5	1	1	1.5	2	1.5	2	2.5
Road network	0.5	1	1	1.5	2	1.5	2	2.5
Infrastructure	0.33	0.66	1.5	1	1.33	1	1.33	2.5
Industrial zones	0.25	0.5	0.5	0.5	1	1.33	1	1.25
Current hospital sites	0.33	0.66	0.66	1	1.33	1	1.33	1.66
Railways	0.25	0.5	0.5	0.75	1	0.75	1	1.25
Landfill sites	0.2	0.4	0.4	0.6	0.8	0.6	0.8	1
Total	***3.36***	***6.72***	***7.56***	***9.85***	***13.46***	***10.68***	***13.46***	***17.66***

Table 7: Pairwise comparison matrix for isolation hospitals.

Criteria	Population density	Urban shops (buffer: 20 km)	Road network	Infrastructure	Industrial zones	Current hospital sites	Railways	Landfill sites	Total
Population density	0.297	0.297	0.264	0.304	0.297	0.280	0.297	0.283	**2.119**
Urban shops (buffer: 20 km)	0.148	0.148	0.132	0.152	0.148	0.140	0.148	0.141	**1.157**
Road network	0.148	0.148	0.132	0.152	0.148	0.140	0.148	0.141	**1.157**
Infrastructure	0.098	0.098	0.198	0.101	0.098	0.093	0.098	0.141	**0.925**
Industrial zones	0.074	0.074	0.066	0.050	0.074	0.124	0.074	0.070	**0.606**
Current hospital sites	0.098	0.098	0.087	0.101	0.098	0.093	0.098	0.093	**0.766**
Railways	0.074	0.074	0.066	0.076	0.074	0.070	0.074	0.070	**0.578**
Landfill sites	0.059	0.059	0.052	0.060	0.059	0.056	0.059	0.056	**0.460**

Table 8: Final resulting weights of applied criteria using F-AHP for isolation hospitals.

Criteria	Weights
Population density	0.26
Urban shops	0.14
Road network	0.14
Infrastructure	0.11
Industrial zones	0.07
Current hospital sites	0.09
Railways	0.07
Landfill sites	0.05

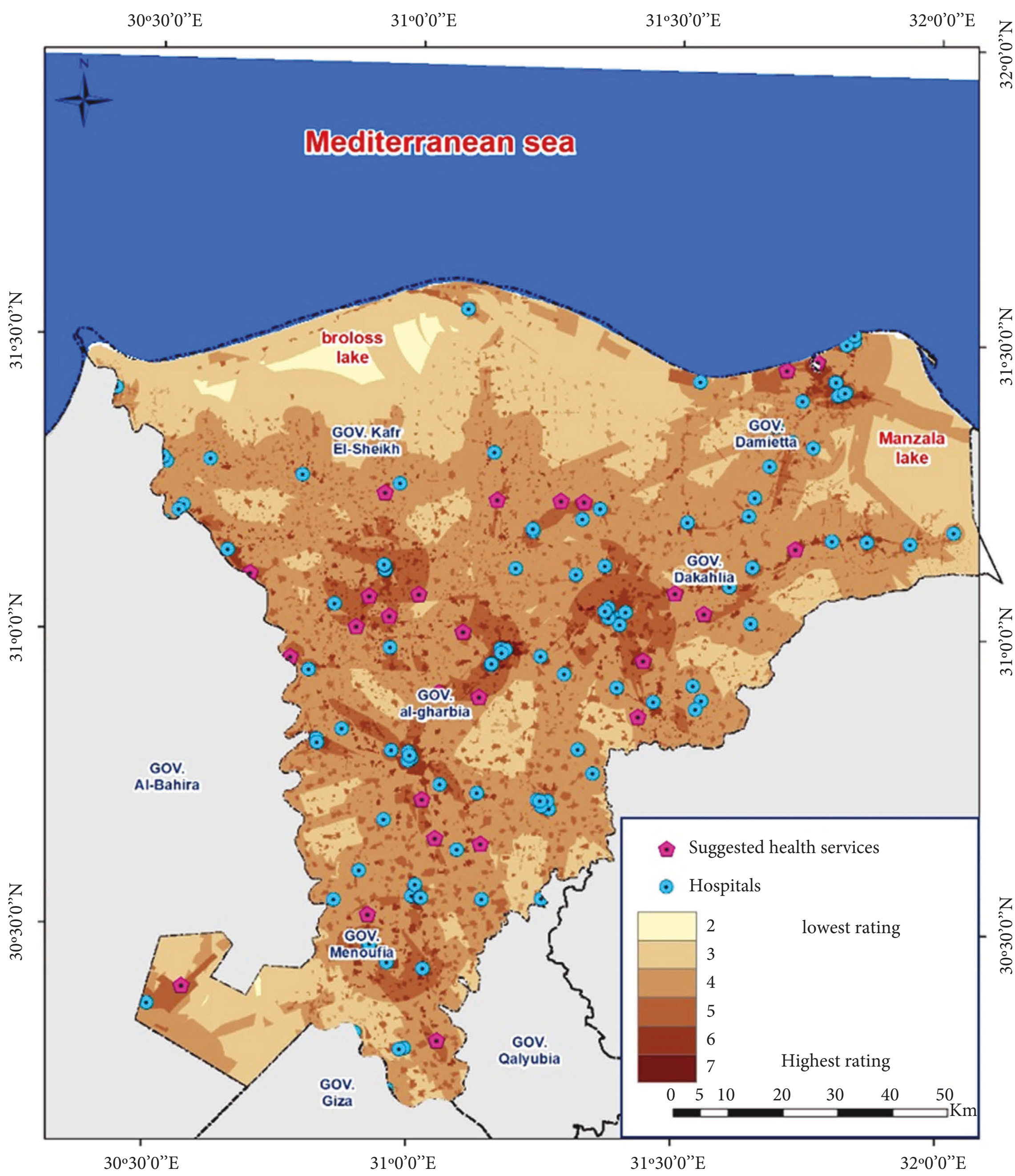


Figure 8: Optimum site selection for coronavirus patient isolation hospitals in Nile Delta, Egypt, using F-AHP method.

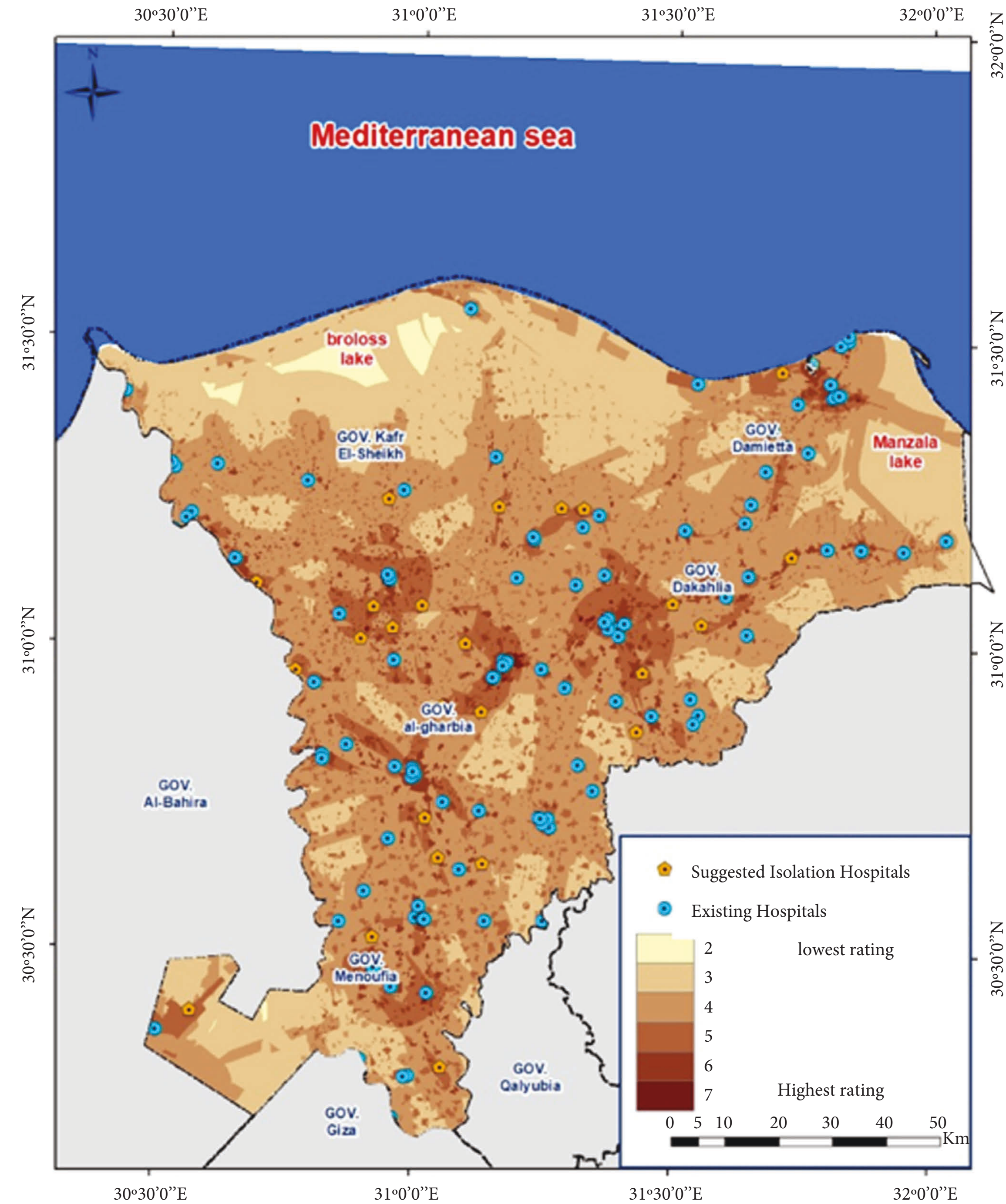


Figure 9: Optimum site selection for coronavirus patient isolation hospitals in Nile Delta, Egypt, using WOA method.

characteristics, network connectivity, and finally, setting network properties.

6.3. Third Step: Data Entry and Processing. A database was created containing spatial and descriptive data in MDB format on the ArcGIS 10.7.1 program. It contains many layers such as the road network, health services, administrative governorate borders, water bodies, land covers, railways, industrial areas, sanitary burial sites, urban communities, and other layers related to the subject and area of study as shown in Figure 6. Then, the program analyzes and displays the information and results in the form of maps and graphic forms.

The study used the quantitative analytical approach of digital data, through quantitative analytical and statistical methods, in order to evaluate the sites of existing public sector hospitals in the delta governorates and the extent of their coverage of population centers, as well as to identify the new proposed sites to choose the best site for constructing an isolation hospital.

Table 9: The areas of optimum location of isolation hospitals and their percentages resulting from F-AHP method and WOA.

Rank/area number	Areas of optimum locations for isolation hospitals resulting from F-AHP method (km^2)	Percentage	Areas of optimum locations for isolation hospitals resulting from WOA method (km^2)	Percentage
2	**4.10**	0.03	**7.18**	0.04
3	**2087.51**	12.60	**4661.12**	28.14
4	**10167.04**	61.39	**8624.42**	52.06
5	**3763.44**	22.72	**2456.32**	14.83
6	**540.12**	3.26	**801.06**	4.84
7	**0.00**	0.00	**15.30**	0.09
Total	**16562.211**	**100**	**16565.396**	**100**

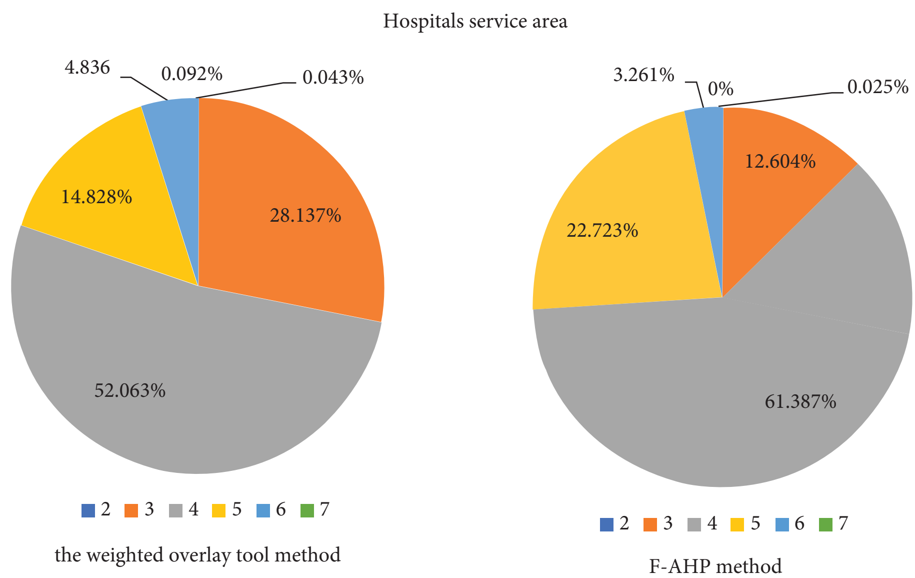


Figure 10: The optimal location areas for isolation hospitals by the two applied methods (F-AHP and WOA).

6.4. Fourth Step: Data Analysis and Processing Tools. F-AHP and WOA models were used to choose the optimal site for coronavirus patient isolation hospital.

The study was applied based on the Network Analyst tools available in the Arc Toolbox within the ArcMap GIS environment. The service area analysis tool determines the population centers that fall within the scope of health care for public sector hospitals and isolation hospitals selected by the Egyptian Ministry of Health and Population. After determining the criteria, their categories, the degree of their importance, and their weights, the cartographic model was built in the Arc GIS software through the builder model, which is based on simplifying complex problems, overlapping data, and their spatial and descriptive relationships. The weighted overlay model is displayed in Figure 7 as a process in model builder. Figure 7 shows the method of entering criteria in ArcGIS, where each criterion was entered separately in order to obtain the final plan for choosing the best sites for isolation hospitals.

7. Results and Analysis

Based on the studied criteria, the following results for optimal site selection for isolation hospitals can be drawn.

7.1. Site Selection Using F-AHP Method. Table 6 shows arrangement of the applied criteria for a pairwise comparison matrix for coronavirus patient isolation hospitals. The numbers in Table 6 were determined based on questionnaires, field visits, and previous research studies in addition to the importance of each criterion in relation to the next.

The term CI, which is referred to as consistency index, provides a measure of departure from consistency. To determine the goodness of CI, the AHP method compares it by random index (RI) and the result is what we call consistency ratio (CR), which can be defined by using the following equation:

$$CI = \frac{\lambda - n}{n - 1}. \quad (1)$$

Random index is the consistency index of a randomly generated pairwise comparison matrix of order 1 to 10 obtained by approximating random indices; then, we use (1) to calculate CI. By applying (2), the consistency ratio (CR) can be calculated: if CR <0.10, then weights are acceptable.

$$CR = \frac{CI}{RI}. \quad (2)$$

Consistency vector is determined by dividing the weighted sum vector by the criterion weights. Once the consistency vector is calculated, then the values for two more terms, λ and the consistency index (CI), can be calculated. The value for λ is simply the average value of the consistency

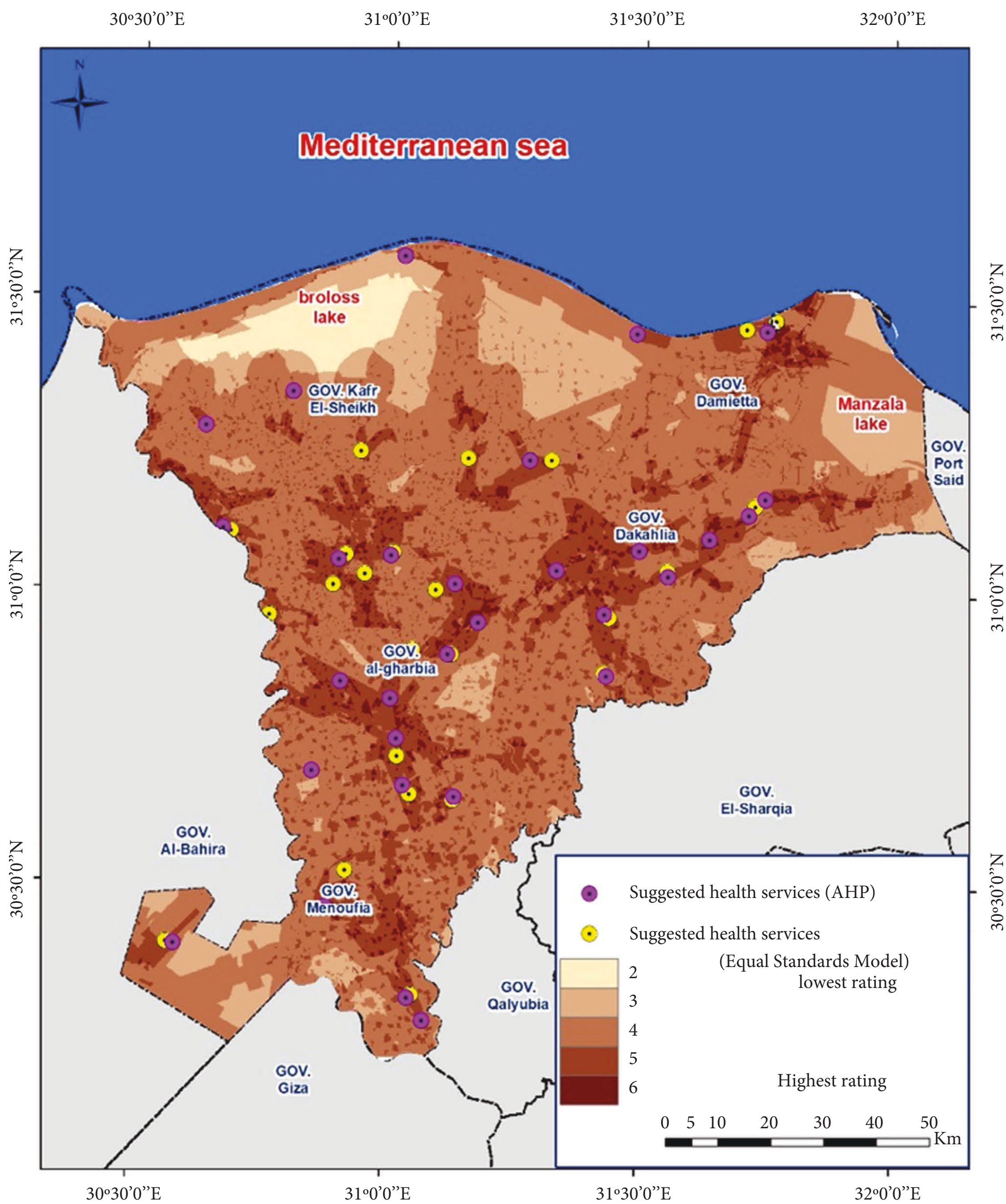


Figure 11: The final resulting optimal site selection for isolation hospitals by the two applied methods (F-AHP and WOA).

Table 10: Suggested number of hospitals from F-AHP method and WOA method for Nile Delta, Egypt.

Governorate	Suggested number of hospitals using F-AHP method	Suggested number of hospitals using WOA method
Kafr El-Sheikh	7	6
Damietta	2	2
El-Dakahlia	7	5
El-Menoufia	7	5
El-Gharbia	6	6
Total	***29***	***24***

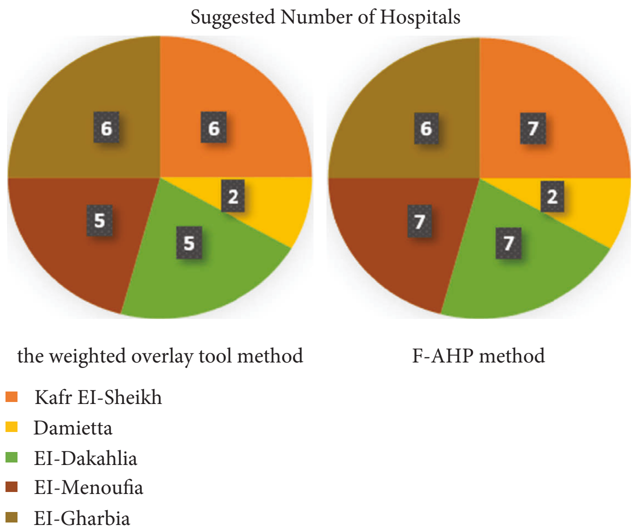


Figure 12: The suggested number of optimal site selection for isolation hospitals using F-AHP and WOA.

vector. The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive value and $\lambda = n$, if the pairwise comparison matrix is consistent matrix. Accordingly, $\lambda - n$ can be considered as a measure of the degree of inconsistency as shown in calculations in Table 7.

Table 7 shows the pairwise comparison matrix and weights for isolation hospital standards using the F-AHP method. The numbers in Table 7 resulted from dividing the column of each criterion by the total sum resulting from each criterion in Table 6, and the default numbers (ranks) were placed according to the importance of each of them in relation to the variable to form the matrix, where the highest importance takes number 1 and the lowest importance takes numbers 2, 3, then 4, and so on.

Table 8 shows the final resultant weights of the applied criteria using F-AHP to select the optimal sites for isolation hospitals in the study area. Therefore, the weights of all criteria were entered using the F-AHP method in the model generator for isolation hospitals in ArcGIS. The resulting digital map showing the optimum site selection of isolation hospitals for the study area is shown in Figure 8.

The areas in dark brown color in Figure 8 show the most areas in which health services can be established, as there are 6 variables. The areas in light brown color represent the least areas in which health services (isolation hospitals) can be established, as they represent risk areas for establishing hospitals in them. The value of 7 was considered the highest degree suitable for optimal sites and the value of 2 was considered the lowest appropriate degree as shown in Figure 8.

7.2. Site Selection Using WOA Method. Each criterion is given a specific weight according to its degree of importance so that the total of weights equals 100%. Depending on the consulting experts, specialists, several references, and the experience of authors [32], the weights of the various studied criteria can be drawn as follows: population density (25%); urban shops (list cities) located in the delta (10%); road network (15%); infrastructure (10%); industrial zones (10%); current hospital sites (20%); future expansions (5%); and landfill sites (5%).

The weight of each criterion was entered to the model builder for isolation hospitals on the Arc GIS program. The resulting digital map with optimal site selection for coronavirus patient isolation hospitals in delta using weighted overlay tool method is shown in Figure 9. In this map, number 7 represents the optimal sites and number 2 is the least important, the blue marks on the digital map (Figure 9) indicate the locations of the current hospitals in the delta region, and the yellow marks are the suggested new isolation hospital sites.

A comparison between the two applied analytical techniques (F-AHP and WOA) was done by calculating the areas of each degree (rank) in each digital map. The results are tabulated in Table 9 and Figure 10.

After studying the two methods (WOA and F-AHP), it is deduced that the F-AHP is better than WOA in increasing the gradation of suggested areas for site selection of isolation hospitals because it takes the effect of all the criteria together (correlation between criteria) but WOA suggested less hospital locations, where it takes the effect of each criterion individually. As shown in Table 9, there is a clear difference between the areas resulting from the two applied techniques.

Depending on the two resulting digital maps (Figures 8 and 9) generated by GIS using the two applied analytic techniques F-AHP and WOA in the research, the number and locations of hospitals that can be established temporarily or permanently to isolate coronavirus patients in the five delta governorates are deduced as shown in Figure 11, knowing that these hospitals can be used as a general hospital after the end of the pandemic. Table 10 shows the number of proposed hospitals in each of the delta governorates for both methods (Figure 12).

8. Conclusions

This paper investigates the possibility of producing digital maps for optimum site selection of coronavirus patient isolation hospitals based on multi-criteria decision analysis using GIS technology and remote sensing for the Nile Delta region in Egypt by applying two different analytic techniques (F-AHP and WOA). Depending on the results that have been reached and numerical results obtained, the following conclusions can be summarized:

(1) From the results of the study, there are 29 sites in the study area (Nile Delta, Egypt) that are valid to construct temporary or permanent hospitals to isolate coronavirus patients according to the requirements of the World Health Organization and the instructions of the Egyptian Ministry of Health. These hospitals can also be used as general hospitals after the end of the pandemic.

(2) The F-AHP method is better than WOA in increasing the gradation of suggested areas for site

selection of hospitals. F-AHP suggested 29 new sites of hospital in the delta because it takes the correlation between all criteria, while WOA suggested 24 new sites of hospital in the delta because it took the impact of each criterion individually.

(3) The specified applied criteria in this study can be used for site selection of isolation hospitals at any country because it depends mainly on the requirements of the World Health Organization.

(4) GIS and remote sensing systems using the applied techniques are modern systems which can be used to select and determine the best locations for general, central, and isolation hospitals. We recommend it for the Egyptian Ministry of Health and governmental agencies working in determining and selecting hospital locations.

Data Availability

All data, models, and codes generated or used during the study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

References

[1] M. S. Daskin and L. K. Dean, "Location of Health Care Facilities," *Operations Research and Health Care*, pp. 43–76, Springer, Berlin, Germany, 2006.

[2] R. D. Gupta, S. Agrawal, and A. K. Tripathi, "NSDI based innovative approach for development of open source sdi for health sector: a way forward," in *Geospatial Data Science in Healthcare for Society 5.0. Disruptive Technologies and Digital Transformations for Society 5.0*, P. K. Garg, N. K. Tripathi, M. Kappas, and L. Gaur, Eds., Springer, Singapore, 2022.

[3] A. A. Abed Alhameed, "Spatial analysis of the relationship between the sites of public hospitals and their accessibility in the governorates of Al-karak and tafieleh using geographic information systems," *Studies, Humanities and Social Sciences*, vol. 46, no. 3, 2019.

[4] S. T. A. Rea, "GIS-Based-Multi-Criteria-Dicesion-Analysis-for-Industrial-Site-Selection-in-Al-Nasiriyah-City-in-Iraq," *doc*, vol. 6, no. 7, pp. 1330–1337, 2015.

[5] N. Ashu, A. Tapan, G. Chandan, and K. H. Bijoy, "Site Suitability Analysis for Turmeric in Jaintia Hills of Meghalaya, India, Using Analytical Hierarchical Process and Weighted Overlay Analysis" A Comparative Approach," 2020, https://www.researchgate.net/publication/341264968.

[6] A. Erdal, A. Mutlu, K. Ali, T. Suat, and A. Ali, "Environmental urbanization assessment using gis and multicriteria decision analysis: a case study for Denizli (Turkey) municipal area," *Advances in Civil Engineering*, vol. 2018, Article ID 6915938, 7 pages, 2018.

[7] S. S. Abhay, "A study on moyna basin water-logged areas (India) using remote sensing and GIS methods and their contemporary economic significance," *Geography Journal*, Hindawi Publishing Corporation, vol. 2014, Article ID 401324, 9 page, 2014.

[8] O. M. Olabanji and K. Mpofu, "Appraisal of conceptual designs: coalescing fuzzy analytic hierarchy process (F-AHP) and fuzzy grey relational analysis (F-GRA)," *Results in Engineering*, vol. 9, Article ID 100194, 2021.

[9] M. Deveci, I. Z. Akyurt, and S. Yavuz, "A GIS-based interval type-2 fuzzy set for public bread factory site selection," *Journal of Enterprise Information Management*, vol. 31, no. 6, pp. 820–847, 2018.

[10] J. Mallick, R. K. Singh, M. A. AlAwadh, S. Islam, R. A. Khan, and M. N. Qureshi, "GIS-based landslide susceptibility evaluation using fuzzy-AHP multi-criteria decision-making techniques in the Abha Watershed, Saudi Arabia," *Environmental Earth Sciences*, vol. 77, no. 7, p. 276, 2018.

[11] A. El Jazouli, A. Barakat, and R. Khellouk, "GIS-multicriteria evaluation using AHP for landslide susceptibility mapping in Oum Er Rbia high basin (Morocco)," *Geoenvironmental Disasters*, vol. 6, no. 1, p. 3, 2019.

[12] B. C. Balusa and A. K. Gorai, "Sensitivity analysis of fuzzy-analytic hierarchical process (FAHP) decision-making model in selection of underground metal mining method," *Journal of Sustainable Mining*, vol. 18, no. 1, pp. 8–17, 2019.

[13] A. K. Tripathi, S. Agrawal, and R. D. Gupta, "Comparison of GIS-Based AHP and Fuzzy AHP Methods for Hospital Site Selection: A Case Study for Prayagraj City, India," *GeoJournal*, vol. 1, 2021, https://doi.org/10.1007/s10708-021-10445-y.

[14] T. Şahin, S. Ocak, and M. Top, "Analytic hierarchy process for hospital site selection," *Health Policy and Technology*, vol. 8, no. 1, pp. 42–50, 2019, https://doi.org/10.1016/j.hlpt.2019.02.005.

[15] H. Mirzahossein, M. Sedghi, H. Motevalli Habibi, and F. Jalali, "Site selection methodology for emergency centers in Silk Road based on compatibility with Asian Highway network using the AHP and ArcGIS (case study: I. R. Iran)," *Innovative Infrastructure Solutions*, vol. 5, no. 3, p. 113, 2020, https://doi.org/10.1007/s41062-020-00362-3.

[16] B. Karatop, B. Taşkan, and E. Adar, "Determination of the focus strategies related to renewable energy for Turkey by using the fuzzy sectional SWOT," *Journal of Intelligent Systems: Theory and Applications*, vol. 5, no. 1, pp. 42–56, 2022, https://doi.org/10.38016/jista.979582.

[17] J. Soroor, M. J. Tarokh, and M. Abedzadeh, "Automated bid ranking for decentralized coordination of construction logistics," *Automation in Construction*, vol. 24, pp. 111–119, 2012, https://doi.org/10.1016/j.autcon.2011.11.013.

[18] G. Aashish, S. D. Ran, and G. Sanjay, "Prioritizing Factors Determining Environmental Responsibility Using Fuzzy Analytical Hierarchy Process": Evidence from India," *doc*, vol. 48, pp. 999–1020, 2021.

[19] E. Karakaş and O. V. Yildiran, "Evaluation of renewable energy alternatives for Turkey via modified fuzzy AHP," *International Journal of Energy Economics and Policy*, vol. 9, no. 2, pp. 31–39, 2019.

[20] I. Yamada and J. C. Thill, "Comparison of planar and network K-functions in traffic accident analysis," *Journal of Transport Geography*, vol. 12, no. 2, pp. 149–158, 2004.

[21] A. G. Abdullah, N. A. Dwitasari, A. H. Setiorini, and D. L. Hakim, "Comparative analysis of AHP and fuzzy AHP for solar power plant site selection," *Journal of Engineering Science & Technology*, vol. 16, no. 4, pp. 3505–3520, 2021.

[22] D. Muhammet, Z. A. Ibrahim, and Y. Selahattin, "A GIS-Based Interval Type-2 Fuzzy Set for Public Bread Factory Site Selection," pp. 820–843, 2018, https://www.emeraldinsight.com/1741-0398.htm.

[23] D. U. Lawal, A. N. Matori, and A. L. Balogun, "A Geographic information system and multi-criteria decision analysis in proposing new recreational park sites in Universiti Teknologi

Malaysia," *Modern Applied Science*, vol. 5, no. 3, pp. 39–55, 2011.

[24] I. P. Online, Z. Nazeri, J. Mirzaee, A. Rostami, J. Bio, and E. Sci, "Application of analytical hierarchy process in land suitability for forest park location (case study: Ilam County, Iran)," *Journal of Biodiversity and Environmental Sciences*, vol. 4, no. 4, pp. 301–309, 2014.

[25] H. Iqbal, A. J. Muhammad, A. Muhammad et al., "Weighted overlay based land suitability analysis of agriculture land in azad Jammu and Kashmir using GIS and AHP," *Pakistan Journal of Agricultural Sciences*, vol. 57, no. 6, pp. 1509–1519, 2020.

[26] I. Hassan, M. A. Javed, M. Asif et al., "Weighted overlay-based land suitability analysis of agriculture land in Azad Jammu and Kashmir using GIS and AHP" Pakistan," *Journal of Agricultural Sciences*, vol. 57, no. 6, pp. 1509–1519, 2020.

[27] J. Jain, N. Walia, S. Gupta, K. Aggarwal, and S. Singh, "A fuzzy analytical hierarchy process framework for stock selection in the Indian stock market," *Journal of Public Affairs*, vol. 1–11, 2021.

[28] Z. Li, Y. Serhat, D. Hasan, M. Shahriyar, and A. Mayis, "The positive influences of renewable energy consumption on financial development and economic growth," *journals.sagepub.com/home/sgo*, vol. 1, 2021.

[29] Z. Li, Z. Fan, and S. Shen, "Urban green space suitability evaluation based on the AHP-CV combined weight method: a case study of Fuping county, China," *Sustainability*, vol. 10, no. 8, p. 2656, 2018.

[30] K. Mark, C. Chair, and A. Nader, *Automating the classification of thematic rasters for weighted overlay analysis in GeoPlanner for ArcGIS*, 2016.

[31] C. J. Mayfield, M. Kumler, and D. Ph, *Automating the Classification of Thematic Rasters for Weighted Overlay Analysis in GeoPlanner for ArcGIS. InSPIRe @ Redlands MS*, 2015.

[32] M. Basharat, H. R. Shah, and N. Hameed, "Landslide susceptibility mapping using GIS and weighted overlay method: a case study from NW Himalayas, Pakistan," *Arabian Journal of Geosciences*, vol. 9, no. 4, p. 292, 2016.