GEOGRAPHIC INFORMATION SYSTEMS AND MARKET RESEARCH

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1. INTRODUCTION

Although the term "Geographic Information System" dates from the mid 1960s, the past few years have seen an explosive growth in the GIS industry. Recent Dataquest and Daratech surveys report that the annual volume of the GIS software business is now worth several hundreds of millions of dollars, rising at perhaps 35% per year, and involving up to 100 different software vendors.

Unlike more conventional databases, the objects and records in a GIS are identifiable by location, which means that a GIS can support various kinds of geographically-based analysis and retrieval, and respond to geographical queries. Given the importance of location in marketing, it is surprising, perhaps, that this sector has lagged behind other GIS applications to date. Annitto and Cromley (2) find that compared to resource management and land use planning, there have been few attempts to apply GIS to market analysis. Two recent guest editorials (1,4) on information technology and its role in marketing in the Journal of Retailing make no mention of GIS at all.

The purpose of the present paper is to examine the current state of GIS in marketing, and its future prospects. To do so, we first look at the definition and nature of GIS from a marketing perspective. The subsequent sections review the potential of GIS in marketing, and associated impediments to its realization.

2. NATURE OF GIS

A GIS is an information system with geographical access; a system for input, storage, analysis and output of geographically referenced data. It is clearly something more than a mapping system, because of the emphasis on analysis rather than display. But the current diversity of interests and disciplines in the field, the variety of software products available and the lack of a clear intellectual core give a very confusing impression to the uninitiated.

The capabilities of a GIS are defined by the contents of its database and the functions which operate on it. In the early days of GIS these varied enormously from system to system, but as the GIS industry matures, a consensus is slowly emerging. The next two sections describe database contents and functionality respectively.

2.1 DATABASE CONTENTS

The features which occur in the real world as points, lines or areas are represented in the database as objects with associated attributes. Different classes of features have different attributes: shopping centers may have attributes of floor area; customers may be identified by income, age and residential address. Because the features are located in space, a great variety of relationships may exist between them: unlike other types of databases, a GIS has the ability to store these relationships and use them as the basis for analysis. For example, the relationship "is within" allows a customer to be assigned to a census reporting zone so that the zone's attributes can be made available in analyzing the customer's behavior.

Relationships can exist between objects of the same or different types. In many applications it is important that the relationships be allowed to have their own attributes: for example, the relationship "patronizes" between a customer and a shopping center may be characterized by length of trip, mode of transport or expenditure.

It is useful to distinguish between three types of relationships. The first are those which allow complex objects to be constructed from simple ones, such as the relationship between a line and the points which define it. The second are those which can be computed geometrically from the locations of the objects, such as "contains" or "is nearest to" or "crosses". Most GISs have the ability to compute and store this second type of relationship, and use them in analysis. The third type are those which cannot be computed from the geometry, and must therefore be input directly. These include the "intersects" relationship between streets, which is not the same as "crosses" because of the possibility of overpasses, and is therefore important in any traffic routing application.

This view of the world as populated by discrete objects is probably appropriate for almost all marketing applications, but in other areas it may be more useful to look at geographical variation as if it were continuous. This "field" view is common in analyzing topography, aerial photographs and images from space, and climatic variables. Although fields and objects have sometimes been seen as competing approaches to GIS, the current consensus is that both are necessary, and that any comprehensive product must accommodate both.

2.2 FUNCTIONALITY

As with any information system, it is essential to provide routine housekeeping functions, including data input and storage. Since the data is geographically referenced, a GIS should be able to generate a map output. However it is able to offer much greater power than a simple automated mapping system for two reasons: because of its analytic functions, and because of the importance of relationships between objects, which are not significant in simple mapping.

The basis of GIS power lies in its ability to carry out several unique classes of functions:

- computing spatial relationships between objects

- using spatial relationships to assign new attributes to objects, e.g. find geographical coordinates for customers using their street addresses ("geocoding" or "address matching"); find the number of customers within certain distances of a shopping center location

- computing new objects from existing ones, e.g. a trade area (area object) from customer locations (point objects)

- analyzing the attributes of a class of geographically referenced objects, e.g. select all customers with income >$30,000 and display locations

- analyzing multiple classes of objects, e.g. forecasting trips to shopping centers based on characteristics of neighborhoods (area objects), shopping centers (point objects) and trips (point-area relationships)

3. GIS POTENTIAL IN MARKETING

With this brief introduction, this section looks at specific areas of application of GIS technology in marketing, ranging from simple data exploration to numerical modeling.

3.1 SPATIAL ORGANIZATION OF INFORMATION

The ability to examine data in its spatial context is enormously important. A simple map gives the eye immediate access to geographical proximity and therefore to the role of distance as an explanatory factor. A customer name, "John Doe", conveys very little, but if John Doe's street address is used to assign geographic coordinates, then he can be related to the known characteristics of his neighborhood, and his proximity to various shopping alternatives. The geocoding process takes a simple street address and matches it to a database containing address ranges for every link in the street network. In this way customer lists may be converted into simple dot maps, or coupled with census data and displayed as maps of market penetration.

3.2 EXPLORATORY SPATIAL ANALYSIS

A map is a static presentation of data which is very efficient at allowing the eye to explore geographical distributions and certain types of spatial relationships. But with a complex dataset, the single perspective offered by a map may be too limiting to be of much value. Recently there have been several significant efforts to use GIS technology to provide market analysts with tools for exploring geographical markets. In a sense this exploratory spatial analysis or ESA is the equivalent for spatial data of Tukey's exploratory data analysis (12), which is a set of simple methods for exploring patterns and structures in numerical data.

One obvious advantage of ESA is that it can avoid the high cost of transporting a real estate specialist to a site. With access to appropriate data and the necessary tools to explore and visualize, one could carry out detailed site evaluations from a remote digital environment. Emergency management services are already using systems which allow attributes to consist of images, so that a photographic view of a burning building can be retrieved before the fire truck arrives at the scene, allowing the crew to develop a detailed strategy in advance.

The data needed to assess a market is multidimensional, and varies geographically as well as temporally. A map is limited to a single geographical slice of this multidimensional data matrix, for one variable and one point in time. In the digital environment it should be possible to explore the data matrix in a much more versatile manner, and the Voyager system provides a recent example of this type of ESA. The user is able to open several windows showing different views of the dataset; one might contain a spatial spatial view, and one a temporal view. When the user points a cursor at a location within the spatial window, the temporal window shows how a particular variable has changed through time at that location. A third window might be used to select the variable of interest.

Another simple type of ESA might be applied to site selection. Suppose the key variable is the total expenditure within 1 mile of the site, and we wish to rate sites on this basis from maps of average per capita expenditure and population density. This would be difficult, as the eye is not good at combining information from two different maps and integrating the result within 1 mile circles. But in a digital environment it is easy to imagine a system which allows the user to move an integrating circle around the screen, continuously updating the desired variable. The value might even be discounted to allow for the locations of existing competitors. This kind of capability has been available for some time in the form of dial-up reports on single sites, but technology has now advanced to the point where it is feasible on a real-time, continuous basis.

Monmonier has described a different kind of ESA called "geographical brushing" (9). To understand the relationship between two variables, the user moves a "brush" within a spatial window. The locations which fall within the current position of the brush are analyzed, and a bivariate plot is displayed within a second window.

3.3 BASIS CHANGE

Market analysts must cope with a variety of data problems, including the propensity of reporting zones to change through time. Although some sets of zones are relatively stable, the lower levels of census geography such as enumeration districts which are essential for market analysis are revised at every census, making longitudinal analysis difficult. Postal zones such as ZIP codes have become increasingly popular recently because of the ease with which they can be linked to address records, but unfortunately the quality control of postal zone geography is poor. So market analysts frequently face the need to transfer data from one set of zones to another, when the second set fails to respect the boundaries of the first. In general, basis change describes any transfer of attributes from one set of spatial objects to another; the primary application is the transfer of socioeconomic and demographic statistics from one set of reporting zones to another. The influence of variable reporting zones on the results of analysis is commonly called the "modifiable areal unit problem".

Beaumont (5) sees basis change as the major area of application of GIS technology in marketing, based on the GIS's ability to handle multiple sets of spatial objects, to compute the relationships between objects, and to base estimates on those relationships. Goodchild and Lam (7) showed how the GIS operation of polygon overlay could be used to compute the areas of overlap between reporting zones, and how these could be used as coefficients in estimation. Flowerdew (6) has extended the technique further, and Arbia (3) has looked at the overall problem of basis change within a GIS environment.

3.4 SITE MODELING

The analytic aspects of early GIS technology were directed toward simple functions like measuring area, selecting and counting objects and computing relationships. However the range of possible analyses can be extended very quickly by linking the GIS to a standard statistical package, or by incorporating such a package into the GIS itself. This allows the full range of statistical methods to be combined with the GIS's power in working with spatial relationships, and in displaying results in their geographical context. In this section we look at how four types of site analysis - analog, regression, spatial interaction modeling and location allocation - can be combined with GIS.

3.4.1 Analog

This is the term given to the process of analyzing a potential site by matching it with records on existing sites; if a close match is found, the attributes, particularly sales, of the matching site are assumed to be valid for the potential site. Analog searches are usually performed within a database. However an analog search within a GIS would allow the selected analogs to be displayed in geographical context. Although the database may contain hundreds of store attributes, the geographical context adds useful new information, for example on the specific configuration of competitors, and allows the user to query other factors which may be suggested by the context.

3.4.2 Regression

By this we mean the use of regression analysis to relate a store's sales to its physical and marketing attributes, such as signage, parking spaces, floor area, traffic conditions and demographics. The coefficients of each variable allow us to predict sales for a new site, or the effects of changing one or more of an existing site's attributes, such as new signage or reduced parking.

There are several benefits to be gained by performing regression analyses within a GIS environment. The GIS provides an efficient way of generating some of the necessary variables, particularly demographic counts within each store's surrounding area. A map of residuals from the analysis may provide useful insights into the factors which have not been included in the regression model, or into geographical variation in the model's performance.

3.4.3 Spatial interaction models

Spatial interaction models can be used to analyze and predict consumer spatial behavior, but are notoriously difficult to calibrate within standard statistical packages. In part this is because all spatial interaction models work with several types of spatial objects at once: attributes of neighborhoods, destinations and trips. In part it is because the functions for working with spatial objects which exist in a GIS are not present in standard statistical packages. For example, the user has functions available within a GIS for measuring trip lengths through street networks, or for locating a representative centroid within a neighborhood, or for aggregating customers from points to census tracts.

3.4.4 Location allocation

This is the term given to a set of techniques for searching an area for the optimum sites for a number of central facilities, and many applications of location allocation to retail site modeling have been described (11). Simple location allocation packages are available, but they suffer from several disadvantages. Although they produce the optimum sites for a particular objective, inevitably the final decision must pay attention to factors which have not been included in the optimization. Therefore it helps to know how much optimality must be sacrificed when the solution must be modified by new factors. It is also useful to have efficient ways of building the database for a location allocation analysis, and ways of displaying the results geographically.

Recently there has been significant interest in the concept of a spatial decision support system, based on a GIS database, which could combine the skills and knowledge of the user with the optimization of a location allocation model. Goodchild (8) described an early version of this concept for a mainframe computer.

4. IMPEDIMENTS

In this section we look at current and continuing impediments to the use of GIS technology in market analysis. If a GIS is a system for handling spatially referenced information, and if spatial referencing is very significant in marketing because of the importance of location, then why is this area of GIS application lagging others at this time?

4.1 DATA

The technology available to market researchers has changed enormously over the past few decades, as computers, statistical and now GIS software have become available. However although much data is now available from data collection agencies in digital form, there has been remarkably little change in the process by which data are collected and distributed. The census is still carried out every 10 years, then tabulated and distributed in tabular form for reporting zones.

We have seen how geocoding allows records to be placed in their geographical context, by matching addresses to street files. In the US the primary data tool for geocoding is the TIGER database, which is in the process of replacing the earlier DIME. Both databases were developed for internal census purposes: as geocoding tools they suffer from incomplete coverage, and currency which is geared to the ten-year census cycle. As a result a 90% "hit" rate is considered good for a typical customer mailing list - over 10% of addresses will not be successfully geocoded.

With the technology currently available it would be a simple matter to build and maintain a complete, current national database of all streets, which could successfully geocode close to 100% of addresses. The problems which have thus far prevented this are almost entirely administrative: the lack of a consistent, uniform method of addressing in rural areas, the problems of coordinating input, and the lack of a federal agency with the appropriate mandate. In general, data collection agencies have been hard pressed to maintain traditional operations, far less undertake new activities in response to the opportunities offered by the new technology.

4.2 SOFTWARE

The GIS software products currently available for marketing applications fall into two broad categories: general "toolboxes" which offer generic capabilities across a wide range of applications, and packages which have been developed specifically for marketing. The first group have been slow to exploit marketing applications for several reasons: more traditional markets, such as resource management, have been strong; marketing has not been perceived as a large market in relation, say, to county government; and a package sufficiently versatile to handle the wide range of marketing applications requires extensive training.

The second group have been more successful. The simple mapping capabilities offered by packages such as SAS and ATLAS have sold well to market analysts, and more recently packages like Map/Info have become available offering significant GIS functionality.

In the longer term a convergence seems likely with the development of more specialized marketing capabilities within the generic GIS packages, particularly better access to statistical analysis, and with wider capabilities within the specialized marketing packages. However any package is ultimately constrained by its own data model and conceptual framework, and it is often difficult to add sophistication to a simple conceptual design.

4.3 HARDWARE

The current explosion of interest in GIS began around 1980 when the new range of super-minicomputers typified by the VAX became available: for the first time the computing power necessary to support GIS became available for a price which was affordable to many resource management agencies. Since 1980 cost-effectiveness has improved by at least an order of magnitude, so that the $250,000 minimal GIS hardware configuration of 1980 is now available based on workstations for under $25,000.

On the other hand the desktop mapping market is a more recent development of the PC world, particularly the AT. GIS packages developed specifically for market research applications tend to be PC-based, and there is a significant hardware-based barrier between them and the workstation-based generic GISs.

4.4 THE STATE OF GIS

At the highest level of abstraction, GIS is an emerging science of spatial information. It deals with how to collect, compile, store, analyze and display spatial data within a digital environment, raising explicit questions which have previously always been implicit within spatial analysis, such as the measurement of the accuracy of spatial data (10). It deals with the theory of spatial relationships and the representation of geographical variation within formal models.

However at a more immediate level GIS suffers from all of the problems of a rapidly expanding industry. It lacks a clear focus, a set of institutional structures around which it might be organized. It has no icons and few heroes. There is confusion about what it is, how to find out about it, what to buy. These are very early days in GIS, particularly in application fields like marketing and health. Although progress has been made, the lack of a clear consensus on these issues remains a significant impediment to the use of GIS in market analysis.

In the long run, much of our intuitive knowledge about the world is organized spatially. The residential location of a customer is used extensively in market research to impute other characteristics, particularly from the aggregate attributes of the neighborhood. Location is particularly important in retailing which serves the needs of a dispersed population from a few central locations. These points suggest that in the long term ESA may be of more significance than EDA, and that the potential market for GIS is at least comparable to that for the major statistical packages. We may be at the early stages of a sustained interest in the geographical context of activities. But while geography can be used to organize intuitive knowledge, it will never substitute for economics or psychology as a basis for understanding human spatial behavior.

5. WHAT DOES MARKET RESEARCH NEED?

GIS technology is capable of providing solutions to several significant needs in market research:

(1) ESA: a package to support exploration of spatial datasets, particularly in providing views which are important to market research but not available from conventional static maps.

(2) Basis change: a GIS application to provide a comprehensive solution to basis change problems. The simplest version would allow conversion from one set of source zones to a target set; more sophisticated versions might introduce ancillary data to improve accuracy.

(3) SIM: a GIS application to support the calibration of a range of spatial interaction models under various conditions.

(4) SDSS: a spatial decision support system, combining GIS capabilities for data input, manipulation and display with a range of optimization routines for location allocation under varying objectives.

The lack of a comprehensive, current digital street network is a critical problem in developing cost-effective geocoding. Site selection would also benefit enormously from a "digital Yellow Pages" - a file of point objects and associated attributes which included all existing retail establishments, updated on a frequent basis.

GIS offers a comprehensive solution to the management of spatially referenced information. Although the term has been around for several decades, the concept is relatively new in market research, which has traditionally relied on intuition, and analysis supported by statistical packages. So although software is increasingly available, acceptance of GIS will continue to be comparatively slow. We have argued in this paper that the value of GIS may be as much in simple exploration of data and in overcoming simple spatial problems, as in sophisticated spatial analysis.

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7. REFERENCES

1. Achabal, D.D. and S.H. McIntyre, 1987. "Guest Editorial: How Information Technology Is Reshaping Retailing". Journal of Retailing 63:321-5.

2. Annitto, R.N. and R.G. Cromley, 1988. "MARKMAP: A GIS for Small Scale Market Area Analysis". In R.T. Aangeenbrug and Y.M. Schiffman, editors, Proceedings, International Geographic Information Systems (IGIS) Symposium: The Research Agenda. Washington, D.C.: NASA, III:37-44.

3. Arbia, G., 1988. Spatial Data Configuration in the Statistical Analysis of Regional Economics and Related Problems. Dordrecht: Kluwer.

4. Beaumont, J.R., 1988. "Guest Commentary: An Overview of Decision Support Systems for Retail Management". Journal of Retailing 64:361-74.

5. Beaumont, J.R., 1988. "Store Location Analysis: Problems and Progress". In N. Wrigley, editor, Store Choice, Store Location and Market Analysis. London: Routledge, 87-105.

6. Flowerdew, R. and M. Green, 1989. "Statistical methods for inference between incompatible zoning systems". In M.F. Goodchild and S. Gopal, editors, The Accuracy of Spatial Databases. Basingstoke: Taylor and Francis.

7. Goodchild, M.F. and N.S. Lam, 1980. "Areal Interpolation: A Variant of the Traditional Spatial Problem". Geoprocessing 1:297-312.

8. Goodchild, M.F., 1984. "ILACS: A Location-Allocation Model for Retail Site Selection". Journal of Retailing 60:84-100.

9. Monmonier, M, 1989. "Geographical Brushing: Enhancing Exploratory Analysis of the Scatterplot Matrix". Geographical Analysis 21:81-84.

10. NCGIA, 1989. "The Research Plan of the National Center for Geographic Information and Analysis". International Journal of Geographical Information Systems 3:117-36.

11. Ghosh, A. and G. Rushton, 1987. Spatial Analysis and Location-Allocation Models. New York: Van Nostrand Reinhold.

12. Tukey, J.W., 1977. Exploratory Data Analysis. Reading, MA: Addison-Wesley.