Title
Linking Geographic Information Systems and Trip Reduction: Limitations in a Pilot Application

Author
Burns, Elizabeth K.

Publication Date
1994

Linking Geographic Information Systems and Trip Reduction: Limitations in a Pilot Application

Elizabeth K. Burns

Reprint
UCTC No. 241

The University of California Transportation Center

University of California
Berkeley, CA 94720

The University of California Transportation Center

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U.S. Department of Transportation, the California Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, Irvine, and Los Angeles; the Institute of Urban and Regional Development at Berkeley; and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in Center activities. Researchers at other universities within the region also have opportunities to collaborate with UC faculty on selected studies.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. It also publishes *Access*, a magazine presenting summaries of selected studies. For a list of publications in print, write to the address below.

University of California Transportation Center

108 Naval Architecture Building
Berkeley, California 94720
Tel: 510/643-7378
FAX: 510/643-5456

Linking Geographic Information Systems and Trip Reduction: Limitations in a Pilot Application

Elizabeth K. Burns

Center for Advanced Transportation Systems Research
College of Engineering and Applied Sciences
Arizona State University
Box 876306
Tempe, AZ 85287-6306

Reprinted from
Journal of Planning Education and Research
Vol. 13 (1994), pp. 208-215

UCTC No. 241

The University of California Transportation Center
University of California at Berkeley

Linking Geographic Information Systems and Trip Reduction: Limitations in a Pilot Application

Elizabeth K. Burns

Abstract

Implementation problems limit the contribution of new methods to transportation planning practice. This case study documents the introduction of geographic information systems (GIS) to a large employer's trip reduction program. This paper's comparative approach outlines six organizational conditions for a successful match of client expectations and GIS performance, describes the Arizona State University (ASU) trip reduction effort, and uses the six conditions to evaluate this application. When technical and administrative problems prevented a quick contribution to measurable trip reduction, the GIS effort lost employer support.

Elizabeth K. Burns is Professor of Geography and Director of the Center for Advanced Transportation Systems Research at Arizona State University, Tempe, Arizona 85287-0104 USA.

Travel-demand management policies are the focus of a national debate on ways to limit the growth of local highway congestion and improve urban air quality (Bae 1993; Orski 1990). One innovative approach, trip reduction programs, requires changes in individual travel behavior, usually in journey-to-work trips. While precise local goals and requirements vary, trip reduction programs focus on large employers who must persuade drive-alone employees to increase vehicle occupancy, limit miles traveled, and eliminate travel (Ferguson 1990).

The locational nature of many transportation planning activities makes geographic information systems (GIS) an attractive application. This innovative method has the potential to assist trip reduction marketing, education, and analysis activities. This computer-based information technology has five related components: locational data, hardware, software, personnel, and operating procedures (Epstein 1991). Integration of GIS with trip reduction can be slowed by implementation problems, however.

This paper provides a case study of limitations in a pilot GIS application. Six implementation principles provide a descriptive evaluation of the initial Arizona State University (ASU) trip reduction program. In this case study, start-up problems slow, but do not prevent, a GIS contribution to trip reduction.

■ GIS Technology and Trip Reduction

GIS clarifies locational aspects of trip reduction research. Trip reduction program requirements for yearly employee surveys (reported at the zip code or major street intersection scale) provide spatial, travel, and demographic data that can be matched with work locations. Data selection procedures identify individuals and work sites with specific characteristics, and map employee commuting areas for single and multiple work sites. Trip reduction incentives can be identified. Existing transit planning, for example, can be expanded by identifying market areas for improved bus and shuttle service. Rideshare efforts can be improved by matching the addresses and schedules of potential riders. Change in travel mode can be monitored spatially and the location impact of specific trip reduction measures can be simulated.

Implementation of GIS as part of a trip reduction program requires more than technical competence. State highway department experience shows that introducing GIS requires both technical and management decisions to make the necessary organizational changes in existing data collection, storage, and analysis procedures (Abkowitz et al. 1990). On-going technical tasks, including traffic engineering design and highway maintenance monitoring, become more efficient and additional spatial analyses can be conducted.

Journal of Planning Education and Research 13:208-215.

Introducing a new technology into a new public program creates multiple implementation issues. Numerous early policy studies document the difficulty of implementing new public programs (Bardach 1977; Pressman and Wildavsky 1973). Mazmanian and Sabatier (1981) provide a conceptual framework to understand the conditions necessary for implementation. Problem tractability, legal and statutory conditions, and other implementation variables affect the actual experience. Both the trip reduction program and the technology face start-up implementation issues.

GIS contributes to the implementation of trip reduction programs by providing information that makes trip reduction a more tractable problem. First, this technology provides appropriate technical support by identifying spatial dimensions of changing travel behavior. Although trip reduction programs focus on changing commuting behavior, these trips are only a portion of the total urban trips. However, commuting trips can be mapped and associated with individual commuters and work sites. Moreover, program progress depends on the size of the commuting group whose behavior is targeted; an ideal target group is small and easily identified. Finally, progress is even more likely if only a small amount of individual behavioral change is required.

Early implementation problems influence the later level of program activity (Sabatier and Mazmanian 1981). If start-up problems with GIS are resolved early, staff enthusiasm is likely to remain high, and strong managerial support is likely to continue. Future GIS activities will then contribute fully to trip reduction program goals.

■ Implementation Tractability

Rapid expansion of GIS use has focused attention on multiple hardware and software choices rather than implementation. This technology raises distinct tractability issues related to its ability to fit into trip reduction programs. A first concern is that technical benefits through locational analysis require organizational changes. Innes and Simpson (1993, 230) emphasize that GIS is a "socially constructed technology" whose character is determined by both human and technical systems in a particular agency setting. In their view, GIS is the most recent stage in the continuing effort to incorporate large-scale computing into state and local agencies.

A related issue is the number of trip reduction program personnel and participants who must change their behavior to accommodate GIS activities. Efforts to improve data quality for locational analysis illustrate this problem. Additional survey questions can be easily arranged for limited employee populations, while changing a survey form used by all program participants is more difficult. The more program participants and agencies involved, the more likely that implementation will be slowed or stopped.

Applications limited to a few agency staff members or a few types of analyses may demonstrate the technology's potential, but often lack broad organizational support. Clarke (1991) recommends a linear planning process to manage the introduction of widespread GIS in a large agency. The agency first evaluates the need to replace and expand current operations. Analysis and specification of user requirements are completed before comparison of hardware and software alternatives. Finally, adoption and purchase decisions are made.

The extent of retraining and reorganization is a final concern. Education of program managers and public officials about GIS is an essential step to ensure continuing support. Staff time necessary to learn new skills should not be underestimated.

■ Implementation Practice

Recent implementation evaluations identify a common situation of a GIS application that does not meet major supporters' expectations (Lyytinen and Hirschheim 1987). Specific issues include agency overambition, insufficient attention to user needs, user conservatism, and overoptimism regarding the difficulty and cost of converting existing data (Department of the Environment 1987).

For these reasons, some researchers urge caution in adopting GIS and recommend cost-benefit analyses comparing existing and future agency operations (McGuire et al. 1991). In their opinion, application problems are primarily related to "organizational weaknesses or political naivety, rather than technical factors" (McGuire et al. 1991, 9). Their view reflects the confidence of experienced users, but ignores the limited experience some agency staffers and managers have with these technical issues.

Moreover, success and failure are not precisely defined for a GIS application (Azad 1993). Failure can be narrowly defined as the inability to generate analysis and map products in a given time-period. Conversely, success can be broadly defined as continuing efforts to develop products and organize GIS activities. Implementation failure then becomes abandonment of the total effort, rather than a specific difficulty.

These evaluations suggest organizational principles to guide implementation practice. This paper uses one checklist of six factors that link a system's users and actual technical performance (Department of Environment 1987). This descriptive evaluation complements recent trip reduction program research that evaluates the measurable reduction in commuter trips (Federal Highway Administration 1990; Guiliano et al. 1993).

Geographical information is essential to operational efficiency. The recent initiation of trip reduction programs means that this new technology is being considered in management situations where policies and procedures are still being developed. While locational analysis can assist with trip reduction measures such as carpool match lists, program managers who have major employer compliance and trip reduction plan review responsibilities may not consider GIS analysis their highest priority.

The agency can afford some experimental work and trials. Flexible deadlines for system installation and production contribute to an application's success. Difficulties can be expected in hiring and training personnel, resolving technical issues, and producing draft products. Inflexible or unrealistic deadlines for GIS products may lead to disappointed program managers. Trip reduction programs, however, usually have deadlines for employer compliance that add time pressure to the activities of employers and program staff.

A corporate approach exists to geographical information and a tradition of sharing information. Sharing multiple data sets is essential if timely, complex analyses are to be completed. If all program participants have similar data requirements, trip reduction employee surveys can generate key information on commuter origins and destinations, travel behavior, and mode preferences. This information can be combined for multiple employers, can be compared to traffic conditions, and can be used in bus or shuttle scheduling. Common data standards, shared effort in coding data, and sharing regional street network files are examples of desirable joint efforts.

There is a multidisciplinary approach tradition. Trip reduction program activities directly involve economics, geography, marketing, and public relations, as well as urban and transportation planning. Program staff and managers are likely to be drawn from a wide range of professional and academic backgrounds. Locational analyses that integrate data from these related fields are likely to be used.

Management provides strong leadership and enthusiasm. If trip reduction program managers are not supportive, a GIS application will have a limited future. This support must include a budget for hiring and retraining staff and purchasing hardware and software. Hardware costs have decreased considerably in the past five years through the increased availability of personal computer–based software. Ideally, managers understand the full range of GIS contributions to trip reduction activities. At a minimum, management patience with technical experiments is essential.

There is some experience with and commitment to information technology and use of existing data bases in digital form. Managers need to be familiar with computer technology in order to have realistic expectations. A computer database for tracking employers' requirements and compliance is an essential first step that supports expanded GIS use for analysis and decision making. Experienced staff and managers familiar with computer use have a broad knowledge-base that allows easier adoption.

■ The ASU Trip Reduction Program

This case study examines one large employer's efforts to introduce GIS at the same time that a trip reduction program started. Regional trip reduction program requirements, the university's approach, and the GIS application and its contribution to trip reduction are reviewed.

The Regional Trip Reduction Program

In 1988 the Arizona legislature, responding to U.S. Environmental Protection Agency concerns about metropolitan Phoenix's continuing noncompliance with federal air quality standards, passed the Air Quality Bill (House Bill 2206) initiating the Maricopa County Regional Travel Reduction Program. This program started in 1989-90 with a large number of employer (491) and employee participants (405,465) (Maricopa County Regional Travel Reduction Program 1991). With a 1990 population of 2,122,101, this metropolitan area had moderately severe ozone levels and continuing air pollution from carbon monoxide and particulates. Arizona State University was the largest employer in the local program with 5,300 faculty and staff and 39,000 full-time equivalent (FTE) students.

This regional program's goal is an absolute reduction in drive-alone commuting. The initial legislation set a first- and second-year target for each employer of a 5% reduction in either the percentage of commuters driving alone or the average number of drive-alone commute miles (Burns 1992). Initially, only employers with 100 or more FTE employees at a single work site had to participate. The 1992 Maricopa County Trip Reduction Ordinance expanded the program by lowering this work site requirement to 75 employees. The program encourages changed commuting behavior from drive-alone trips to increased use of alternate modes of transportation, including carpooling with two or more persons, using buses, bicycling, walking, and vanpooling and trip elimination measures of telecommuting and flexible work schedule options. Yearly employee surveys monitor travel behavior using county forms that include questions on current mode of travel; preferences for incentives to use other modes; a single, preferred alternate mode; and limited demographic information on gender, occupation, and age. Residential origin and work site destinations are recorded as major street intersections on the metropolitan arterial street grid.

Employer compliance requires a good-faith effort toward achieving trip reduction goals by four program activities. Major employers must 1) conduct an annual survey of all employees, 2) disseminate alternate mode information, 3) appoint a transportation coordinator, and 4) produce a trip reduction plan stating how trip reduction measures will be implemented. School districts and universities are required to reduce student travel. The county staff focuses on educating employers to encourage compliance. Regional

Rideshare staff assist employers in developing trip reduction measures and plans. To date, no employers have been cited with civil penalties for noncompliance.

ASU Program Activities

This campus is a prominent regional destination located in suburban Tempe, Arizona. Past parking demand has been met by providing 18,000 parking spaces in multistory structures surrounding central academic and administrative buildings and by peripheral surface lots served by shuttles. Parking charges, a key factor in reducing trips, already exist. Both employees and students are charged a maximum yearly parking fee of $105. The city of Tempe minimizes spillover parking on nearby residential streets through resident-only, on-street parking permits. Students who live near campus rely on bicycling and walking.

From 1988 to 1990, ASU delayed participating in the county program. Legal and administrative objections included the university's autonomy under the State of Arizona Board of Regents, the new costs of survey administration, and the difficulty of designing effective trip reduction measures for the large employee and student populations. The initial legislation was considered unfair for requiring a reduction in student commuting trips. If students were considered to be customers coming to campus for educational services, the university administration's position was that other service employers should also be required to regulate their customers' travel. A series of confrontations took place between county staff and university administrators. County officials, charged with implementing state law, took the position that the university had to participate in the program.

The university's program began after the new university president demonstrated his support by being photographed riding his bicycle to campus. The program was initially administered as an outreach activity through the Office of the Vice-President for University Relations. A key administrator, the acting provost, understood that travel behavior research was needed to support marketing and educational activities. With his influence, the campus transportation research center received a 15-month contract (April 1990 through June 1991) to develop specific travel reduction measures and write the required plan.

The project team of geographers and transportation planners developed a linear planning process intended to select a rational set of measures most likely to produce measurable trip reduction. Current travel information was provided by county staff from employee and student surveys. Telephone interviews identified the range of costs and services provided by parking and trip reduction programs in other comparable western universities. A comprehensive set of trip reduction measures was developed by reviewing current literature. A GIS application was authorized to analyze the survey data for specific measures, including carpool matches, bicycle lanes, and an off-campus shuttle service.

The campus trip reduction plan incorporated employee preferences for bus and carpool measures and student preferences for carpool and bicycle measures. Fifteen measures were recommended in a program budget based on high per capita estimates. The project team assumed that travel behavior would change only if improved facilities and monetary subsidies for alternate mode use were substantial. University administrators, however, eliminated all measures that the university could not directly control and all measures requiring substantial costs. Subsidized bus passes were eliminated because the university could not ensure improved regional bus service. A low-cost measure allowing carpoolers to purchase reduced-price parking decals was retained in the plan. A telecommuting pilot program was included for employees who already had computer equipment in their homes and required no additional capital expenditures. Alternate employee schedules of four-day, ten-hours-per-day workweeks were strongly encouraged.

ASU met the regional trip reduction program compliance requirements when the employee plan was completed in August 1990. The final plan was submitted in January 1991 after being revised to include student survey analyses.

The GIS Application

This effort had two purposes: research support for trip reduction activities and direct assistance in increasing carpooling and bicycle use. Once the university began participating in the county program, administrators and the project team expected that a high-quality effort using university research strengths would serve as a model for other metropolitan employers. Mapping the present and potential markets for specific alternate modes was expected to support the combined efforts of the Regional Rideshare agency, the city of Tempe, and the university to establish a

	Employees		Students Who Purchased Parking Decals	
	1990 (19,157)	1991 (16,019)	1990 (40,097)	1991 (49,008)
Drive alone	71.4	71.3	77.6	76.5
Carpool	11.4	11.7	5.9	7.1
Bicycle	9.1	9.4	5.8	5.3
Bus	2.4	2.3	1.0	1.0
Walk	3.3	2.8	6.6	7.2
Motorcycle, Vanpool, Work at Home	2.4	2.5	3.1	2.9

Table 1. Arizona State University commute mode split (n=trips per week).

joint carpool matching list. The county program did not have the staff or the technical resources in 1989 through 1992 to develop its own GIS applications.

Data quality problems limited the initial activities. The database of travel, demographic, and locational characteristics included 3,825 employee surveys completed in April 1990 and 9,344 surveys from students who purchased parking decals in August 1990. The student survey approach was a university proposal accepted by county staff to minimize campus survey costs for the first two program-years. This approach understated the full extent of student alternate mode use, incompletely reported residential locations, and overstated drive-alone commutes. University administrators did not support, until 1993, the alternate survey approaches of a student census or a random sample.

The ASU plan was based on these incomplete 1990 survey results (Table 1). Baseline drive-alone employee commute trips were 71.4% of all trips per week; carpool trips, 11.4%; bicycle trips, 9.1%; and walking trips, 3.3%. Automobile-dependent students who purchased parking decals drove alone for 77.6% of their trips per week, a slightly higher rate than the drive-alone employee rate. These students also carpooled (5.9%), used bicycles (5.8%), and walked (6.6%). Bus use was only 2.4% of employee trips and 1.0% of student trips. A lower employee response rate and a higher student response rate in the second annual survey changed the number of reported commute trips.

Early technical decisions contributed to delays that disappointed key administrators. Maps were not ready to submit with the final trip reduction plan in January 1991. When the project started, International Business Machine's (IBM) *Geographic Facilities Information System* software was already analyzing trip reduction survey data sets of up to 2,500 cases for other research projects. This software allows point-to-point and network analysis useful for the physical networks operated by utility companies and is appropriate for transportation planning. IBM eagerly supported this new application by making ASU a field test site for its

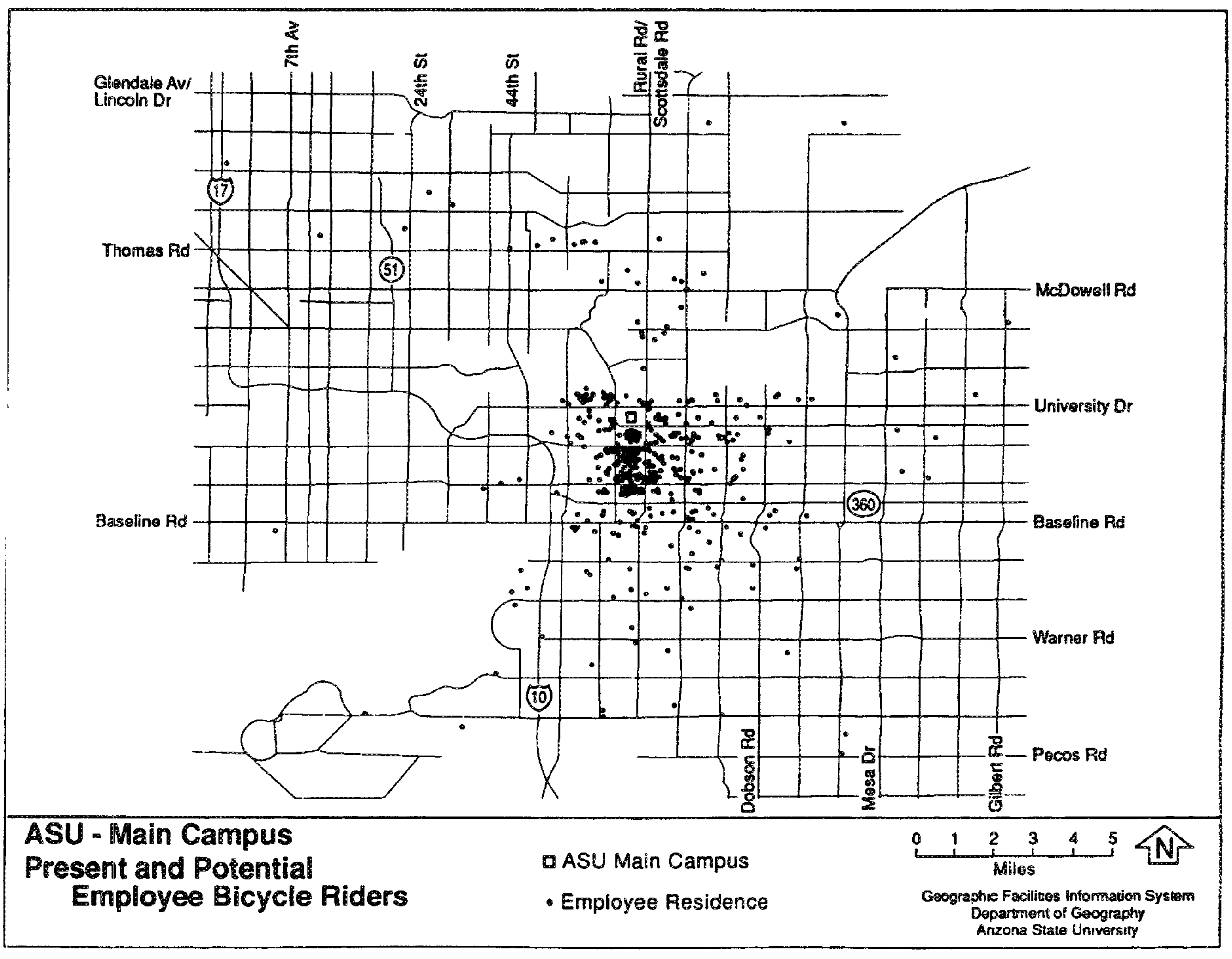

Figure 1. Combined residential locations of present and possible future employee bicycle riders, ASU 1990.

geoManager relational database program. This program was installed on the university's mainframe computers and was used with IBM's *Graphics Program Generator* software to generate graphics.

The disadvantages of using already-existing softrware became evident. County staff optically scanned the surveys onto a computer tape, with residential origins and the campus destination in alphanumeric characters. Data screening by the university project team eliminated surveys with inaccurate or missing major street locations—20% of the total cases. An address-matching program was required to associate each employee's data with the correct residential origin on the metropolitan street network. Computer consultants did not deliver this program until May 1991. A student team then finished digitizing origin and destination locations in late June 1991, leaving little time for analysis before the end of the contract period.

The application's first maps were aggregate carpooling and bicycling analyses prepared for the university's second trip reduction plan completed in June 1992. Figure 1 (employees) and Figure 2 (students) show the residential locations of current bicycle riders and present drive-alone commuters who reported a willingness to bicycle. University administrators felt that these maps showed county staff that considerable time and money were being spent on in-house research.

Contribution to Trip Reduction

Specific trip reduction benefits from the GIS application are limited, although research uses of the survey data continue. The 1992 employee survey included demographic questions on marital status, number of vehicles in a household, and age of children; these data are used to support the campus guaranteed ride home program and child-care center.

Improvements in local bicycle travel were partially based on the location of present and potential bicycle users (Figures 1 and 2). An estimated 15,000 bicyclists come to

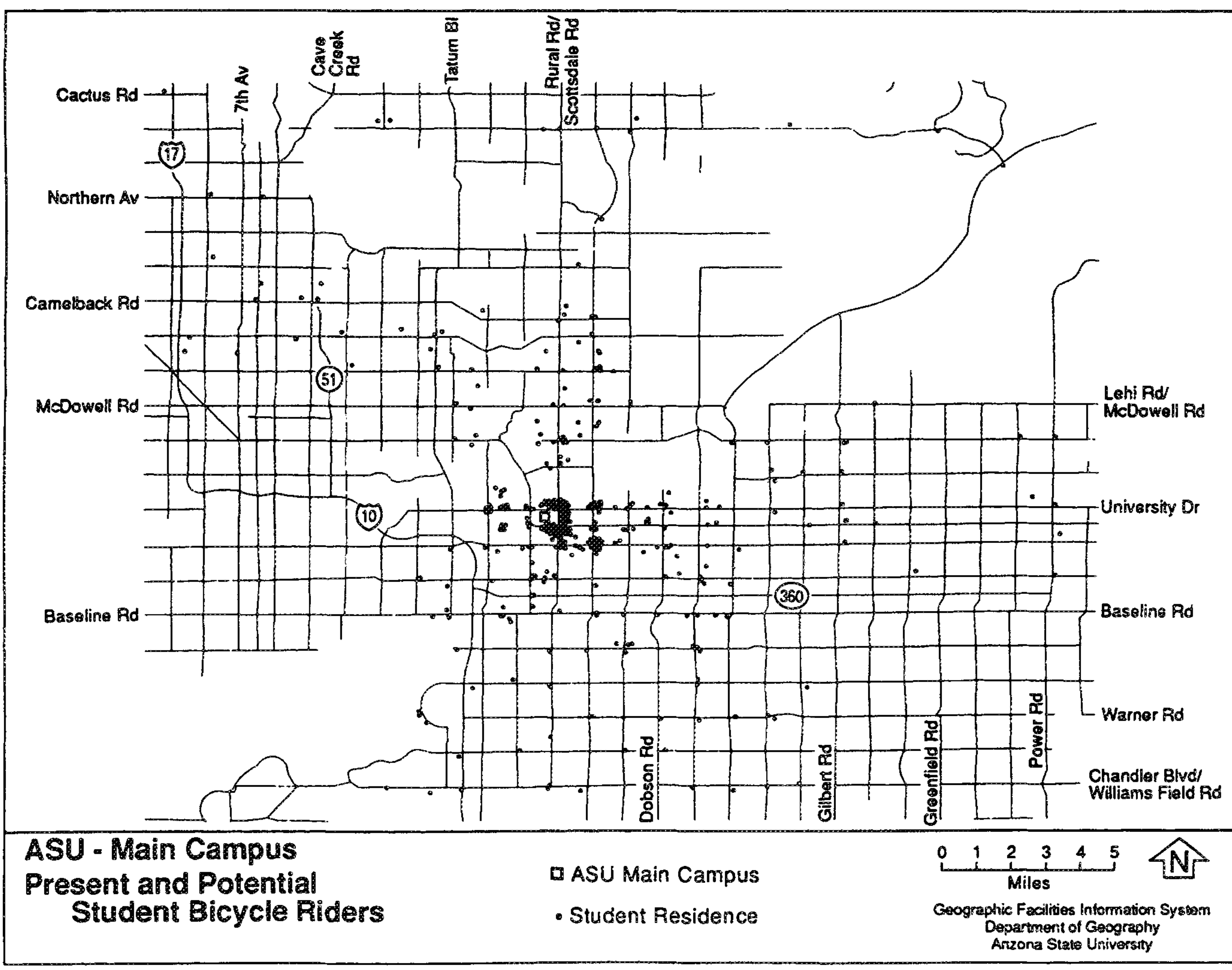

Figure 2. Combined residential locations of present and possible future student bicycle riders, ASU 1990.

campus daily. Campus physical plant staff and the city of Tempe worked together to add bicycle lanes on existing streets (Figure 3). Traffic probes (buttons mounted at bicycle height on street sign poles) allow riders to trigger a traffic light change. Both actions improve access to and across arterial streets for riders traveling to neighborhoods east and south of campus. To date, no joint carpool match effort has been conducted with the city of Tempe.

Changed requirements make the county program less burdensome to university administrators. The 1992 Maricopa County Trip Reduction Ordinance now requires an employer to show progress over a period of five years toward a drive-alone rate of 65% both for commute trips and average drive-alone vehicle miles traveled. An August 1993 random survey of 3,260 students documented a low drive-alone rate (47.0%) and high bicycle (21.3%) and walk (20.4%) trip levels. The ASU trip reduction program will focus on reaching and maintaining this low student drive-alone rate in the future.

Lessons Learned

The six implementation guidelines discussed above explain the limitations of this ASU pilot application.

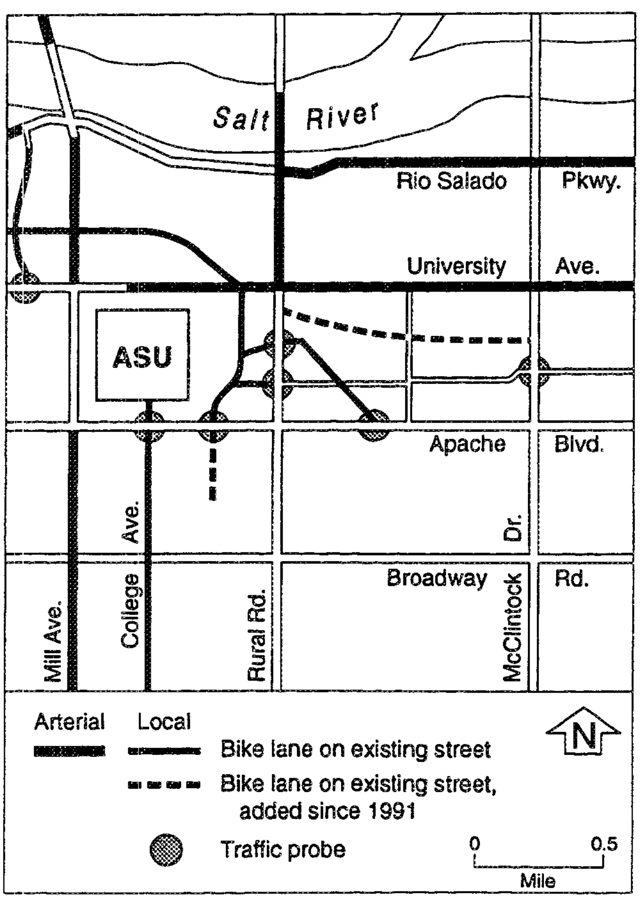

Figure 3. Bicycle lanes near ASU main campus.

Geographical information was not essential to operational efficiency. ASU was in compliance with the county trip reduction program because participation requirements were met, not because GIS contributed to measurable trip reduction. The university was considered to be making a good-faith effort, even though trip reduction goals were not achieved. From 1991 to 1992, drive-alone employee commuters decreased by only 0.53%; students drove alone for 1.4% fewer trips. Average drive-alone vehicle miles increased 1.39% for employees and 3.11% for students.

University administrators did not support experimental work and trials. Short time-lines for plan development and trip reduction implementation made an immediate GIS contribution difficult. Both university administrators and project staff had unrealistic expectations about the speed with which initial maps and analyses could be developed. Although technical problems are now resolved, top-level administrators remain cautious. Funding is low and GIS activities are peripheral to the full trip reduction program.

A corporate approach did exist to geographical information. The Maricopa County Regional Travel Reduction Program shared survey information in a digital form that minimized data transfer problems. County staff did not screen the data for residential location errors that had to be removed before locational analysis. ASU and local agencies have agreed to adopt the same microcomputer software package, but different data coding standards limit the sharing of data sets.

A multidisciplinary approach on campus was not successful. Project staff focused on detailed technical research for trip reduction plan preparation and locational analysis. University administrators viewed trip reduction as a marketing and education effort requiring only the minimum analysis to achieve county program compliance.

Management provided varying leadership and enthusiasm. The university's reluctant participation in the regional program provided a weak basis for the ambitious technical effort. Once the campus program started, administrators provided budgetary support for plan development and research. Early management enthusiasm waned as mapping delays continued.

There was limited experience with information technology and use of existing data bases in digital form. In retrospect, a microcomputer software package could have been adopted immediately. Positive experience with the existing mainframe software led to overoptimism that technical problems related to the large data sets, address matching, and digitizing could be quickly solved. This decision would have required learning to operate new software to produce GIS products for the January 1991 plan deadline.

CONCLUSIONS

Considerable start-up problems need not prevent continuing GIS involvement in a trip reduction program. However, the ASU pilot application resulted in lost credibility with key administrators and a low level of continued support. Campus administrative shifts created a permanent staff housed in the Office of Parking and Transit Services. This staff provides a minimum budget for GIS data entry and analysis. Early data-handling problems are now eliminated by using microcomputer software with address-matching capabilities.

This case study's lessons can be applied to other situations in which innovative methods are introduced to transportation planning practice. The six factors identifying GIS implementation issues are a checklist that can be used before, during, and after an application is completed. If early weaknesses are corrected, chances for success improve. At ASU the gap between administrators' expectations and actual GIS progress became apparent soon after the trip reduction program began, and was not resolved.

This documentation of GIS application experience contributes to the improvement of transportation planning practice. Implementation issues related to innovative methods merit careful attention on the part of transportation planners. While GIS can contribute to trip reduction programs by locational analysis, this method is not yet seen as essential to program operations. Additional case studies can refine these findings. This joint effort between academic researchers and practicing planners will increase the probability that actual trip reduction occurs.

Author's Note: *The University of California Transportation Center provided funding support for this study. I wish to thank three anonymous reviewers for their comments and Barbara Trapido for her assistance in preparing the figures.*

REFERENCES

Abkowitz, M., S. Walsh, E. Hauser, and L. Minor. 1990. Adaptation of geographic information systems to highway management. *Journal of Transportation Engineering* 116:310–327.

Azad, B. 1993. Theory and measurement in GIS implementation research: Critique and programs. Paper presentation at the 3rd International Conference on Computers in Urban Planning and Management, Atlanta, Georgia, 23–25 July 1993.

Bae, C. C. 1993. Air quality and travel behavior: Untying the knot. *Journal of the American Planning Association* 59:65–74.

Bardach, E. 1977. *The Implementation Game.* Cambridge, Massachusetts: MIT Press.

Burns, E. K. 1992. Arizona's metropolitan travel reduction programs. In *Proceedings of the National Conference on Transportation Planning and Air Quality*, eds. R. Wayson and A. Chatterjee. New York: American Society of Civil Engineers.

Clarke, A. L. 1991. GIS specification, evaluation, and implementation. In *Geographical Information Systems*, Volume 1: Principles, eds. D. J. McGuire, M. F. Goodchild, and D. W. Rhind. New York: John Wiley & Sons, Inc.

Department of the Environment. 1987. *Handling Geographic Information.* London: Her Majesty's Stationery Office.

Epstein, E. P. 1991. Legal aspects of geographic information systems. In *Geographical Information Systems*, Volume 1: Principles, eds. D. J. McGuire, M. F. Goodchild, and D. W. Rhind, New York: John Wiley & Sons, Inc.

Federal Highway Administration. 1990. *Evaluation of Travel Demand Management Measures to Relieve Congestion.* Washington, D.C.: U.S. Department of Transportation.

Ferguson, E. 1990. Transportation demand management: Planning, development and implementation. *Journal of the American Planning Association* 56:442–456.

Guiliano, G., K. Hwang, and M. Wachs. 1993. Employee trip reduction in Southern California: First year results. *Transportation Research A* 27:125–137.

Innes, J. E., and D. M. Simpson. 1993. Implementing GIS for planning: Lessons from the history of technological innovation. *Journal of the American Planning Association* 59:230–236.

Lyytinen, K., and R. Hirschheim. 1987. Information systems failures: A survey and classification of the empirical literature. *Oxford Surveys in Information Technology* 4:257–309.

Maricopa County Regional Trip Reduction Program. 1991. *Results of Companies in the Baseline and the First Compliance Year of the Travel Reduction Program.* Phoenix, Arizona.

Mazmanian, D., and P. Sabatier, eds. 1981. *Effective Policy Implementation.* Lexington, Massachusetts: Lexington Books.

McGuire, D. J., M. F. Goodchild, and D. W. Rhind. 1991. Introduction. In *Geographical Information Systems*, Volume II: Applications, eds. D. J. McGuire, M. F. Goodchild, and D. W. Rhind. New York: John Wiley & Sons, Inc.

Orski, C. K. 1990. Can management of transportation demand help solve our growing traffic congestion and air pollution problems? *Transportation Quarterly* 44:483–498.

Pressman, J. L., and A. B. Wildavsky. 1973. *Implementation.* Berkeley: University of California Press.

Sabatier, P. A., and D. Mazmanian. 1981. The implementation of public policy: A framework of analysis. In *Effective Policy Implementation*, eds. D. Mazmanian, and P. Sabatier. Lexington, Massachusetts: Lexington Books.

Comments

Observations on the Role of Computers

It is not necessary to belabor the growing importance of computers in many aspects of professional practice and research. There are also aspects of the organization of space and living which computers will change, and this, in turn, will change the setting for transport planning. I do not consider these impacts, but confine myself to the work of planning itself.

Computers will have at least two kinds of direct impact which I want to discuss here: they offer enormously increased speed and capacity, and they offer many new ways of working. In addition, they are already enhancing the independence of individuals and organizations from restrictive central management control, improving turn-around time for analysis, and reducing the unit costs of computing while increasing the demand for these "units" or services. The storage and presentation of geographic information for transport analysis is facilitated by many new systems, including GIS (geographic information system).

The increased speed and capacity of computers make it possible to undertake more analysis more rapidly. Scores, or even hundreds, of transport improvement schemes can be detailed and their impacts simulated with minimal input from planners but with more responsiveness to their needs and intentions. The obvious linkage between transport and land use can be seriously considered, as land-use simulation models and the data they need become more available, as their linkage with transport models becomes easier, and as they become more appropriately responsive to transport considerations.

Transport and land-use analysis should take up many questions which have been neglected because trying to answer them on a regular basis has appeared to be computationally too costly. Transport demand models should be disaggregated in many directions. More modes could be considered. The behavior of different classes of travelers and system users could be modeled with different parameters. In route selection, more dimensions than time and cost could be considered: safety, amenity, reliability—and many others suggest themselves. This line of analysis opens up the possibility of defining and computing many different types of alternative routes to be available for choice, beyond the present all-or-none assignment and its limited extensions. The transport demand behavior of many special groups in the population could be studied and incorporated into practical methods—suggestions include the young, the old, the functionally impaired or disabled, single parents, and households with two or more workers (especially two parents).

The preceding paragraph contains in condensed form an agenda for behavioral modeling and its applications which might take several years to digest. It is probably safe to predict that the need to move in these directions will increase rather than decline, because the rate of technological, economic, and social change is constantly accelerating, thus heightening uncertainty and the need for informed experiments in planning as well as for plans which are responsive to a variety of social needs. There is, however, a whole new dimension of computer utilization which is equally exciting and which will make a very different set of demands on the various professions involved.

The fundamental technology of transport planning has changed very little since the time of the Chicago Area Transportation Study. There, the first application of high-speed computers accomplished in a single pass the choice of route (tree tracing, to be followed by assignment), discrete choice of destinations (trip distribution with a modified gravity model), and a primitive form of representing equilibrium network congestion (capacity constraints). This was a good software technology, and it has been modified and improved just as the host machines which use this software have been technologically improved. But to some extent it may be that the software is a captive of these machines and their limitations.

These limitations are essentially those of a "von Neumann machine," which has a single processor and executes long and arduous computations tediously, one single step at a time. (These are the machines which have been mathematically analyzed using the idealized description called a "Turing machine.") The single processor is a bottleneck not only to computation but also to progress, because the only way to get increased speed from computers has been to speed up the processor's calculations and its access to memory. There is still room for progress in these