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Integration of Geographical Information Systems Based Spatial Analysis in Recreational Demand Analysis

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ABSTRACT

This study has examined the use of an Object-Oriented GIS framework to generate and analyze spatial data in recreation demand analysis. Several forms of GIS analysis are introduced and explained as how they can be utilized in recreational demand analysis. An application of GIS to calculate journey distance and duration has been illustrated with a case study of camping activities in Cherokee National Forest, North carolina. The recreation demand models using these travel distance and duration are then compared with the models using respondent's stated values and models using distance data obtained from ZIPFIP software. Based on the criteria such as χ^2 statistic, individual coefficient significance, it is found out that travel cost functions based on GIS calculated distance and time performed better than the other two functions. The coefficients of travel cost and travel time in the GIS-distance based models are highly significant. Thus, a measurement approach that combines the accuracy of GIS approach with route itinerary information elicited from respondents would provide a significantly superior basis for travel cost studies.

Key Words: GIS, Spatial Analysis, Recreation Demand, Travel Cost method,

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Introduction

Geographical information systems were initially developed as tools for the storage, retrieval, and display of geographical information. Capabilities of the geographical analysis of spatial data were enhanced by better integration of GIS and the methods of spatial analysis (Goodchild, 1987; National Center for Geographic Information and Analysis, 1989). Economics and social sciences in general might benefit from the addition of spatial analysis to their research. Many datasets economists use already have a component that may be thought of as spatial, that is, the data occur at specific geographic locations.

Bailey (1995) evaluates the progress that has been made in using GIS technology and functionality for problems requiring spatial statistical analysis. He also assesses the potential for future developments in this area. Haining (1995) provides a complementary assessments of the interface between GIS and spatial statistical analysis. He reiterates the value of linking spatial statistical analysis and GIS, and argues for GIS developments that aid both exploratory and confirmatory modes of analysis.

A Geographical Information System provides an efficient method of spatially referencing geographic and economic information that describes natural resources, cultural resources, human resources, and institutions. The information derived from this data can be grouped into three important categories: (1) attribute information, the phenomena or characteristics including the variable itself, its characteristics, and its name, (2) locational information, the geo-spatial location of the data, often stored as latitude and longitude, and (2) temporal information, the time period associated with the data. Many modern GISs include comprehensive functions for data capturing, editing, and display and have only limited operations for the analysis of spatial data. The analysis functions are usually limited to overlay, buffer, and query (Burrough, 1990). With the growth of GIS applications, many GIS users demand more sophisticated analytical functions in GISs (Goodchild and Brusegard, 1989).

Spatial Data:

The analysis of spatial data has always played a central role in the quantitative scientific tradition in many fields such as geography, natural resource economics, environmental economics, market research, etc. In the past, there have appeared a considerable number of publications devoted to presenting research results and assessing the techniques of analyzing spatial data in the field of geography. Goodchild (1987), Odland (1988), and Anselin (1990) introduce the concept of spatial autocorrelation. Anselin (1990) and Griffith (1987) deal with a wider range of methodological issues in spatial econometrics and spatial statistics. In addition, spatial data analysis has received considerable attention as an essential element in the development of GIS and as an important factor in regional modeling (Anselin, 1989).

Recreational Demand Analysis:

Outdoor recreational policy and environmental policy have changed significantly since 1970; an important component of this change has been the increased emphasis placed on the environmental issues, public lands upon designation of wilderness areas and other preservation classifications. The U.S.D.A Forest Service manages vast tracts of publicly owned land and water resources across the U.S. especially in the South and the West. Comprehensive reviews of previous outdoor recreation demand studies are provided by many researches in the past

(Bergstrom and Cordell, 1991; Walsh et al., 1988). Most of the models related to recreation demand analysis take advantage of the fact that each individual's visit to a recreation site involves considerations such as travel distance, travel expenditure, travel time, substitute site distance, possibilities of multi-activities, and multi-sites. Thus, many items in the recreation data are spatial in nature.

Objectives

The overall objective of this paper is to identify different components for the development of an Object-Oriented GIS framework, and to utilize GIS to generate and analyze spatial data in recreational demand analysis that would complement the existing body of econometrics and statistical analysis.

Methods

GIS and Spatial Analysis:

Researchers have used different forms of analysis to integrate GIS and spatial analysis. These analyses, are often called "quasi-analysis" as they are employed to generate and analyze spatial phenomena and used for further statistical analysis using probability distribution and econometrics tools (Burrough, 1989). Seven forms of analysis are commonly found in current application of GIS technology. The following sections deal with some forms and their applications in dealing with the spatial data in recreational demand analysis.

Query Analysis:

The combination of a database and digital map make it easy to extract information from a GIS. Extracting information in this way is referred to as *querying* the database. The language used for executing queries is called Structural Query Language (*SQL*). If a research study needs data from all the recreational visitors from a state whose income is greater than $20,000. It can be extracted and displayed using the following query:

select *

from visitor and Georgia

where income >= $20,000

Where ***select**** selects all variables to be queried, ***from*** specifies which database is to be queried, and ***where*** specifies what criteria are to be used in picking observations (Oracle, 1990).

Query analysis may also be extended to predictive types of query analysis. If a specific function can be estimated or approximated showing how one variable affects another, this function can be entered into the databases. Then a new variable may be developed based on this function. Also, the databases can be queried to determine what might happen if a new variable is introduced or one of the existing variables changes (Palicki, 1993). The California Department of Conservation (CDC) has used this type of analysis to model King County land use, in particular how to keep as much agricultural land in production as possible and still manage urban growth while protecting the environment and endangered species.

Overlay Analysis:

This function of GIS involves its most useful type of spatial data manipulation: overlaying one map on top of another. Using this, any map that was accurately digitized with correct latitude and longitude can be viewed on top of any other map that covers the same geographical location as if the two maps were a map. An example in recreation demand analysis is visitors' pattern/origin to two substitute or nearby sites that offer the same set of activities. This analysis helps to visually inspect the pattern of the data variables and to see if there is any correlation exists.   Many levels of data could be overlayed in this manner.

Transportation/Transshipment/Routing Analysis:

GISs can provide insight into logistical concerns as well. Since the GIS knows the exact location of points, the GIS can easily compute exact distances among points either along a line such as a road or direct distance. Additionally, if the GIS is programmed with certain parameters and then queried, the GIS can compute the distance avoiding established criteria such as heavily populated areas or routes with substandard roadways. In North Carolina, the Department of Public Instruction uses a GIS to plan school bus routes to minimize costs. The system also includes a minimization module programmed with the objectives such as minimizing the total number of buses required, minimizing the total travel time of all buses, arriving at certain time, etc.

In the recreational demand analysis, a simple test of the effectiveness of GIS in providing data on distance and time traveled is to compare respondents' perceptions of travel distance and duration with those calculated using a GIS (Brainard et al., 1995). If visitors' estimates are used, these should reflect individual routing decisions and travel speeds. In particular, they will highlight visitors who, in order to increase the enjoyment of their journey, select routes that are not of the shortest distance/duration. However, a problem with reliance upon respondents' descriptions of their journey is that estimates of both distance and time are liable to suffer from rounding effects. Table 1 shows the comparison of mean stated distance, ZIPFIP software calculated distance, and GIS calculated distance.

Previous studies have adopted various methods to determine visitor travel times and distance. A simple approach is to ask visitor respondents distance and time of travel to reach the destination sites. However, such estimates are often inaccurate as found in many previous studies (Brainard et al., 1995). Another common approach is to draw concentric, distance- based rings around site and create a market area. Two types of distances are calculated. Great circle distance is calculated "as the crow flies" straight line distance between two locations, whereas road distance is calculated by multiplying great circle distance with a circuity factor (ZIPFIP, 1993). An obvious criticism here is its implicit assumption of a uniform and universal road network around sites.

One of the important factors visitors consider is travel time to reach the site. If the activity at the site not the journey to the site is of importance to the visitors, which is often the case, visitors want to minimize the travel time. Since ZIPFIP does not calculate the travel time, an average speed such as 50 mph is assumed to calculate travel time in the method using ZIPFIP.

The GIS approach produces accurate estimates of the distance between the recreational site and the point of origin, which can then be used to derive estimates of travel time. This approach can attach different travel speeds to different segments of routes, find out the proper routes based on the existing road map considering various alternative routing strategy.

Methods to Calculate GIS based Distance:

This section gives a procedure to employ GIS to create, manipulate and analyze spatial data used for the econometric analysis in the case of recreational demand analysis. Recreational demand estimation uses many sources of data; on-site/sample survey data, population census data, and various secondary databases maintained by government agencies. Some of these are purely spatial in nature.

Calculations of GIS trip costs first require accurate information regarding trip origins and the sites of visitation. The grid reference of trip origins and visitation site were located by using zip code of the origin and attaching latitude and longitude to the origin location. To accomplish the whole task of spatial data manipulation and analysis, ARC/INFO and Arcview GIS softwares were used (ESRI, California). In this case study, demand functions for Primitive and Developed Camping activity in the Cherokee National Forest, North Carolina are estimated from different sources of the data and compared. The following steps were followed:

1. Create a map of the study area. The study area depends on the location of visitors'origins. It may comprise either the state of Georgia, or multiple states. ***overlay*** state boundaries if the study area includes more than one state.
2. ***overlay*** road maps. Roads can be classified into interstate, US highways, State highways, county roads as given in Table 2. The georeferenced data on state boundaries, various categories of roads are obtained from the ESRI, and TIGER databases, Department of Transportation website.
3. Put the site under consideration on the map using its coordinates,
4. Create references of all the origins from where trips are generated to the abovementioned site. In this study, origins are the countries in various states that are referenced with county fips code, latitudes and longitudes.

The classification of individual roads is defined in the National Transportation Atlas database, 1996. By applying differential road speeds to these details, travel times can be calculated for discrete sections of roads. From these, travel times can be calculated for routes across the whole study region. Data detailing average travel speeds for differing categories of road were obtained from documents obtained from Department of Transportation. The details of road speeds are given in Table 2. Travel times from each road segment in the network were calculated via equation (1):

$$\text{(1)} \qquad Travel\ Time = \frac{Length\ of\ Road\ Segment\ (miles)}{Speed\ (mph)}$$

A study by Colenutt and Sidaway (1973) showed that minimum travel time provided a strong explanatory variable in models predicting the number of visits to a site. Minimum travel time can be calculated by specifying the time from equation (1) as the impedance associated with a particular road segment in the digital network. An algorithm is then used to identify the route between the trip origin and the site that minimizes the cumulative impedance, thereby isolating the minimum travel time. The GIS calculation of individual's travel times and distances can be broken down into three steps as below:

Table 2. Classification of Highways and Roads in the United States

Type of Road	Speed Limit (miles per hour)*	
	Rural	Urban
Interstate Highway	65 - 70	55 - 60
US Highway	55 - 65	45 - 50
State Highway	45 - 55	40 - 45
State Road	45	35 - 40
County Road	35 - 45	25 - 35
City or Campus Road	25	15 - 25

Note: * indicates average speed limit. Speed limit varies from state to state.
Source: Road Transportation Network, Department of Transportation.

A. Identify the site on the road network. Perform ***allocate*** operation of the **ARC/INFO** software. Determination of optimal routes in **ARC/INFO** uses an algorithm credited to Dijkstra (1959) that seeks to minimize a criterion such as time or distance to move between two points. The assumption of travel time minimization may not be true for all visitors- local visitors who are meanderers. This command operated within the ***Arcplot*** module of the **ARC/INFO** GIS, finds the route that minimizes the sum impedance between a specified point (the site) and each segment of road. ***Allocate*** therefore determines the minimum cumulative time for each road segment. For each visitor origin, the travel time to the nearest point on the road network can be assigned as the travel time for that journey's start point. Specific commands can do these calculations in **ARC/INFO.** These times are stored in an **ARC/INFO *'Output'*** table.

B. The second step involves finding the nearest point on the road network to each individual visit origin. Travel time from this point to the recreation site can then be estimated both by use of the ***output*** table and interpolation between the two endpoints of the road segment. This step can be performed by means of the **ARC/INFO *addroutemeasure***.

C. The third step involves in determining the distance traveled by each visitor along these minimal-impedance routes using quality sensitive road speeds given in table 2. This step is difficult as it considers minute details and complexity of road network and varying speeds for each observation. ***addroutemeasure*** can be used to find distance of each road segment from individuals origin to recreation site.

Other Data Sources and Estimation Techniques:

Data Sources:

Data for the study were obtained from the Public Area Recreation Visitors Study (PARVS) and the CUSTOMER survey for Cherokee National Forest (Bergstrom and Cordell, 1991). PARVS and CUSTOMER are ongoing multi-agency efforts to collect data on the use of public areas for outdoor recreation. The major component of these efforts is on-site interviews of recreationists conducted at public recreation areas. Information regarding number of trips visitors took to Cherokee National Forest, household income of the visitors, distance traveled (in miles), number of hours traveled (stated hours), quality of sites etc. were obtained from these surveys.

Per trip travel cost is defined as a composite of variable operating costs ($0.10 per mile) and the opportunity cost of time in travel. Following previous studies, the opportunity cost of time in travel was calculated as the product of 25 percent of wage rate and the estimated time in transit from the origin to the site. This procedure was used to estimate three sets of distance travel cost using stated distance and time, ZIPFIP calculated distance and time, and GIS calculated distance and time. The substitute site was determined as the site closest to the individual's origin that offered the opportunity for the same main activity. The procedures are used to find the distance and calculate substitute variable. In addition, a binary variable (NON) to differentiate local from nonlocal participants was included. The classification was made on the round-trip distance of 100 miles.

Estimation Techniques:

Individual travel cost method (ITCM) is quite often used to estimate the recreation demand for a site that provides many recreation activities to a visitor. Here, travel cost relationships are solely based on individual observations. The individual approach has been used by many economists including Adamowicz et al. (1989), Creel and Loomis (1990). The conceptual model used in this study is specified as:

$$Trips_{ij} = f\ (Inc_i,\ TC_{ij},\ Subst_i,\ NON) \tag{2}$$

where, $TRIPS_{ij}$ represents annual trips by individual i to the site j for camping activity, INC_i is annual household income of individual i, TC_{ij} is the travel cost per trip from individual i's origin to site j, $SUBST_i$ is price of a logical substitute, and NON is binary variable classifying observation as local on nonlocal.

Empirical individual demand functions were estimated using truncated count data estimators as described in Creel and Loomis (1990) and Grogger and Carson (1991). These models were chosen because the dependent variable, the number of trips taken over a year, is nonnegative integer. The statistical model fitted using the truncated Poisson (TP) is given by

$$P(Y_i = y_i | Y_i > 0) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i![1-\exp(-\lambda_i)]}, \quad y_i = 1,2,..., \quad i = 1,2,...,n \tag{3}$$

λ_i is parameterized for estimation as

$$\ln \lambda_i = X_i\beta + u_i \tag{4}$$

where Y_i is a random variable, trip taken by a visitor. X_i represents the vector of explanatory variables, β is the parameter vector and u_i is random disturbance.

Results and Discussion

Table 1 shows a comparison of three distances used to estimate recreation demand functions in this study. Mean stated distance is the elicited average distance obtained from the respondents from a particular origin to the Cherokee NF site. ZIPFIP distance is calculated road distance using ZIPFIP Software as explained above. GIS distance is the distance calculated using GIS software as explained in the above section.

Comparison of the three distance estimates indicate that respondent stated distance measure is often an overestimation of the other two estimates. On the other hand, ZIPFIP calculated distance is always on the lower side of the GIS based distance estimates. ZIPFIP considers the straight line distance (‘as the crow flies’) between a pair of points (Great Circle distance) and corrects that distance for route circuity. The average circuity factor is 1.15 (ZIPFIP, 1993). An obvious criticism here is its implicit assumption of a uniform and universal road network around sites.

Similar observations can be made for the comparison of travel time based on the three procedures, i.e., stated travel time is an overestimation of the GIS calculated travel time, and ZIPFIP travel time is an underestimate of the GIS time. To calculated time based on ZIPFIP-based distance, an average of 50 mph is assumed.

Table 1. Comparison of Mean Stated vs. Calculated Distances

Origin of visits		Distance			Time		
Fips	County name	Stated	ZIPFIP	GIS	Stated	ZIPFIP	GIS
1073	Jefferson, AL	239.00	127.00	176.50	4.66	2.54	3.53
12071	Lee, FL	883.33	595.00	705.8	16.33	11.9	13.31
12083	Marion, FL	555.00	456.00	504.5	12.50	9.12	9.51
12099	Palm Beach, FL	725.00	572.00	728.00	12.00	11.44	13.23
13067	Cobb, GA	105.00	88.00	97.00	2.50	1.76	2.06
13089	Dekalb, GA	150.00	102.00	116.10	3.00	2.04	2.46
13111	Fannin, GA	21.00	62.00	41.80	1.00	1.24	0.92
13135	Gwinnet, GA	150.00	104.00	108.70	3.00	2.08	2.31
13313	Whitefield, GA	50.80	24.00	28.90	1.20	0.48	0.62
37023	Burke, NC	340.00	215.00	200.70	5.5	4.30	4.01
47051	Franklin, TN	150.00	69.00	80.30	3.00	1.38	1.60
47065	Hamilton, TN	40.00	19.00	19.70	4.33	0.38	0.43
47139	Polk, TN	19.18	24.00	23.40	1.00	0.48	0.52

Fig. 1 shows the behavior ratios of stated/ZIFIP and stated/GIS distances over different distances. This implies significant differences in distance estimates for the shorter distances. In the long run, ratios are smoother as the distance increases but consistently higher than one indicating stated distance are overestimated.

The ITCMs were estimated using a maximum likelihood routine for the truncated Poisson models (SAS Institute Inc., 1995). Estimated demand equations are given in Tables 3 through 8. Each table consists of parameter estimates, standard errors, t-ratios, χ^2 statistics, and consumer surplus per trips estimates. Table 3 through 5 considers variables such as income, different distance measures, different substitute measures, and binary variable NON where as tables 6 through 8 considers travel time variable in addition to above variables. In first three models, model based on GIS distance shows highly significant travel cost coefficient whereas travel cost variables are not significant in the other two models (stated distance based and ZIPFIP distance based). Similar patterns are observed in the case of models with the inclusion of different travel time measures. Both travel cost variable and travel time variable are highly significant in the models based on GIS distance and travel time. This implies that both distance and travel time are important in visitors' decision to visit the site.

Fig. 1 Ratio of Stated vs. Zipfip and GIS Distance

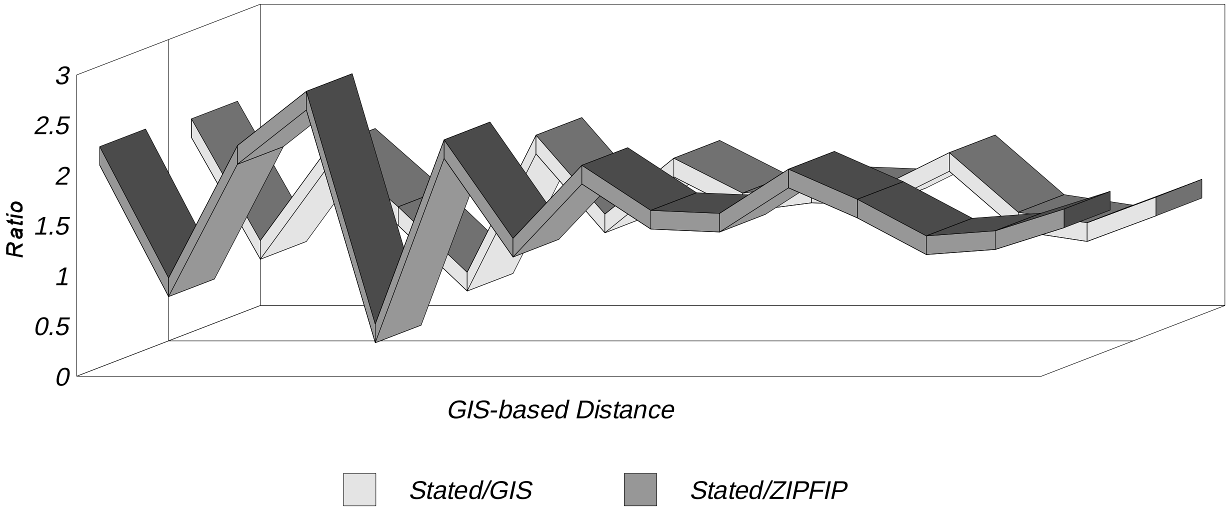

Table 3. Poisson Model Results with ZIPFIP Calculated Distance

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.87179	0.1069	8.15
income	0.000011	0.000003	3.89
travel cost	-0.0152	0.007022	-2.16
substitute	0.07190	0.02237	3.21
NON	-1.7623	0.4305	-4.09
χ 2 statistics	284100.00		
Per trip consumer surplus	65.71		

Table 4. Poisson Model Results with Respondents' Stated Distance

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.857450	0.1067	8.03
income	0.000012	0.000002	4.11
travel cost	-0.00126	0.00163	-0.77
substitute	0.04856	0.02017	2.40
NON	-2.2229	0.3857	-5.763
χ 2 statistics	1931.8		
Per trip consumer surplus	791.06		

Table 5. Poisson Model Results with GIS Calculated Distance

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.91385	0.1144	7.99
income	0.000014	0.000003	4.46
travel cost	-0.01565	0.003254	-4.81
substitute	0.67419	0.02067	3.26
NON	-1.5563	0.3557	-4.37
χ 2 statistics	1186200000		
Per trip consumer surplus	63.89		

Table 6. Poisson Model Results with ZIPFIP Calculated Distance and Time (50 mph)

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.82417	0.1133	7.277
income	0.000012	0.000003	3.85
travel cost	-0.023469	0.009263	-2.53
substitute	0.08235	0.02415	3.41
NON	-1.7319	0.4463	-3.88
hour	0.02675	0.01316	2.033
χ 2 statistics	1068700		
Per trip consumer surplus	42.60		

Table 7. Poisson Model Results with Stated Distance and Time

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.7686	0.1390	5.53
income	0.000013	0.000003	4.043
travel cost	-0.05393	0.03738	-1.44
substitute	0.053479	0.02062	2.59
NON	-2.2306	0.3925	-5.68
hour	0.034587	0.02699	1.28
χ 2 statistics	2514.1		
Per trip consumer surplus	185.42		

Table 8. Poisson Model Results with GIS Calculated Distance and Time

Parameters	Parameter Estimates	Standard Errors	t-ratio
constant	0.2382	0.1581	1.50
income	0.000034	0.000004	7.41
travel cost	-0.07975	0.01131	-7.05
substitute	0.091806	0.02171	4.22
NON	-1.4617	0.3733	-3.916
hour	0.52402	0.08261	6.343
χ 2 statistics	549820		
Per trip consumer surplus	12.53		

Conclusions

This study has examined the use of an Object-Oriented GIS framework to generate and analyze spatial data in recreation demand analysis. Several forms of GIS analysis are introduced and explained as how they can be utilized in recreational demand analysis. An application of GIS to calculate journey distance and duration has been illustrated with a case study. The recreation demand models using these travel distance and duration are then compared with the models using respondent's stated values and models using distance data obtained from ZIPFIP software. Based on the criteria such as χ^2 statistic, individual coefficient significance, it is found out that travel cost functions based on GIS calculated distance and time performed better than the other two functions. The coefficients of travel cost and travel time in the GIS-distance based models are highly significant. Thus, a measurement approach that combines the accuracy of GIS approach with route itinerary information elicited from respondents would provide a significantly superior basis for travel cost studies.

As the travel cost model is based on the recognition that the cost of traveling to a site is one important component of the full cost of a visit, the accuracy in calculating travel distance is an important step in recreation demand estimation. Errors in the measurement of a explanatory variable leads to the corresponding coefficient biased toward zero, and other coefficients biased in unknown directions, called ***attenuation*** (Greene, 1993). There is a need for furthur research to address travel distance and duration measurement issues using GIS that may improve the recreation demand model fit. Also, GIS can be utilized to estimate the circuity factor for the calculation of distance using straightline distance method.

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