This section includes shorter (e.g., 10–15 double-spaced manuscript pages or less) papers describing methods and techniques that can improve evaluation practice. Method notes may include reports of new evaluation tools, products, and/or services that are useful for practicing evaluators. Alternatively, they may describe new uses of existing tools. Also appropriate for this section are user-friendly guidelines for the proper use of conventional tools and methods, particularly for those that are commonly misused in practice.

Geographic Information Systems (GIS) as an Evaluation Tool

RALPH RENGER, ADRIANA CIMETTA, SYDNEY PETTYGROVE, AND SEUMAS ROGAN

ABSTRACT

Evaluators must seek methods that convey the results of an evaluation so that those who intend on using the information easily understand them. The purpose of this article is to describe how Geographic Information Systems (GIS) can be used to assist evaluators to convey complex information simply, via a spatial representation. Although the utility of GIS in such disciplines as geography, planning, epidemiology and public health is well documented, a review of the literature suggests that its usefulness as a tool for evaluators has gone relatively unnoticed. The paper posits that evaluators may have not recognized the potential of GIS, because of two beliefs that GIS can only provide cross-sectional, snapshots of data, and hence cannot depict change and that many of the available databases that underlie GIS do not contain data relevant to the evaluation at hand. This article demonstrates how GIS can be used to plot change over time, including impact and outcome data gathered by primary data collection.

INTRODUCTION

> Evaluation reports should clearly describe the program being evaluated, including its context, and the purposes, procedures, and findings of the evaluation, so that essential information is provided and easily understood Sanders (1994, p. 49).

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There are many methods by which evaluators attempt to convey the results of an evaluation to ensure that is easily understood by those who intend to use the information. Examples of tools traditionally used to present information include stories, graphs, tables, and figures. The purpose of this article is to describe how another tool, Geographic Information Systems (GIS), can be used to assist evaluators in presenting the results of their evaluations in a user-friendly way. The utility of GIS will be demonstrated in the context of a neighborhood revitalization project. However, the process we describe of using GIS is applicable to all evaluators attempting to depict change within a defined geographical area, regardless of the context.

GIS is simply any set of information that has a spatial component (Pettygrove, 1997). Developments in computer hardware and software have made possible electronic mapping with dynamic connections between maps and database information. These developments make it possible to manipulate maps and information to analyze spatial aspects of data. ArcView (http://www.esri.com/software/arcview/index.html) is a computer software package that stores information about points, lines, and polygons, as well as the spatial relations between these features. The location of a residence is an example of a point in a vector system. Rivers and roads are lines. Census tracts and other administrative units are examples of polygons. Information is stored about the locations of lines, and intersections (nodes), and the location and shape of polygons (Pettygrove, 1997). GIS software such as ArcView can associate databases of attribute information with associated map objects. One database might contain information about streets names and numbers; another might have census information. Data can be displayed as thematic maps. For example, population information in a census database can be displayed as a dot-density map or by shading the census tracts according to their population. In addition to feature/object attribution (what am I), the notion of topology is critical in GIS—each feature (point/line/polygon) in GIS can "answer" three additional questions—"who am I," "where am I," and "who is next to me?"

This article is intended to be an introduction to GIS for evaluators who have little or no familiarity with representing information spatially. Therefore, the example we chose to present here is deliberately simplistic, using GIS primarily to facilitate the *visualization* of information. GIS can also be used to *analyze* spatial relationships. For example, by overlaying map layers with different attributes, GIS can be used to identify areas that meet specific criteria for each attribute (e.g., you can identify areas with housing values within a specified range, within a set distance of an elementary school, etc.). GIS can also be used to *model* spatial relationships. Guerra et al. (2002) used GIS to model the spatial relationship between the density of blacklegged tick, Ixodes scapularis (carrier of Lyme disease) and environmental conditions such as soil order and texture, land cover, and bedrock geology. Based on such a model GIS may be used to map the risk of acquiring Lyme disease in regions known to be inhabited by the tick. It could also be used to assess whether other habitats have the necessary combination of environmental factors to support Ioxedes scapularis infestation. This work demonstrates both the explanatory power and predictive capability of GIS.

The utility of GIS has been recognized in a variety of disciplines and contexts. In the most recent issue of *ArcNews* (Miller & Hurlbutt, 2001–2002), a publication dedicated to describing the contexts in which GIS is being used, GIS has been used to study disaster management plans in New York City; develop homeland security strategies; analyze employment, health, and human services trends in Ohio; track state park assets in Arkansas; plan k-12 enrollment; and help plan a new corridor in San Antonio. In public health, GIS has been used to: conduct exposure assessment (Briggs, Collins, Smallbone, 1994; Dolk, Grundy, Kleinschmidt, & Elliot, 1994; Kallenbach, 1994; Maslia, 1994; Nuckols, Reich, Chiou, 1994a; Nuckols, Stallones, Reif, Clderon, 1994b; Nuckols, Ellington, Faidi, 1996a; Nuckols, Faidi, Xiang, Stallones, 1996b; Staatsen, Doornbos, Franssen, & Lebret, 1994; Stockwell, Sorensen, Eckert, & Carreras, 1993), present data on environmental contamination (McManmon, Knorr, & Stap, 1994); identify high risk areas (Guthe, Tucker, & Murphy, 1992; Wartenberg, 1992); look for spatial patterns of disease that will give a clue the etiology of infant mortality (Andes & Davis, 1995) and prostate cancer (Hanchette & Schwartz, 1992); and to aid in the control of vector-borne diseases (Beck, Rodriguez, & Dister, 1994; Glass et al., 1995; Mott, Nuttall, Desjeux, & Cattand, 1995; Rogers & Willians, 1993; Washino & Wood, 1994).

Investigators have utilized GIS to model high-intensity and violent crime in English cities (Craglia, Haining, & Wiles, 2000; Craglia, Haining, & Signoretta, 2001; Nelson, Bromley, & Thomas, 2001) and the U.S. (Groff & La Vigne, 2001). Local communities have also incorporated GIS in crime mapping, 'hot-spot' identification, and needs assessment (American City & County, 2000; Rich, 2001). Researchers at the Prevention Research Center (PRC) in Berkeley, CA, have made extensive use of GIS in their investigations of the spatial relationship between alcohol outlets and alcohol-related problems such as driving while intoxicated (Gruenewald et al., 1996; Gruenewald & Treno, 2000). They have also described how spatial models and GIS may be used to evaluate community prevention programs related to changes in the distribution of alcohol outlets (Millar & Gruenewald, 1997). Although numerous professions have used the GIS in depicting and interpreting data, it is clear to us that the utility of GIS has gone relatively unnoticed in the discipline of evaluation as evidenced by our literature search of evaluation journals, in which only one reference to GIS was found (Suggett & Larsen, 2000).

Based on our experience, we can offer two explanations as to why the potential of GIS has not been recognized by evaluators. First, the databases to which GIS are linked are cross-sectional. That is, GIS can provide meaningful snapshots of data in time. It may not be obvious to some evaluators how GIS could be made to show *change* over time. And it is depicting change, of course, that is often of most interest to evaluators. Second, many of the available databases that underlie GIS were created for reasons unrelated to what an evaluator might be trying to assess. Because the databases do not include the relevant outcomes, evaluators may overlook the possibility of using GIS. Evaluators have failed to realize the potential of using GIS by adding the results of primary data collection to an existing secondary database.

Within the context of a neighborhood revitalization study, we demonstrate, first, how GIS can be used to depict change. Second, we demonstrate how primary data collected can be plotted using the databases and associated spatial relationships underlying GIS. Sixty-seven objectives were evaluated as part of the neighborhood revitalization study. GIS was used to evaluate several of these objectives, such as changes in homeownership rates, infill construction, affordable housing, residential character, housing quality, and so forth (Renger & Passons, 1999; Renger & Cimetta, 2001). For clarity, this article only describes the simplest of these examples, the monitoring of changes in land vacancies.

PROCEDURE

Data Availability/Finding Shapefiles

The process begins by defining a geographical space of interest. To do this one must first have files that include the geographical boundaries and spatial features of interest in the format required by the software to be used. These files are referred to by different names in the context of different software. They are called "shapefiles" in ArcView, "coverages" in ArcInfo, and "data layers" in MapInfo. The most recent version of ArcView has adopted the term "data layers." Shapefiles may include polygonal features, such as county and state boundaries or census blocks, zip codes, and parcels; linear features, such as streets, railway tracks or streams; or point features, such as households, schools, or factories.

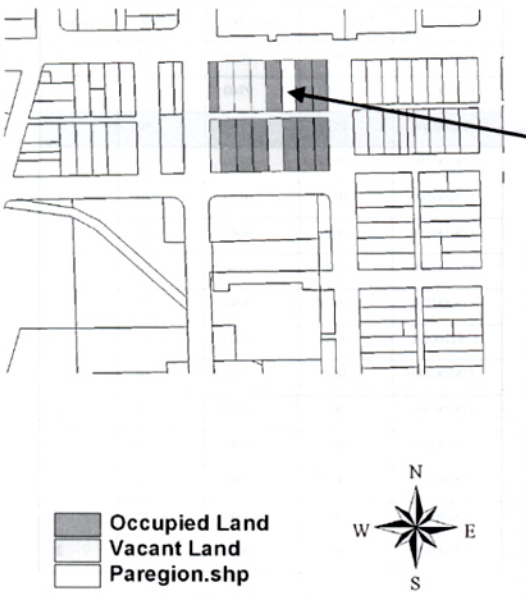
Data are available from government and commercial sources. In Pima County, Arizona, the Department of Transportation has developed a GIS for the county, known as the Pima County Land Information System (PCLIS http://www.dot.co.pima.az.us/gis/pclis/). This set of shapefiles and the databases associated with them are now available for a fee. Many municipalities and other local governments have been assembling such systems for their own use in services planning and may make them available. The United States Census Bureau uses a set of files known as Topologically Integrated Geographic Encoding and Referencing system (TIGER). These files are available to download from the Internet (http://www.census.gov/geo/www/tiger/index.html), but to use them in commercially available software packages such as ArcView or MapInfo requires that they be translated into the appropriate file type. One software package that handles this translation is available from GIS Tools (http://www.gistools.com). The TIGER files include shapefiles and some associated data for census blocks and tracts, voting districts, congressional districts, traffic zones, tribal subdivisions, school districts, hydrogeology, and more. Commercial vendors also have GIS data available; Claritas (http://www.claritas.com), Geoplace (http://www.geoplace.com/), and the GIS Data Depot (http://www.gisdatadepot.com/) have free and or low-cost spatial data. ESRI, the company that produces ArcView, has data available for purchase (http://www.esri.com) as does MapInfo (http://www.mapinfo.com). Data layers are available that can locate addresses based on interpolation of the known address range of each street segment—a process known as geocoding.

In the neighborhood revitalization project with which we were involved, the shapefiles needed were available from the tax assessors' office. The tax assessor's office provided shapefiles for the census tracts, census blocks, zip codes, and parcels within the county. In subsequent studies, we have found the library and state offices to be excellent sources in finding and providing shapefiles for a host of natural and anthropogenic point, line, and polygon spatial data.

Defining the Geographical Area of Interest

The focus of our evaluation was a small neighborhood in downtown Tucson, AZ. Three zip codes and multiple census tracts intersected the neighborhood. The fact that zip code and census tract boundaries did not coincide exactly with the street boundaries of our neighborhood posed a problem. Including zip codes or census tracts that only partially intersected the neighborhood would under- or over-estimate the study population and result in misclassification. In most cases the data layers combined in GIS analysis were generated by different sources at different scales/resolutions at a different time for a different purpose; thus, mismatches or non-congruence between the boundaries and features of spatial data layers is not uncommon.

The solution to this problem was to use the shapefile that defined parcels of land, the smallest feature of interest. The challenge was that the tax assessor's office provides parcel information for the entire county. Fortunately, ArcView contains a tool that allows the user to select parcels of interest from the master file. Once these parcels are selected, the user then creates a new shapefile that only contains the parcels of interest. During the selection process the database that underlies the shapefile is truncated to only include information relevant to the selected parcels and the new shapefile. The advantage of using parcels is that the *exact*



Parcel	Use	Landclas	Landrat	Vacant
118220010	0820	0830	25	1
118200270	9700	9440	16	1
118200260	0121	0160	10	2
118200250	0121	0150	10	1
118200240	0111	0150	10	2
118200230	0011	0040	16	2
118200220	0111	0150	10	2
118200210	0910	0140	16	1
118220020	0999	0999	0	1
118200280	0998	0998	0	1
118200290	0131	0150	10	1
118200300	0011	0040	16	2
118200310	0011	0040	16	1
118200320	0011	0040	16	1
118200330	0011	0040	16	1
118200340	0011	0040	16	2

Figure 1. Map of selected parcels by occupancy status and associated database (feature attribution) for 1997.

geographical region of interest can be defined resulting in accurate estimates. A sample of parcels and the associated database are shown in Figure 1.

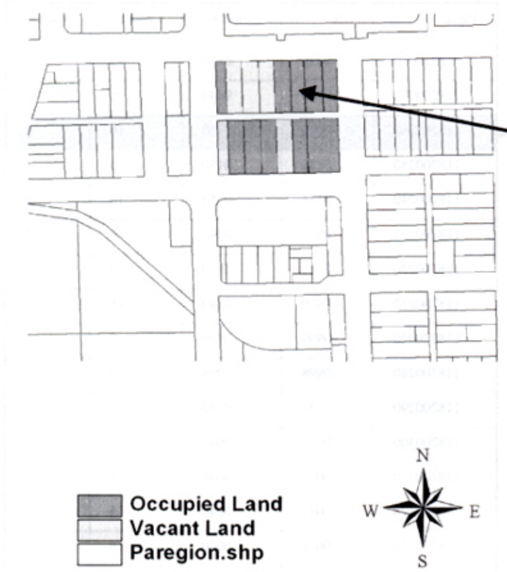
In this example we have selected 16 parcels of land. The paregion.shp refers to all the parcels of land in the county made available by the tax assessor's office. The truncated database created when selecting a subset of the parcels is shown on the right hand side of the figure. The Use, Landcla, Landrat, and Vacant variables are a small sample of the data that is made available by the tax assessor's office.

The Challenge of Visually Representing Change

GIS can be used to illustrate static conditions; however, it can also be used to illustrate changes. Layers of attributes from an earlier time period can be overlaid and "subtracted" from a layer depicting a later time. The layer that results from this operation can be displayed using a graduated color scheme that indicates the degree of change—from dark blue for the most positive change to white in areas where there was no change to deep red for the most negative change or, as illustrated below, types of change from one category to another can simply be color coded.

It is important to realize that the map shown in Figure 1 is a cross-sectional snapshot of information. In our study the information shown in Figure 1 represents data prior to the onset of a program intervention (1997). The tax assessor's office is continually updating information in the database and makes this available on a quarterly basis. Following the same process, a second cross-sectional snap shot was obtained 3 years later (2000). This is shown in Figure 2.

Because our illustration only includes a small subset of parcels, it is possible to assess change by simply placing the two maps side by side and comparing them. Even then the reader



Parcel	Use	Landclas	Landrat	Vacant
118220010	0820	0830	25	1
118200270	9700	9740	16	1
118200260	0121	0160	10	1
118200250	0121	0150	10	1
118200240	0111	0150	10	2
118200230	0011	0040	16	2
118200220	0111	0150	10	2
118200210	0910	0940	16	1
11822002A	0121	0160	10	1
118200290	0131	0150	10	1
118200300	0011	0040	16	2
118200310	0011	0040	16	1
118200320	0011	0040	16	1
118200330	0011	0040	16	1
118200340	0011	0040	16	2

Figure 2. Map of selected parcels by occupancy status and associated database (feature attribution) for 2000.

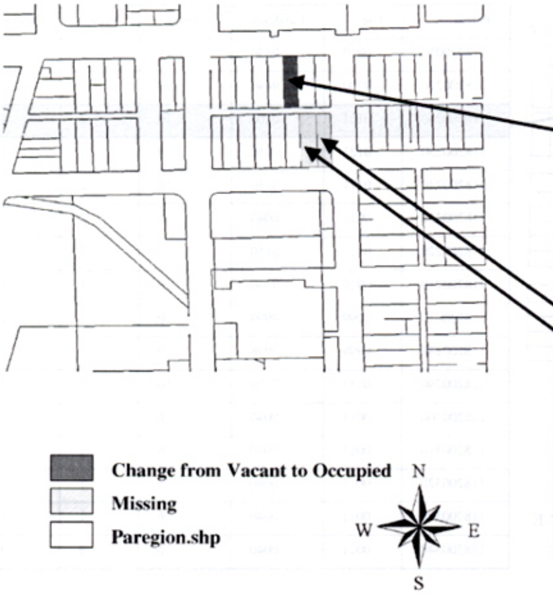
may find it difficult to quickly identify what parcels changed. In reality, comparing maps by placing them next to each other is impractical. For example, in our study there were over 1000 parcels of land within a 1 $mile^2$ area, making a visual inspection for change impossible. There is an obvious need to be able to depict change on a single map.

Manipulating Databases to Develop a Change Map

We felt that information would be more easily understood if a single "change" map could be developed. Conceptually, the creation of such a map is simple. One simply needs to subtract the variable of interest at 1997 from 2000. Values of zero would indicate no change, while nonzero values would indicate change. Further, depending on the context nonzero values may require additional coding to depict *types* of change.

In practice, developing the change map is slightly more complex and requires an understanding of the databases that underlie the shapefiles and how to manipulate them. The data files associated with the shapefiles are stored in dBASE (http://www.dbase.com/) format. One option in developing a change map is to use the database management utilities in ArcView. These allow interactive and command line user-defined querying and selection of the feature attribute tables of spatial objects. New variables may be created using the Field Calculator. The database utility can accommodate one-to-one, one-to-many and many-to-one joins based on common values of variables in two or more attribute tables. Users may also easily export the feature attribute tables for use in other data management programs such as Statistical Package for the Social Sciences (SPSS), EXCEL, or ACCESS.

The method *we* employed to develop a change map was to first import the dBASE files associated with the 1997 and 2000 shapefiles into SPSS. Using the parcel lot as the unique identifier, we then merged both files to create what we refer to as the "change" file. We then



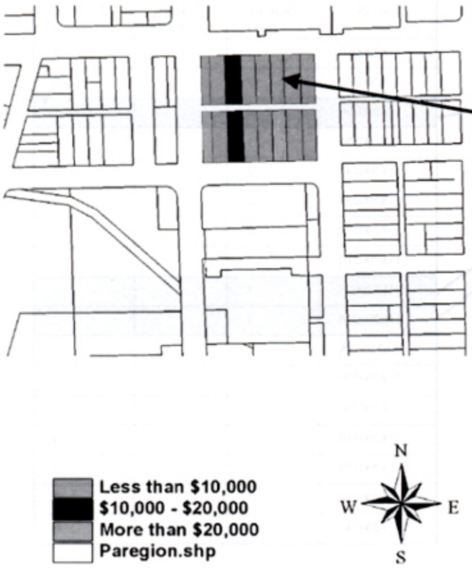
Parcel	Vacant 1997	Vacant 2000	Change
118220010	1	1	0
118200270	1	1	0
118200260	2	1	-1
118200250	1	1	0
118200240	2	2	0
118200230	2	2	0
118200220	2	2	0
118200210	1	1	0
118220020	1	.	.
118200280	1	.	.
11822002A	.	1	.
118200290	1	1	0
118200300	2	2	0
118200310	1	1	0
118200320	1	1	0
118200330	1	1	0
118200340	2	2	0

Figure 3. Map of selected parcels by occupancy change status and associated database (feature attribution).

created a change variable by subtracting the 1997 vacant variable from the 2000 vacant variable. We then recoded the types of changes into categories, as shown in Figure 3. The change file was then saved in dBASE format.

Once a change file was created we had two options with respect to plotting the data. The change file could be merged to the dBASE file associated with the 1997 shapefile, or it could be merged to the dBASE file associated with the 2000 shapefile. In our case, we merged the change file with the original 1997 shapefile using the join command in ArcView.[1]

Regardless of which shapefile we chose, we would be faced with the dilemma of missing data. In our example the 1997 dBASE file (see Fig. 1) contained 16 parcels. The 2000 dBASE file contained 15 parcels (see Fig. 2) because two of the parcels were collapsed into a single parcel between 1997 and 2000. Merging the two dBASE files results in a total of 17 parcels, three of which will contain missing data (see Table in Fig. 3). The two parcels from 1997 (118220020 and parcel 118200280) will contain missing data because there were no associated parcels in 2000 from which to subtract. The parcel from 2000 (11822002A) will also have missing data because there is no corresponding parcel number in 1997. Therefore, if the evaluator chooses to plot the change data using the 1997 shapefile, two parcels will be plotted as missing data. If the evaluator chooses to plot change data using the 2000 shapefile, then one missing value will be plotted. In our case, records from the county assessors office, which documented the aggregation of multiple parcels into one, or the disaggregation of a single parcel into multiple parts, might allow for the generation of a re-map table. Using this table, the status of the combined parcel in 2000 would be compared to the constituent elements in 1997 for use in our change analysis. These data may not be available for all parcels, or appropriate for all analyses. In summary, if the spatial characteristics of the shapefile, or key geographic features, shift over time, the evaluator may find it difficult to completely capture change for each unit.



Parcel	Use	Landclas	Landrat	Vacant	Income
118220010	0820	0830	25	1	1
118200270	9700	9440	16	1	1
118200260	0121	0160	10	2	1
118200250	0121	0150	10	1	1
118200240	0111	0150	10	2	1
118200230	0011	0040	16	2	2
118200220	0111	0150	10	2	1
118200210	0910	0140	16	1	1
118220020	0999	0999	0	1	1
118200280	0998	0998	0	1	1
118200290	0131	0150	10	1	3
118200300	0011	0040	16	2	1
118200310	0011	0040	16	1	1
118200320	0011	0040	16	1	2
118200330	0011	0040	16	1	1
118200340	0011	0040	16	2	3

Figure 4. Map of selected parcels by household income and associated database (feature attribution).

Plotting Primary Data

In the "INTRODUCTION" section, we noted that perhaps one reason why the full potential of GIS has not been realized by evaluators is the belief that the spatial representation of data are limited to the actuarial databases that are made available and already associated with the shapefiles. In our case, the tax assessor provides data on vacant land, land classification, land use, and so forth. Data needed for a comprehensive evaluation was much broader and included information collected by way of survey from neighborhood residents.

Plotting the survey information was relatively simple and could be done using ArcView functions. In the dBASE file associated with the shapefile of interest (feature attributes), we used the start editing command and then added a new field. Using the editing icon we entered the survey information, being careful to ensure that the data matched the correct parcel number. This was possible because the tax assessor database provided the street address for each corresponding parcel. In the example below, we added a variable called household income to the 1997 shapefile. Three categories of income were possible: below $10,000, $10,000 to $20,000, and above $20,000. The plot of the primary data is shown in Figure 4.

Within the context of the neighborhood revitalization study, GIS was only used to plot resident survey data. However, the ability to plot primary data using GIS may also benefit evaluators in other ways too. For example, one could envision how a visual representation of needs assessment data could facilitate program planning, or how a GIS plot of census information could assist in selecting a representative sample, or how GIS could be used to evaluate whether differences in perceptions vary as a function of distance from fixed points such as the U.S.–Mexico border or a toxic land fill site.

DISCUSSION

By understanding the databases that underlie the spatial representation of information, we used GIS to depict change over time, and to display impact and outcome data gathered through primary data collection. As evaluators we must find ways to present information that are easy for our stakeholders to interpret and use. Comparison of cross-sectional snap shots of data can be difficult. For the purpose of illustration, we limited our example to a small number of parcels. However, pinpointing change becomes more difficult as the volume of information plotted in a defined area increases. Our experience is that the change map is a very useful tool in conveying information about the impact of a study in a simple, visual format. Further analyses are now possible. We can consider whether change is restricted to certain clusters in space (e.g., locales). We can evaluate the relative rate of change as a function of proximity to select features—such as amenities, arterial roadways, and point-source pollution facilities. We can evaluate whether change occurs sporadically throughout a community, or if there is a contagion or spread from multiple "pockets" radiating outward. This is not quickly and easily discernable using traditional methods of conveying results, such as using tables and charts.

Databases associated with shapefiles are often not relevant to the evaluation at hand. In our study, most of the databases made available by the tax assessor were unrelated to the evaluation. However, the shapefiles (in our case parcels of land), in conjunction with address information associated with each parcel made it possible to plot data that was collected for the specific purpose of the study. Evaluators should be cautioned, however, that plotting primary data might pose an ethical problem as it may violate anonymity and confidentiality. For example, in our study we could not freely distribute our data or graphical output because responses could be linked to an individual house address. Whether the map violates confidentiality depends on the scale used. Individual address may be represented on a map without violating confidentiality as long as the scale is sufficiently large so that the addresses cannot be discerned from the map. In this way, a general picture of the distribution of the addresses of interest can be conveyed.

Although GIS has been used extensively in many disciplines such as geography, planning, epidemiology, and public health, its power to depict complex information in a simple visual format has gone relatively unnoticed in the evaluation literature. It is our hope that we have been able to demonstrate the utility of GIS in evaluation and to encourage evaluators to explore the possibility of using GIS as a tool for conveying the results of their work.

ADDITIONAL RESOURCES

National Center for Geographic Information and Analysis (NCGIA): http://www.ncgia.ucsb.edu/
University Consortium for Geographic Information Science: http://www.ucgis.org/index.html
National Center for Health Statistics: GIS & Public Health: http://www.cdc.gov/nchs/gis.htm

NOTE

1. Using the join command is critical. We explored the possibility of simply adding the change variable to the original dBASE file and overwriting it. The overwritten file imports into ArcView and

the database appears to be intact. However, the integrity of the spatial information is lost, as the change variable is not plotted to the appropriate parcel.

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