GIS ANALYSIS AND CARTOGRAPHIC PRESENTATION OF A SITE SELECTION PROBLEM

Rowena Bassi QUIAMBAO
Senior Science Research Specialist
Philippine Institute of Volcanology and Seismology (PHIVOLCS)
C.P. Garcia Street, University of the Philippines Campus
Diliman, Quezon City 1101
Philippines
T: (632) 426 14 68 to 79
F: (632) 920 70 58, 927 45 24
weng@phivolcs.dost.gov.ph

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ABSTRACT: A network can model many real systems like roads, water bodies, and contours. On the area of GIS analysis, networking has become a very useful tool. Nowadays, networks from the infrastructure of the modern world commonly occur through definable network systems: transportation and distribution of goods and services, communication, delivery of resources and energy, among others.

An exercise on site selection and evaluation using the tools of Geographic Information System (GIS) is presented herein. Solution to a typical problem of regional and national governments, namely to locate potential and evaluate existing sites, is hereby given utilizing the GIS tools.

Geographic and network analyses were made using Arc/Info version 7. In the geographic analysis, selection of potential sites was made based on a set of criteria - accessibility, proximity to certain natural or manmade area, among other limitations as needed. The network analysis provided answers to questions on the suitability of the selected sites and who can access the sites within a specified time or distance. Using the criteria, GIS processes such as buffering, union, erase, dissolve, and intersect narrowed down the number of possible sites. Results of the geographic and network analyses were then ranked accordingly.

1. INTRODUCTION

Presented in this paper is the case study result of the group final project for the Integrated Map and Geoinformation Production (IGP3) course in the International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands (1995). It was a project on recreation site-selection in the Twente Region using GIS tools and analysis and cartographic presentation of the results (Quiambao, et al, 1995).

Site selection was based, mainly, on the number of potential users in the area and the accessibility of these sites in terms of time and distance.

The data provided and used were PC Arc/Info export files from the IGP3 1994 case study consisting of geographic features such as roads and canals in 1:50,000 scale; digital population data based on postal code areas; and topographic, tourist and bike maps. These data were checked, corrected, edited, and updated to suit the requirements of the case study analysis.

Overijssel, one of the 12 provinces of the Kingdom of the Netherlands, is the province where the study area is located. Twente Region is bordered to the east by Germany, to the west and south by Gelderland Province, and to the north by Drenthe Province. It lies between latitude $52^0$00'N-$52^0$30'N and longitude $06^0$30'E-$07^0$00'E. The average population density of Twente Region is 500 persons per square kilometer while the area of each region averages to about 2,280 sq. km.

The climate of the region is temperate with an average temperature in January of 0^0C (32^0F), while the average temperature in the summer is 21^0C (70^0F). The most spoken language within the region is Dutch, which is the official language of the country. The Gross National Product (GNP) measured at average 1990-1992 prices, was US$312,340 million, equivalent to $18,840 per head (World Bank estimates, 1992). During 1985-1992, it was estimated that the GNP per head increased at an average annual rate of 2.1%. Over the same period, the population increased by an annual average of 0.7% (Europa World Year Book 1994). In 1992 there were about 2,118 km of motorway and some 104,590-km of roads in the country. From the total road density within the country 9% of the road network is concentrated in Twente Region.

The main tourist attractions in the country are the outlying islands, old towns, canals, and cultivated fields of spring flowers, art galleries, and modern architecture. Tourist arrival for the period 1990-1992 averages 5.556 million people per year, which is an indication of potential users of recreation sites. There was also a clear indication of good tourism revenue from the receipts of 1992 visitors amounting to a total of US$5,004,000. In the Twente Region, there are considerable potential tourist attractive places like the canals and the cultivated fields of flowers.

Typically, it is required to locate and evaluate existing and potential recreation sites based on the number of potential users and the accessibility of these sites. In general it is essential to think about selection of additional recreation sites within the region, because per capita is high, potential visitors are available, and population is increasing significantly.

2. GEOGRAPHICAL ANALYSIS

2.1 Classification of Recreational Areas

There are three existing recreational sites in the region, which are located in Enschede, Hengelo, and Oldenzaal. Areas like Almelo, Reijssen, Goor and Borne, which are rich in potential users, has no recreational site within or nearby.

According to previous researches and literature, activities in the recreational areas that are applicable to Twente Region may be classified as follows: picnicking, pleasure driving, camping, heath walking, bird watching, natural studies, and photography. In addition to its attractiveness, the site was recommended to have access to the following public services: good sanitation, water point, shelter huts, restaurants, facilities for special interests, free parking place, and free movement at the entrance. Using the available information, the analysis was formulated to meet the following requirements:

1) good access by car and bicycle;
2) close to woodland and heath but not to both;
3) close to water/lake;
4) not inside or immediately adjacent to built-up areas;
5) not inside or immediately adjacent to airport; and
6) not inside or immediately adjacent to harbor and industry.

Based on the above assumptions and criteria there were seven recreation sites selected. A reselection was done which excluded the sites within two-km distance from existing recreational sites. This resulted into only four selected recreation sites.

2.2 Evaluation of Selected Recreation Sites

After the geographical analysis, the total number of available sites selected was four. Most of them are concentrated at the central and northwest portions of the region. This is because heavy emphasis has been given to the site being near lakes and forest. Therefore, the result is highly influenced by these two. In this case, the lakes and vegetation of the site were considered important with respect to its influence on the physical suitability for recreational use as well as because of its contribution to scenic quality. In order to maximize the chance of accessibility as well as to minimize the concentration of sites in just the central and northwest portions of the region, it was decided to revise the analysis by using these additional criteria:

1) the site should be close to stream but not lake;
2) the site should not be located within 2 km radius of built-up areas; and
3) the number of recreation site should not exceed ten.

Based on the above practical considerations the resulting sites selected were sixteen. Five sites from these sixteen were excluded after buffering the existing recreational sites with a 4km-distance. Then, only eight sites were left after selecting the polygons with areas between 0.5-2.0 km^2. The eight selected sites were then analyzed using the network analysis in Arc/Info. The procedures involved in the classification and evaluation of selected recreation sites are shown in Geographical Analysis Flowchart (Figure 1).

3. NETWORK ANALYSIS

A good way to generate optimal results was found using network analysis. Questions like which parts of the network will be selected for certain recreational sites and who can access the sites within a specified time or distance were satisfactorily answered. Comprising the road network, four road types were selected:

A: Existing high-/motorways
B: Main roads
C: Connection road
D: Regional road

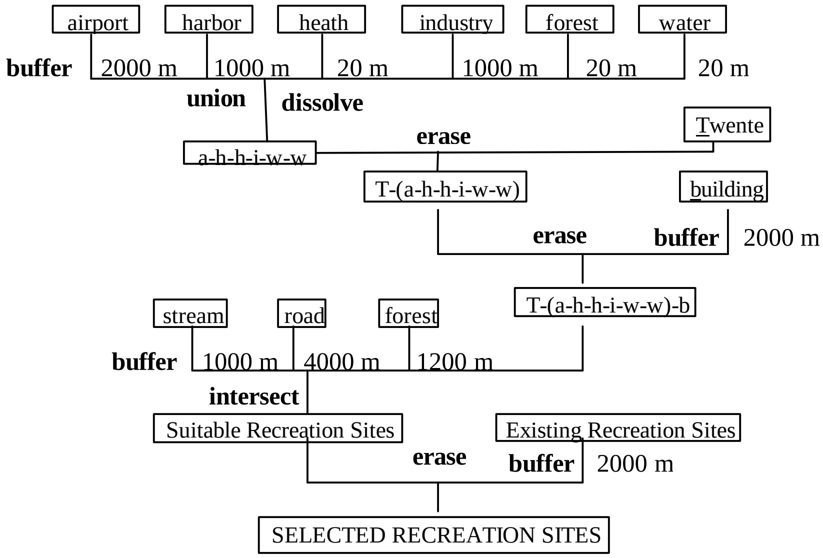

Figure 1. Geographical Analysis Flowchart

3.1 Adding Demand Values

In order to evaluate the number of people that could have access to a certain site, one of the requirements for the analysis was to attach population data along each arc. The road network, symbolized by an arc or a line, was linked with the population data, which was contained in polygon attribute. Intersection of the road network coverage with the postal code polygon coverage attached polygon attributes to the arc attributes.

Once the intersection was done, the result had arcs with the polygon coverage's attributes. Each arc ended up with a population item. However, all the arcs in a certain polygon each had the same population number. There existed, therefore, many arcs with the same population data.

To solve this problem, a distribution of people living in a certain postal code was calculated. The total length of arcs per polygon was calculated. The percentage of the arc passing through a polygon was calculated by dividing the length of an arc over the total length of arcs per polygon. Next, the number of people assigned to each arc was computed by multiplying the percentage of the arc that passes through a polygon over the total number of people per polygon.

3.2 Adding Impedance Values

In order to evaluate how resources can move through the network, impedance value has to be calculated. Impedance is the cost associated with the utilization of the supplied resources.

For the car network, the criterion used was that the recreation site should be reachable within 30 minutes (1800 sec). Using the length of the arcs and the corresponding car speed for certain road types, the following computation of the From-to-impedance and To-from impedance was made:

From-to-impedance = Length/speed * 3.6
To-from-impedance = Length/speed * 3.6
Factor = length /speed = 1/1000 over 1/3600 = 3.6

The average speed values of car for the four road types were as follows:

Road A: 80 km/h
Road B: 60 km/h
Road C: 45 km/h
Road D: 30 km/h

For the cycle network, the criterion used was that the recreation site should be reachable within 20 km. The following impedance-values were used:

From-to-impedance = 20,000 meters
To-from-impedance = 20,000 meters

3.3 Creation of Centers File and Turntable

Network analysis commands have to be issued along arc features with identified nodes as the centers nodes. Suitable recreation sites, which are polygons, have to be related to a node. Identifying the closest node to each polygon site was done interactively with the cursor and if there was no node near the polygon, one was created. Thus, the CENTERS FILE was created.

TURNTABLE command generates a table containing turns for each node of the network coverage. A turntable was created for one of the centers for comparison purposes. An extra item (time-impedance) was added to the turntable in order to make the result comparable.

3.4 Execution of the Network Analysis

Network analysis was done twice, with and without using a turntable. The use of turntables has very small variation compared with the result without using the turntable. The length of time it will take, if the allocated routes of the best center were used, dropped to only 23 seconds after a turntable was used. The reason for this is that the values given to the time impedance for the turn table are all arbitrary values not taking into account parameters like flow of traffic, stop signs, traffic lights, etc. All of these values were not available for this case study and were not easily obtainable. Although using a turntable in the network analysis resulted into a small variation, it should not be considered insignificant (the turntable) since the network analysis will definitely be affected provided the required parameters were considered.

The turntable was not used for the cycle network since the impedance value used for this was distance (length of arcs). Using a turntable with the cycle network will not be logical since the impedance value to be specified could not be stated in terms of for example, 2 km, if one turns to the left.

From the eight recreation sites resulting from the geographical analysis, only six sites were chosen based on the results of the network analysis. For traveling by car, the factor considered was the shortest time of arrival to the site. While for travel by cycle, the shortest distance traveled to the site was the factor considered. For both the car and bicycle transportation, the ranking results of the recreation sites were the same proving that the network analysis done was plausible and convincing enough. These selected and ranked recreation sites are shown in Figure 2 (route by car) and Figure 3 (route by cycle). The map showing the existing and selected recreation sites is shown in Figure 4.

4. CARTOGRAPHIC PRODUCTION

The results of the geographic and network analyses were cartographically enhanced, prepared, and presented. Cartographic production involved data checking and conversion, cartographic editing and symbolization, creation and printing of check plots, and finally, printing of final maps.

4.1 Data Checking and Conversion

All the Arc/Info coverage and map compositions were checked for completeness, contents, and correct formats. Once this was done, conversion of the data followed. To be able to use the Arc/Info coverage, a conversion from one format to another was necessary. These conversions enabled the GIS-based outputs (the Arc/Info coverage) to be enhanced and manipulated into the cartographic-based environment for printing of the final map outputs (Aldus files).

4.2 Cartographic Editing and Symbolization

Once the data has been converted into Aldus files, cartographic enhancement had to be done in order to have good quality maps for presentation. These enhancement techniques could be done using the Aldus software such as setting the line thickness and color, shades and style of map features. Adjustment on the symbolization of certain features in the map was made from polygon symbol to point symbol for airport and harbor, for example.

5. CONCLUSIONS AND RECOMMENDATIONS

Geographic and spatial analysis of the recreation site-selection in the Twente Region was done using GIS. The problem of selecting potential recreation sites based on the number of potential users and the accessibility of these sites by car and by cycle was addressed using geographic criteria such as adjacency to woodland, heath areas, built-up areas, etc. These criteria were evaluated and refined repeatedly until finally, the resulting sites were selected according to optimum standards.

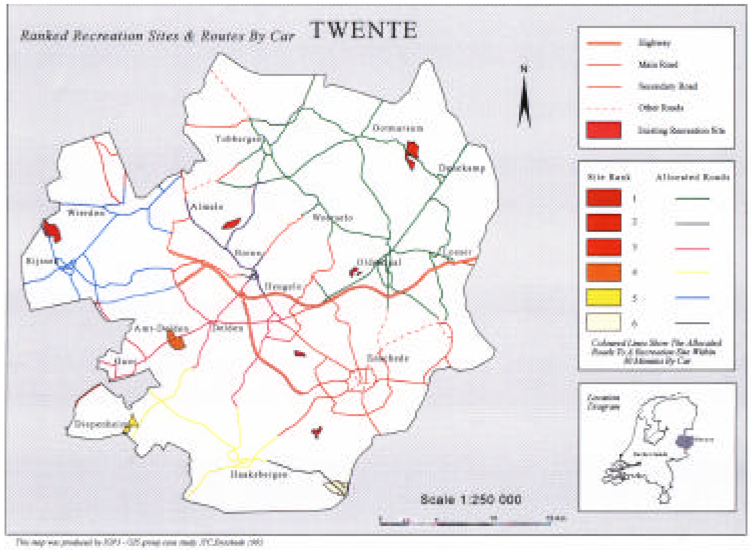

Figure 2. Map of Ranked Recreation Sites and Routes by Car in Twente Region

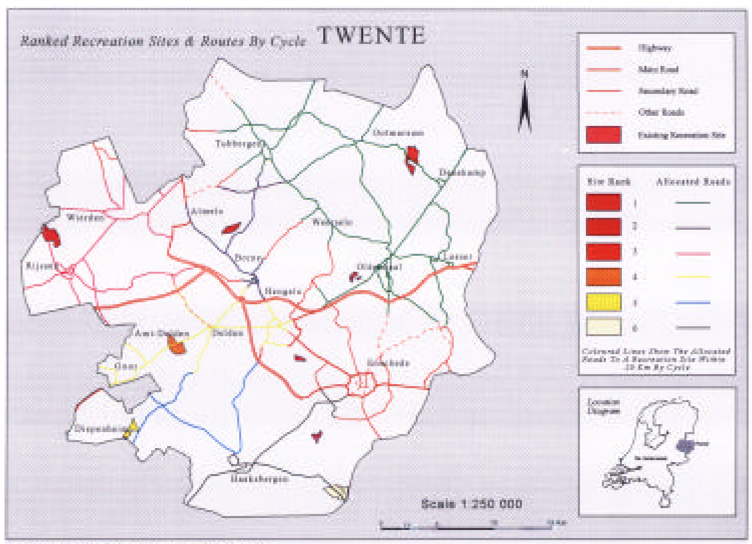

Figure 3. Map of Ranked Recreation Sites and Routes by Cycle in Twente Region

Network analysis was done to find out the allocated road and cycle tracks for a certain recreation site. The result of this procedure answers the following:

a) corresponding number of people that the recreation site could accommodate if they travel through the allocated road or cycle tracks;
b) total length of time it will take to travel by car; and
c) total distance it will take to travel by cycle.

Based on these information, ranking of the selected potential recreation sites was made choosing the best site as having the highest number of people that it can accommodate and

a) the least possible time it can be reached in the case of the car network; and
b) traveling the shortest distance to it in the case of the bicycle network.

The questions such as how many people could be accommodated by a specific recreation site if they travel through the allocated routes (either by car or by cycle) and how long or how far will it take these people to reach that site were answered by the analysis. For decision-making purposes, these questions are considered vital and necessary. Aside from this, simple queries such as what optimum route (in terms of least possible time, for example) should one take in order to reach a recreation site could be immediately answered.

If some additional constraints within the road network system were added the results were modified. In the network module of Arc/Info, this was done using the TURNTABLE command, which added impedance or the corresponding constraint values.

In view of the fact that real-life road involve much more parameters to be considered as part of an in-depth traffic flow analysis, the addition of impedance on the turns that could be taken resulted into almost negligible results. For example, a difference of 23 seconds in terms of the length of time that a site could be reached by car and 190 meters in terms of distance if the site is to be reached by cycle were obtained if there were turns considered in the network analysis. On this note, it is highly recommended that identification of the necessary parameters needed for in-depth analysis of traffic flow be considered and added in the network analysis.

One of the most obvious sources of inaccuracies in the network analysis is the fact that for the centers, only nodes that are within the network can be chosen and used. The selected recreation sites were polygon features and the choice of the node that corresponded to a site was arbitrarily made with the criteria that it should lie along the network. Hence, some nodes that were used either were the nearest one from the selected polygon or were created. Disadvantage of this process was that the resulting time and distance values after the ALLOCATE command will be different if a different center node was chosen.

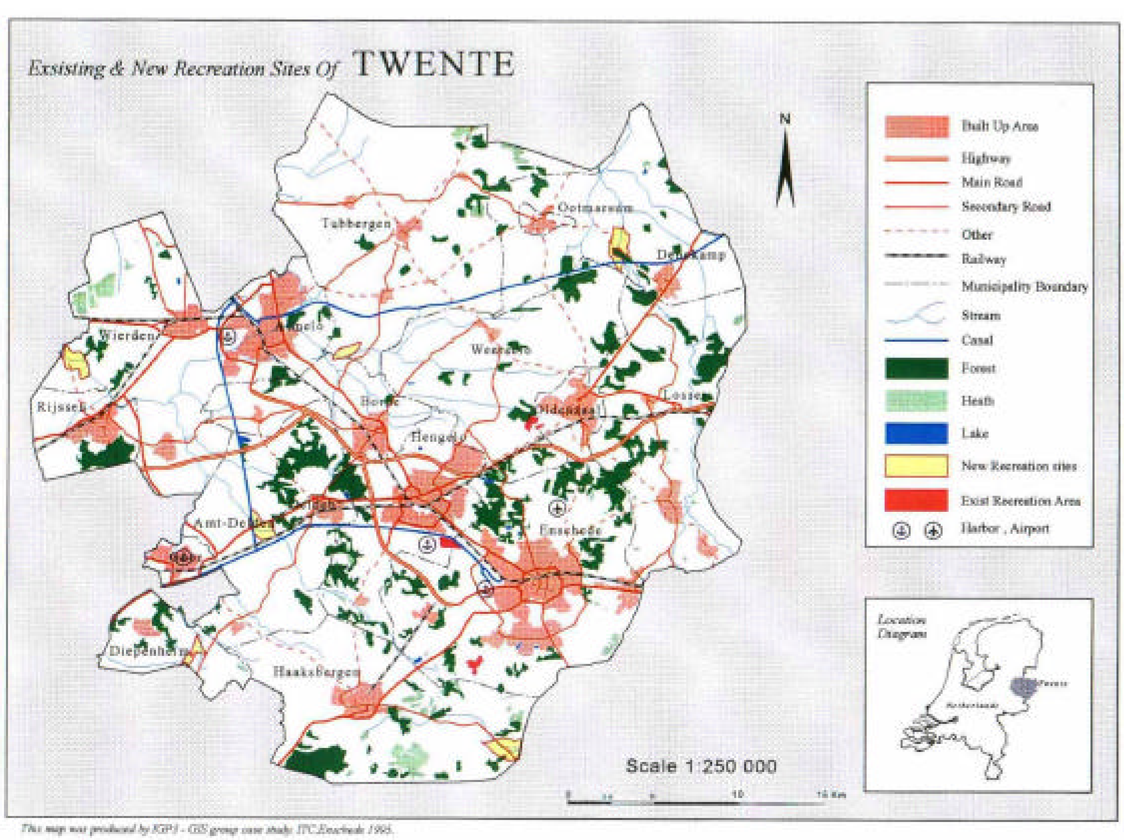

Figure 4. Map of Existing and Selected Recreation Sites in Twente Region

6. REFERENCES

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