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ABSTRACT

This paper addresses the application of Geographical Information Systems (GIS), a computerized tool for associating key information by geographical location, to the institutional research function at institutions of higher education. The first section investigates the potential of GIS as an analytical and planning tool for institutional researchers. The second section addresses the opportunities for new research, as well as for revising existing research programs, both for institutional research and for other university functions. This section also considers potential obstacles to GIS implementation, both political and physical. The third section more fully elaborates on the potential applications of GIS to institutional research and includes examples of selected uses. The conclusion discusses efficacy issues for institutions considering acquiring a GIS. Contains 12 references. (DB)

Geographical Information Systems: A Tool for Institutional Research

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Geographical Information Systems:
A Tool for Institutional Research

Geographical Information Systems (GIS) is a tool for associating key information by geographical location. There are those who feel that the impact of GIS on Institutional Research will be comparable to the impact of computers on research in the social sciences during the last three decades. GIS allows researchers to link data from disparate sources, which allows for the systematic analysis of issues that had previously been viewed in a haphazard manner. This new face of information technology has the potential to revolutionize the way certain aspects of Institutional Research are carried out.

Many colleges and universities are making substantial investments in GIS. The systems are designed to store, interrelate and display large amounts of spatial information which can assist institutional researchers in fulfilling their traditional responsibilities. Because GIS uses geographical data, it can be used to plan the locations of satellite campuses, to determine sites for course offerings which will make the most of student demand, to recruit new students, and to maximize fund-raising efforts.

Before such potential can be put into practice, however, substantial time and resource commitments to GIS must be made. The complexity of GIS applications far exceeds the needs of the typical Institutional Research user. Thus, a strategy that adjusts this technology to reflect organizational factors is required for successful GIS implementation. And while there are many spatially oriented issues handled by institutional researchers, there are also many obstacles to implementing a successful GIS application. Data, hardware and software needs differ among the various components of a college or university. In addition, often the complexity of the system and its uses makes it difficult to convince decision makers and administrators that the benefits of GIS will outweigh the costs of purchase, start-up and maintenance.

The three sections of this paper will deal with the application of GIS to the Institutional Research function. The first section investigates the potential of GIS as an analytical and planning tool for institutional researchers. The second section addresses the opportunities for new research, as well as for revising existing research programs--both for Institutional Research and for other university functions. It also addresses potential obstacles to GIS implementation, both political and physical. The third section more fully elaborates the potential Institutional Research applications of GIS, and includes examples of selected uses. The conclusion discusses efficacy issues for institutions considering acquiring a GIS.

I. GIS as an Analytical and Planning Tool

It has been estimated that about 80 percent of all information held by government and private businesses is geographically referenced. This includes not only census data, but also utility networks, telephone directories and systems, mailing addresses, and land-use information (Franklin, 1992). GIS and the field which spawned it, Geographic Information Management, seek to make use of this spatial information in order to discover correlations which were previously difficult or impossible to calculate due to technological limitations. Perhaps more than any other application, GIS represents a "computer package," comprising "not only hardware and software but also people, personal skills, operational practices and corporate expectations" (Campbell, 1991, p. 216). Thus the GIS package is not envisioned as an independent entity, but as something which is integrated into the human and institutional milieu in which it is located.

While some types of spatial analysis may be performed *without* GIS, in many cases GIS will be able to provide certain insights which would be missed if the data were not analyzed within GIS. Because GIS allows the linking of data from disparate sources, it can allow for improved understanding of the way certain variables play out in different environments and communities. For instance, GIS would allow for an examination of alumni gifts based such factors as the geographical distance from campus of the alumni's residences. In this case, it could be discovered whether in-state or out-of-state alumni are more likely to give, or whether high-level givers are concentrated in particular geographical areas--thereby allowing for more explicit targeting of the planning of alumni events.

GIS allows two different levels of data integration: relational integration and geographic integration (Welte, 1993). Relational integration creates relational links between databases--that is, links among data points are made based on commonalities of attributes. This type of integration forces the researcher to make connections which otherwise may not have been made. For example, demographic census data could be linked to student demographic data, allowing higher education officials to better plan activities and services which will both attract and retain students. Geographic integration acknowledges that data points may impact each other because of a geographical relationship. For instance, when assessing a potential cohort of students or of participants in continuing education programs, whether people in these sets choose an institution may be related to such variables as the proximity of a competing educational institutions, and geographic variables such as ease of access via public transportation and interstate highway.

Before making an institutional commitment to GIS, researchers should conduct an information needs assessment (INA) to determine the extent of GIS' applicability to current and future information functions. Berry (1994) suggests that researchers conducting an INA first envision institutional uses for GIS in terms of finished products, such as campus maps which highlight the proximity of restaurants, shopping and public transportation. Researchers then trace backward to determine the intermediate steps, the data, and the hardware and software needed to accomplish the product. The process has four steps:

1. List the application areas that GIS might contribute to.
2. For each application area, describe specific GIS outputs to include a sketch and legend of the final map.
3. For each final map, determine its base maps by successively deriving its supporting maps (with sketch and legend) and the GIS analysis tools needed at each step.
4. Construct two tables summarizing the number of times each base map and each GIS tool are referenced in the various proposed applications.[1]

The difficulty with the process is in getting a non-GIS literate group to envision what they need, and what GIS could do, rather than simply reiterating what they already produce. In order to accomplish this, a degree of information-provision and training for target users would be appropriate in steps 1 and 2. The costs of this investment may be offset later by building a vested interest in GIS among this group, and by forming the beginning of a support coalition which may be necessary in later stages.

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[1] Berry (1994), p. 22.

The INA is then followed by a GIS reality assessment, or GRA. The process has three steps:

1. Develop an implementation scenario for meeting the GIS products identified in the INA process.
2. Determine how and how much it will cost to acquire the data and capabilities implied by the scenario.
3. Repeat steps 1 and 2 until a "realistic" implementation plan emerges.

It is during this process that the ideas of what GIS could do are transformed into an implementation strategy which fits the institution's available resources, as well as its political and social culture.

One of the major objections to purchasing and installing a GIS is the cost. In recent years, however, the costs of both hardware and software for GIS has dropped. GIS software is available both for workstations and for personal computers (PCs). Both IBM- and Macintosh-compatible PC applications are available--and many applications for Windows NT have just been and are being developed--thereby allowing access through existing computers in many office environments (Franklin, 1992). And the availability of moderately priced ready-made data sets is increasing. For instance, the U.S. Bureau of the Census has just lowered prices for their Topographically Integrated Geographical Encoding and Referencing (TIGER) maps more than 50 percent. These digital, county-level maps are updated to the 1990 census and contain every street, block and address in the United States (Lang, 1993). A number of privately produced geographic maps are also available, as well as data sets with demographic, housing and spending patterns. There are often many vendors offering the same or similar information, so it has become markedly easier to find a better data set "fit"; the competition is also helping to keep prices relatively low.

But as Bikson's 1987 study of the introduction of computers to public and private organizations finds, success in introducing such technological innovations as GIS may have more to do with organizational factors than with technological ones. For instance, if the organization is marked by a strong mission to implement GIS, multiple channels of communication (in both the development and the use of GIS), and opportunities for training, then the organization is more likely to implement the technology effectively and to initiate uses which fit the needs of the workplace. Indeed, the more complex and important planning tasks will need a GIS which is comprehensive, multipurpose and multiuser. This may prove to be beyond the organizational prowess of an institution, and may disrupt existing power relationships. Due to the somewhat fluid nature of higher education administration--especially at state institutions--it may also be difficult to interest certain programs and offices in a long-term, comprehensive system. An additional impediment to coordination is that a multipurpose GIS "requires common data standards, software, and agreed-upon management and access principles for all who provide or use data" (Innes and Simpson, 1993, p. 232). When a multiuser GIS is planned, the different software and hardware needs of the departments and programs which will use the GIS must be taken into account.

In addition to the set-up and maintenance costs, GIS also requires expenditures for training, and staff time for input and analysis. This may exceed the anticipated cost reductions for the first few years, and may cause support for the GIS to diminish or to disappear. It is therefore important for institutional researchers using GIS to make clear linkages between the costs and

benefits of GIS, both in their own work, and in work done for others. In this way, users and consumers of GIS can be mobilized into a political constituency which will help to ensure the continued funding of GIS. Potential components of this constituency will be addressed in the next two sections.

II. Opportunities for GIS Research

The atmosphere of higher education presents at once many opportunities for GIS use and many potential roadblocks. GIS applications may be utilized in academic, administrative and planning situations, thereby providing a potentially diverse base of users. Yet in comparison with governmental and private-business GIS users, educational institutions are not as able to disperse the start-up and maintenance costs of GIS. Therefore concerted efforts must be made to mobilize all potential users of GIS within an educational institution to maximize cost dispersal, and to create and maintain demand for its services. The previous section included some examples of potential uses for GIS. This section will expand upon those, as well as present other uses both for institutional researchers and for other institutional users.

Institutional researchers may be one of the largest and most easily identifiable institutional users of GIS. The nature of the institutional research function lends itself to the gathering, processing and analyzing data, then disseminating the resulting information. Applications which can facilitate this process are and will continue to be in demand. Institutional researchers can use GIS to augment traditional projects, such as studies of retention and graduation rates, and analyses of student and faculty demographics. In addition, GIS can help to introduce new or to enhance existing research projects. Identifying potential student cohorts for recruitment efforts, for instance, can be much more effectively performed with a GIS. Students can be identified not only by the geographic location of their residences and/or high schools, but also by the location of their workplaces, by their access to public transportation and highways, and by the density of an institution's students in their neighborhood and/or workplace. This information can then be cross-referenced by the geographic proximity of the students' residences and workplaces to other colleges and educational providers in order to determine competition.

Because GIS allows researchers to look at the geographic locations of the homes and workplaces of students, then to further stratify that data by college or academic program, it can be instrumental in schedule planning. These types of calculations may allow for more efficient planning of course offerings at satellite campuses, as well as more efficient timing of courses throughout the day. By linking census demographic data to existing student demographic databases, new insights can be gained as to the composition of the student body. Instead of just knowing an institution's percentage of minority students or their retention rates, GIS analysis of census demographic data would allow an institution to determine whether minority students from specific schools or neighborhoods are more likely to attend and/or to be retained.

In addition, the tracking an institution's graduates by such indicators as place of residence and workplace can help to determine local alumni support for events and clubs. The ability to mobilize significant numbers of alumni in a given area can enhance the institution's marketability, most notably in recruitment. And while alumni contributions have traditionally been linked to current salary, academic major and gender, GIS would allow for an examination of alumni gifts based also on the geographic distance and other factors. In addition to discovering whether in-state or out-of-state alumni are more likely to give, GIS analysis could determine whether high-level givers are concentrated in particular geographical areas--thereby allowing for more

explicit targeting of fund-raising campaigns, the positioning of local alumni clubs, and the location of alumni events.

Other institutional users may find GIS uses which supplement existing projects or aid in providing new services and functions. College and university administrators may use GIS to develop campus and neighborhood maps for use during orientation and student recruiting. These maps may include not only the location of campus facilities, but also the location of fast-food outlets, laundromats, shopping, houses of worship, location of public transit and parking. Maps may even be targeted to the needs of specific student groups, such as those living a mile or more from campus and commuter students.

Several institutions have had success in supplementing their academic programs with GIS projects. GIS could have instructional uses in such programs as health care, marketing, and planning. It could also be used to determine appropriate advertisers for student publications. Many institutions have formed successful partnerships with city and/or county governments for the conduct of research. Such partnerships use GIS to do everything from government planning projects, to helping to orchestrate big events, such as the Olympics. Students can conduct land-use studies, environmental impact reports, analyses of traffic flow patterns, and even natural-disaster abatement projects.

One potential difficulty with GIS analysis is that certain GIS datasets contain large quantities of spatial data which has been collected at different time periods (for instance public health records and satellite mapping). Such data needs to be monitored and examined for spatio-temporal variations in order to avoid faulty causal linkages. There are other potential data problems, as well. Depending on the data set an institution invests in, the geographical data may be too vague or nonspecific for certain types of research. For certain projects, such as retention or transfer studies, an institutional researcher may need to know factors other than those contained in the data set. And certain types of data may be politically sensitive and/or unavailable, making it difficult or impossible to make some comparisons. For instance, many private colleges do not release faculty salary or student demographic data, making it difficult for other institutions to assess their competitiveness vis a vis the private institution. It is extremely important that initial research be done before purchasing any data sets--not just on the extent of the information included in the set up, but also on all potential variables a researcher might need for the projects which will utilize the data set.

The expense of GIS set-up may be also become a problem--especially for financially strapped institutions. While there are PC versions for GIS, they are slower to process information and have limited applications. A potential problem with GIS for Windows NT is that the initial versions require at least 16 megabytes (MB) of random-access memory (RAM) to operate--some require as much as 32MB. This may be more memory than many standard office PCs have. Newer versions requiring less memory are currently being developed, and will not be available until the end of 1995 ("Microsoft Windows," 1994). At this point, only UNIX workstations are able to take full advantage of the services GIS has to offer. An additional problem may surface once researchers begin producing maps with GIS. Certain highly detailed maps including data from one or more sources may be difficult to laser print on current office printers. Printers with as much as 5 megabytes of RAM can experience delays of up to an hour in printing such maps. Depending on the number and frequency of map production, it may be economical for an institution to invest in a high-memory laser printer.

Thus large initial expenditures for hardware, software and training may be difficult for decision-makers to authorize. And continued funding for maintenance and new projects may

also be difficult to attract--especially if it is discovered that the system, or an expensive program, is not being fully utilized. In order to take full advantage of GIS, there needs to be a group of people who already know how to use it and to apply it to their courses. In most cases, it is unlikely that this group of people will already be resident at an institution. An influx of highly trained personnel may upset existing power structures within an institution. Their central role in GIS administration and management may result in turf protectionism and power-politicking--an environment not conducive to the smooth implementation and continued funding of GIS projects.

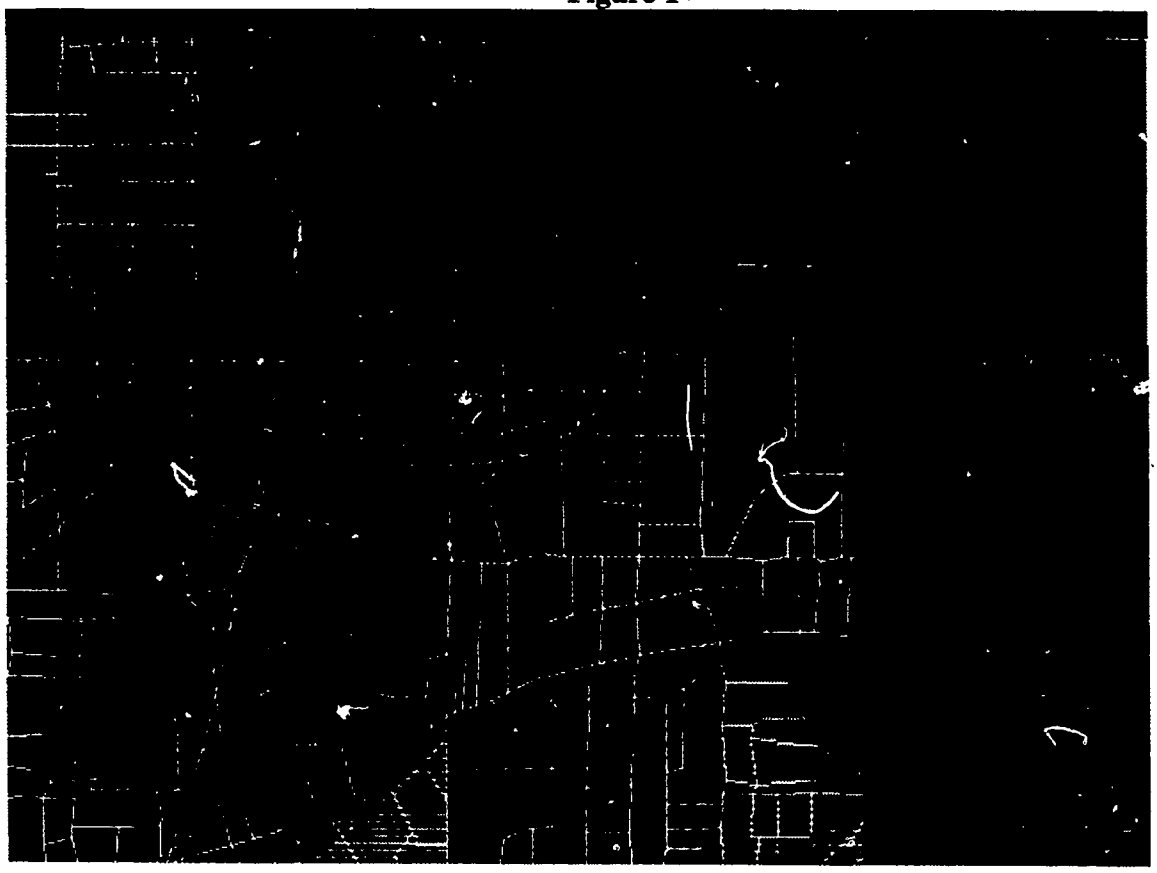
III. Institutional Research Applications for GIS

As previously stated, Institutional Research is one of the most easily identifiable institutional users of GIS. Information clearinghouse activities are a key component of Institutional Research. With a little advance planning, staff training and time investment, institutional researchers can use GIS to update their existing studies and analyses, and to gain new insights into time-honored concepts. The integration of various data sources and databases on a spatial basis would enhance the available information for institutional planning and decision making. Thus, GIS analysis can significantly expand the role and viability of the Institutional Research function. In this section, the potential for GIS to expand the researcher's analysis of student demographics, schedule planning and alumni participation will be considered in-depth.

Student demographics. As the recession of the late 1980s and early 1990s has slowly abated, institutions are looking beyond the fiscal triage of short-term cost-cutting measures, and searching for long-term ways to increase financial stability. One way attractive to many is aggressively seeking to increase enrollments through more active recruitment strategies. In years past, institutional researchers have been at the forefront of this effort, helping to identify key sources of students (such as specific high schools and junior colleges), as well as assessing the performance of the students once they enter the institution. These functions continue to be important and to be a cornerstone of recruitment and retention efforts. GIS can help in this process, however, by bringing added clarity to variables which had once been considered unidimensional. A GIS approach to student recruitment could achieve several goals: ensuring a diverse student body; maximizing the productivity of the recruitment process; and expanding into previously underutilized student markets.

By combining student demographic databases with U.S. Census demographic databases within a GIS, institutional researchers can look at other factors which may influence students' decisions to attend an institution, and their success once they are there. A database with a ZIP+4 feature will allow researchers to position students within three blocks of their residences; a more specific database with street and house information will allow researchers to position students exactly. In this way, areas which consistently produce promising students can be identified for recruitment efforts. Other areas with potential to be key sources of students can be earmarked for special recruitment efforts. Census data provides limited insights into students' household incomes, as well. The first step in accomplishing any of these studies is for institutional researchers to combine their student demographic database with the appropriate census-type demographic database, such as the U.S. Census' TIGER databases. Figure 1 shows a sample neighborhood chart drawn with TIGER data. It gives a basic demographic breakdown by census block group, including by age, race/ethnicity and household type.

Figure 1



Researchers then could identify each of their students on the census data; this would allow an analysis of the residential locale of each student. The researcher would then be able to answer questions such as: Is the student an isolated incident in that geographical area? Are they typical of the other students from that area? Are they typical of other residents of that area? Since students are known to move frequently, researchers could monitor this activity to determine whether students move further from campus, move closer to campus, or execute distance-neutral moves. The results of this analysis could have applications in planning and analyzing student housing, shuttle bus services, parking, and class scheduling and location. The census data on the general income level of students' households can provide planning data for the financial aid office on the mix of loans, grants and scholarships that are likely to be needed to recruit in a certain area.

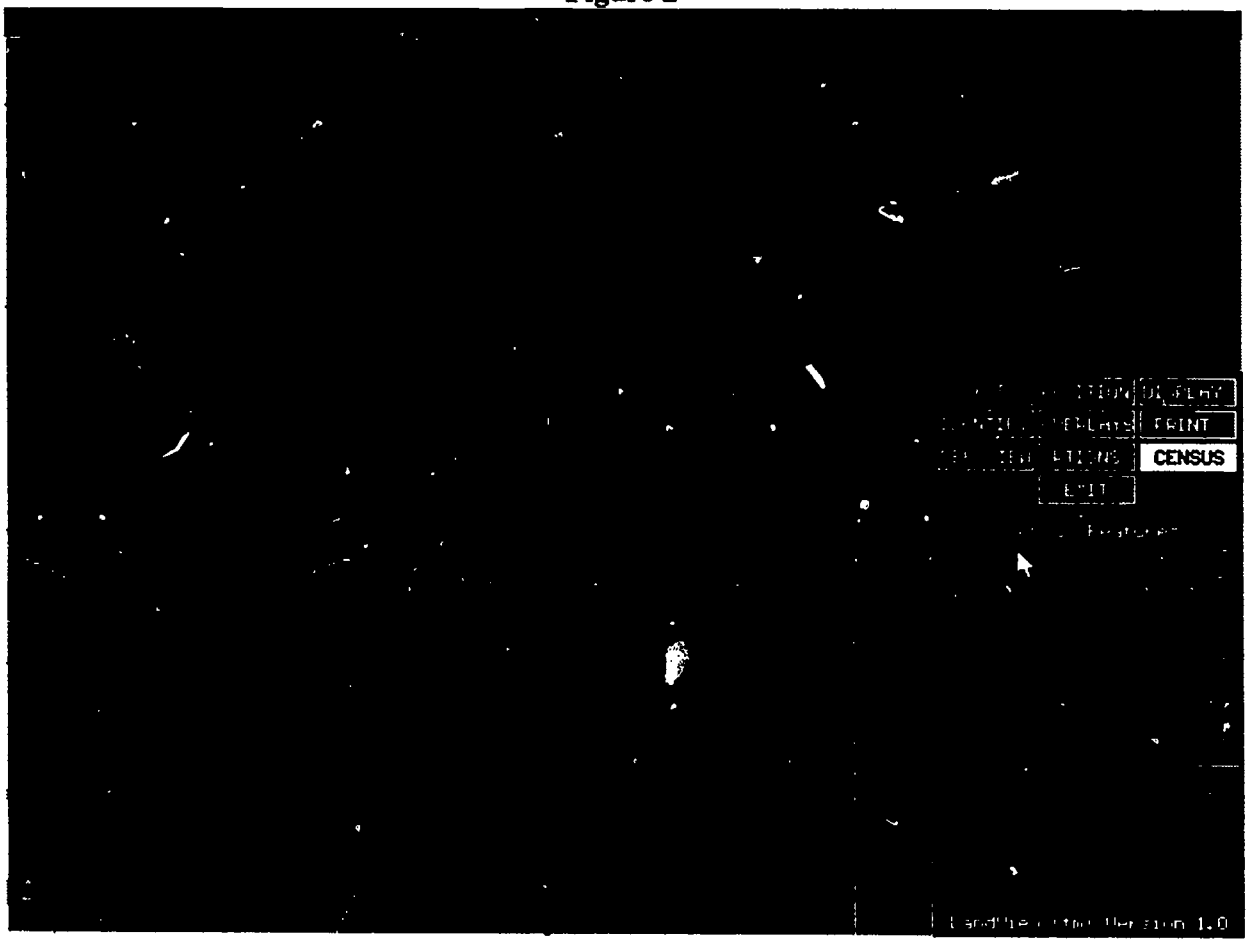
If students are more likely to be retained at an institution when they have an academic and social support network, such databases can allow researchers to pinpoint students who live or work in areas with low densities of college students. If a sizable proportion of students work as well as attend school, census data will allow researchers to more fully analyze the "triangle" of home-school-work. Targeted efforts to involve these students in academic activities may help to compensate for lack of a college-attending peer group at home or work. This matching of students with special needs (such as those in danger of not being retained, those who live and work in areas without sizable college-attending populations, and those who may be new to an area) and mentoring students can be supported through GIS analyses. GIS can help researchers more accurately to identify not only students with potential special needs, but also mentors with characteristics that match the target student's needs, including geographic proximity to the student's home

or workplace. GIS will also be helpful in assessing competing college's and university's draw on potential and attending students, by assessing such factors as the geographic proximity to home or office, ease of access via public transportation or interstate highway, and class scheduling. It can help to identify student candidates for participation in car-pool networks. If enrollment and course-scheduling information is available for the competing institution, researchers can investigate whether the availability of majors or the scheduling of courses has an effect on students' decisions to enroll or to transfer.

Schedule Planning. The variety of courses offered and the scheduling of offerings can have a profound impact on the class enrollments. In many institutions, this is based on seasonal or traditional patterns of course offerings, at times shaped by faculty preferences. While a traditional approach may have an appeal for those who enjoy maintaining the status quo, for institutions interested in maximizing enrollments, a more student-oriented approach to course scheduling may be appropriate. While a certain number of courses are required each year, such as undergraduate core courses and those required for a given major, greater specificity and targeting of course offerings can be achieved by using GIS analysis to support course-offering planning.

If it has not already been done, colleges and universities can computerize students' academic records. In this way, institutions can keep track of which core courses students have taken, which they have yet to take, and, once they declare a major, their progress through the requirements of the degree program. On a term-by-term basis, researchers can compile lists of high-demand courses, then use GIS analysis to calculate the most effective times and places for course offerings using census data on students' residences and workplaces, as well as Department of Transportation data on traffic-flow patterns. Figure 2 shows a rudimentary transport map, showing interstate and rail access routes to the university. This information can be combined with residence and workplace data from the census and other sources, then cross-referenced with university data on students' majors.

Figure 2



This process may be especially effective for institutions that offer courses at one or more satellite locations. Researchers can also compile lists of "emergency cases"--students who require one or more courses in order to graduate. In the interest of expediting the completion of these students' degrees, departments can be notified of these students' course needs, as well as the names of other students whose interests would be served by those courses. Departments would then be able to make more informed decisions on the allocation of faculty time; student advisers would also be helped by these "progress reports."

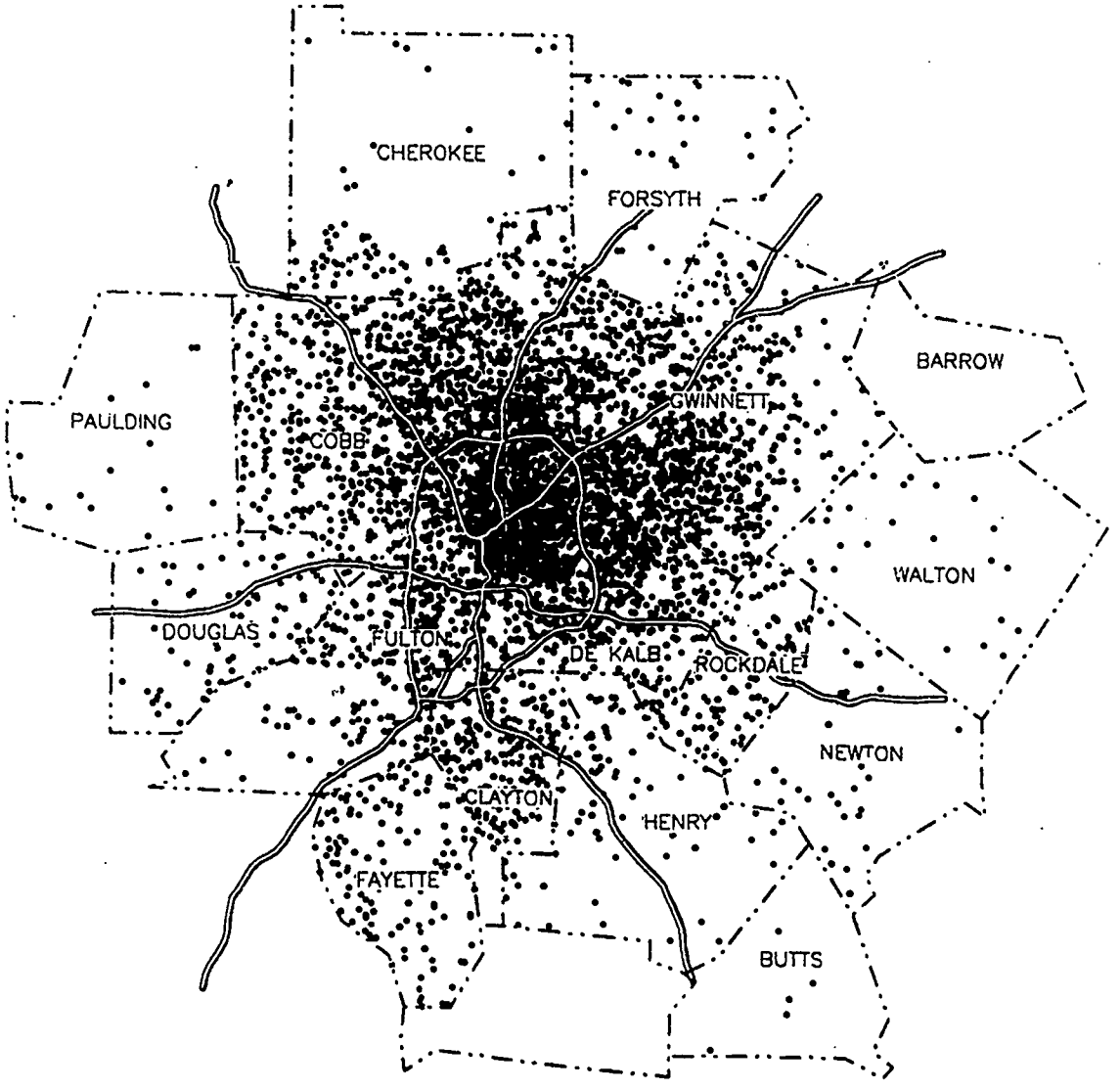
Alumni. For some institutions, the cultivation of alumni support is an important goal. Alumni support is important not only financially, but in student recruitment, as a political constituency for the institution and in attracting and maintaining public support for an institution's programs and activities. The success of capital campaigns are heavily influenced by alumni participation and support. GIS's greatest potential for institutional researchers may lie in research on alumni. By definition this group is geographically dispersed, and more likely to move from one area to another. GIS can help researchers to target the most efficient ways to maintain and enhance alumni contacts.

Through the use of census-type data combined with student and alumni databases, researchers can obtain information on alumni not only by geographical location, but also by major, type of degree, year of graduation, income level, occupation, gender, minority status, and age. GIS can show alumnus' histories of contributions, the progress of pledge campaigns, pledge

fulfillment rates, the success and productivity rates of capital campaigns, and can help researchers to make linkages between these factors and the alumnus' geographical region, location of home and workplace, proximity to the alma mater, and proximity to alumni clubs and events. The mobilization and residence patterns of new alumni and existing alumni can be compared with data on contributors vs. non-contributors. Figure 3 shows the residence patterns of Georgia State University alumni organized by ZIP code.

Figure 3

Georgia State University
Alumni by zip code, 1994



One dot represents ten alumni

This type of university-level data can be combined with census and business GIS data to plan the locations of alumni clubs and events to maximize potential participation. Information on where alumni work can be helpful in recruitment and in gaining political and financial support for the institution.

IV. Conclusions

This paper has presented several examples of how GIS could be utilized by an Institutional Research function. Depending on the institution's needs, the benefits of doing GIS-based research may likely outweigh the drawbacks. Possible benefits include:

- GIS could enhance the clearinghouse function of Institutional Research by enabling the consideration of diverse sources of data for use in planning and decision making.
- GIS applications can be used in many traditional areas of Institutional Research, including student demographics, course planning, and alumni research.
- The ability to add a spatial component to analyses may allow institutional researchers to move into new and productive research venues.
- GIS can become a major instructional and analytical tool throughout the university--in both academic and administrative departments.
- The availability of GIS at an institution may become a marketing advantage, as demand for GIS services from the public and private sectors continues to grow.

The following might be considered potential drawbacks:

- Certain GIS datasets might include spatiotemporal variations which would need to be acknowledged and corrected.
- Some GIS geographical datasets may be too vague or nonspecific for certain types of research.
- Certain types of data may be politically sensitive and/or unavailable through GIS, limiting its ability to be used in some research projects.
- The expense of GIS set-up may be also become a problem--large initial expenditures for hardware, software and training may be difficult for decision-makers to authorize.

If GIS is acquired by an institution, care will need to be taken in the implementation of the GIS and in the distribution of data produced by GIS. Those assigned to purchase and implement the institution's GIS must set aside enough money and time to ensure that a large number of persons are trained to use the system. Without this critical mass of users, interest in and support for the system could wane with the passing of those responsible for its acquisition. Those doing GIS research should also be careful to accompany their results with explanations and interpretations in order to increase awareness of GIS's utility. But for those institutions which are able to shoulder the cost burden of starting up and maintaining GIS, the long-term benefits will be significant.

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