New Technologies for Household Travel Surveys

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The advent of new technologies and recent advances in travel survey techniques have marked a new era in household travel surveys. Computer-assisted interviewing (CAI) technology has been available for more than 20 years; however, its widespread use in household travel surveys is a more recent trend. The reasons for this trend include advancements in personal computers, the introduction of graphical user interfaces, and the sophistication of CAI software. Some of today's CAI software includes built-in logic that can identify inconsistencies in a survey as it is being completed. Technologies designed specifically for use with spatially referenced data (e.g., geographic information systems and the Global Positioning System) also benefit travel surveys. These technologies can result in more efficient data collection, improved data quality, reduced survey costs, and more flexible output products. This paper discusses current and potential uses of new technologies in household travel surveys. The advantages of these technologies are identified along with potential biases and errors that they may introduce into travel survey data. A discussion on possible research areas that focus on taking full advantage of new technologies is also presented.

At a recent conference on the use of data in transportation planning, it was observed that "because the effectiveness of planning depends so strongly on the existence of a good database, designing a data collection and management plan for an urban area becomes an important task in transportation planning" (*1*). Key elements of such a plan are to determine which data will be collected, which types of techniques will be used, and the reasons for collecting the data. Although data needs vary from one urban area to another, information that can be obtained from household travel surveys will continue to be critical to successful planning. Such information allows one to relate daily travel patterns and trip-making behavior to household and individual characteristics—a relationship that is the foundation for understanding network flows. Time-of-day trip making, mode choice, trip chaining, and other information obtained from surveys will continue to be vital to planning transportation systems and in formulating traffic management schemes.

Such data can be collected with a variety of techniques. Roadside interviews, postcard surveys, license plate surveys, phone surveys, and travel diaries have been used in the past to collect personal travel information for transportation planning purposes. Computer-assisted interviewing (CAI) techniques, such as computer-assisted telephone interviewing (CATI) and computer-assisted personnel interviewing (CAPI), have greatly improved the efficiency and effectiveness of travel surveys. Travel diaries combined with in-vehicle dataloggers can provide information on vehicle speed distribution by road class by time of day and length of trip. Such a combination has been used in Atlanta as part of a research project that monitors vehicle activity for air quality modeling. In addition, simple dataloggers have been used to monitor vehicle activity for 100 vehicles during a 2-week period (*2,3*). However, this experience has shown that this combination of data collection techniques is often unwieldy and makes results difficult to interpret

One of the key challenges facing today's transportation planner is to develop a cost-effective way of collecting and managing travel data, particularly with the spatial and temporal disaggregation capability that is critical to providing the varying scales of analysis that characterize effective planning in the 1990s. Two emerging technologies—geographic information systems (GISs) and the Global Positioning System (GPS)—could have a significant impact on the effectiveness and usefulness of survey data.

The purpose of this paper is to examine the use of new technologies, including advances in CATI and CAPI technologies, GIS, and GPS in household travel surveys. The following section (*a*) describes the basic characteristics of these technologies, (*b*) the advantages of using them in concert with travel surveys, and (*c*) the potential biases and errors they may introduce into data bases. The remaining sections of the paper discuss possible research areas that focus on taking full advantage of new technologies.

Computer-Assisted Telephone Interviewing

The telephone, in conjunction with computers, has been used in household travel surveys since the 1970s. Early CATI packages were designed primarily to simply "computerize" traditional paper and pencil procedures to collect survey data more efficiently. The advent of personal computers and the introduction of graphical user interface technology has brought about significant changes in today's CATI systems. New CATI systems incorporate capabilities that support nearly every phase of the overall survey process and can greatly reduce postprocessing The 1990 Nationwide Personal Transportation Study (NPTS) used CATI technology with great success; more innovative CATI tools are planned for the 1995 NPTS For example, a "trip-rostering" routine has been built into the interviewing software to reduce interview time and the redundancy of trip reporting, particularly when household members travel with each other.

There are many other examples of how CATI has been enhanced to improve the interview process. While some survey firms are using existing CATI software (e.g., Ci3 software for personal computers and Survent software for mainframes), others have developed their own proprietary software for data collection. Shanks describes a computer-assisted execution system developed by the University of California, Berkeley, with extensive survey data checking capabilities that can greatly reduce survey errors and minimize postprocessing or follow-up contacts with survey respondents (*4*). Ng and Sargent describe a specialized CATI system used in Canada that uses extensive look-up tables to assist the interviewer (*5*) On-line detailed tables of helpful information on the different working screens is key to the smooth operation of this CATI system. This feature reduces keystrokes while enhancing data quality by minimizing spelling errors.

Telephone retrieval has several benefits because interviewers can interact with responding households and can obtain clarification of data that have omissions or are not logically consistent with other answers in the survey. The sophistication of the CATI software make it possible to flag logically inconsistent responses automatically for clarification Further, telephone interviewers can clarify confusing questions when interviewees seem confused or resistant. Doing this tends to increase the response rate A number of Canadian urban travel surveys have demonstrated that with sufficient interviewer training, a relatively high survey response rate can be achieved (*5*). In mail-back surveys, for example, the respondent burden is high, especially on detailed travel survey questionnaires. Therefore, mail-back surveys can underrepresent groups that are not accustomed to filling out complex forms or are not fully literate in English (e.g., senior citizens and recent immigrants).

There are a number of disadvantages in using CATI. First, biases may be introduced in the survey sample For example, the portion of the population without a telephone will be underrepresented if other methods of interviewing are not used. Second, there is concern that telephone retrieval methods may yield fewer trips. As the number of trips to be reported increases, the tendency to underreport trips becomes more apparent. This occurs because to offset the great deal of time respondents spend on the phone, they may not report short trips. Hassounah, Cheah, and Steuart (6) describe a CATI survey of 61,000 households in Toronto in which trip underreporting was the rule for short discretionary trips and trips made during off-peak periods, and they describe procedures to correct for trip underreporting. Other CATI limitations can be attributed to the increased use of answering machines, the advent of caller ID to screen calls, and the tendency of people to avoid unsolicited phone calls

COMPUTER-ASSISTED PERSONAL INTERVIEWING

Computer-assisted personal interviewing (CAPI), similar to CATI, relies on a computing device to directly input survey information CAPI systems are used by interviewers in the field to interview survey respondents directly, either at home or at another location, such as a roadside. CAPI systems also make use of sophisticated software to make the interviewing process more efficient and to minimize postprocessing Notebook and palm computers are the most common hardware used in CAPI systems. The interface can be enhanced if pen-based or touch-screen technology is used.

The advantages of CAPI are similar to those of CATI, and results from previous surveys show that personal interviews provide the best response rate of any survey methodology currently used. One advantage that CAPI has over CATI is that it encourages the respondent to answer more fully and honestly. Facial expressions can make it evident whether a respondent is confused or insincere Personal interviews also allow the interviewer to use other survey aids in an interactive manner, such as showing the interviewee hard copy or digital maps to help clarify trip origins, destinations, or both

The major disadvantage of CAPI is cost. The National Travel Survey conducted in the United Kingdom ruled out the use of CAPI because of the cost of hardware (7). Even though hardware costs have come down considerably, the cost of face-to-face interviews is still a major consideration. Another disadvantage of CAPI is that interviewers are at risk for becoming victims of crime In some instances, two interviewers and even a uniformed police officer have been used in the survey, however, this adds to the survey cost. The challenges faced by interviewers in recruiting households is magnified by the increase in controlled access communities (e.g., country club communities). This can result in survey bias.

GEOGRAPHIC INFORMATION SYSTEMS

GISs are designed to handle spatially referenced data, such as cartographic data Such systems facilitate the storage, retrieval, manipulation, analysis, and display of large amounts of spatial data. General coverage of the topic of GIS technology can be found in Huxhold (*8*) and Antenucci et al. (*9*). Aronoff (*10*) presents a management perspective of GIS. An in-depth treatment of GIS can be found in Maguire, Goodchild, and Rhind (*11*)

For purposes of this paper, a GIS is defined as a spatial display and analysis tool for decision making that allows the user to overlay attribute data of each referenced location to produce information related to different combinations of these data. A GIS consists of a data base containing spatially referenced, land-related data as well as procedures for systematically collecting, updating, processing, and distributing these data. The fundamental base of a GIS is a uniform referencing scheme that enables data within a system to be readily linked with related data. A true GIS can be distinguished from other systems through its capacity to conduct special searches and to generate overlays that actually produce new information. This is in contrast to a large number of systems that are limited simply to graphics reproduction, such as computer-aided design and drafting (CADD) and data selection and reports, such as traditional data-base management systems (DBMSs) Even when CADD and a DBMS are linked together through a common interface, they only constitute a sophisticated computer mapping system, not a GIS. A true GIS integrates modern principles of software engineering, data-base management, and mapping theory. It provides the user a wide range of automated tools for the capture, manipulation, storage, analysis, query, and display of map and other land-related data.

A GIS comprises five basic elements:

1 Selected data about geographic locations,
2 Software to manipulate and manage these data;
3. Hardware on which the data and software are stored, input, and displayed;
4 People responsible for overseeing GIS operations, and
5 Procedures for using and maintaining the GIS.

Each of these five elements plays an essential role in the functioning of a GIS and must be fully understood before a system can be designed and implemented.

Characteristics of GIS Spatial Entities

The primary purpose of a GIS is to organize extensive and varied data into a common spatial framework There are two common methods, or data structures, that are used to organize spatial data. These are the raster, or grid, data structure and the vector, or polygon, data structure Figure 1 contains a raster map and a vector map. The raster map, which shows part of Thailand, has a 0.5-km cell size. The vector map shows a downtown area for a small town in central Georgia. These maps illustrate the differences between raster and vector data maps A raster data structure is not appropriate for use in travel surveys because it is difficult to link attribute data such as census information to a spatial object (e g. census tract)

Vector-based GISs store spatial data as points, lines or arcs, and polygons. Descriptive attribute information can be associated with each of these basic spatial entities. Thus, it is possible to query a road segment stored as an arc to identify an associated attribute such as vehicle miles traveled (VMT). More sophisticated GISs have an additional data structure, known as paths, for storing spatial information. Paths are simply a collection of arcs that are grouped into a single entity. Attributes can be associated with a path as a whole or can be linked to individual lines or arcs that make up the path. An example of a path might be a public transit bus route. A bus route in this case is a single entity (GIS path) that has attributes associated with it such as bus route ID, patronage, and schedule information The GIS path representing a bus route consists of several roadway links, each with their own set of attributes (e g , number of lanes and posted speed limit). A travel route from an origin to a destination is another example of a GIS path.

Fundamental GIS Capabilities

The strength of a GIS is its capability of manipulating and aggregating spatial data. With its robust set of spatial analysis tools, a GIS can be used to count the number of trip origins that fall within a traffic analysis zone (TAZ) (a point-in-polygon operation). In addition, a GIS can be used to proportion a census block group's attribute information to a TAZ (polygon-overlay operation) and to calculate total VMT within a grid cell (line-through-polygon

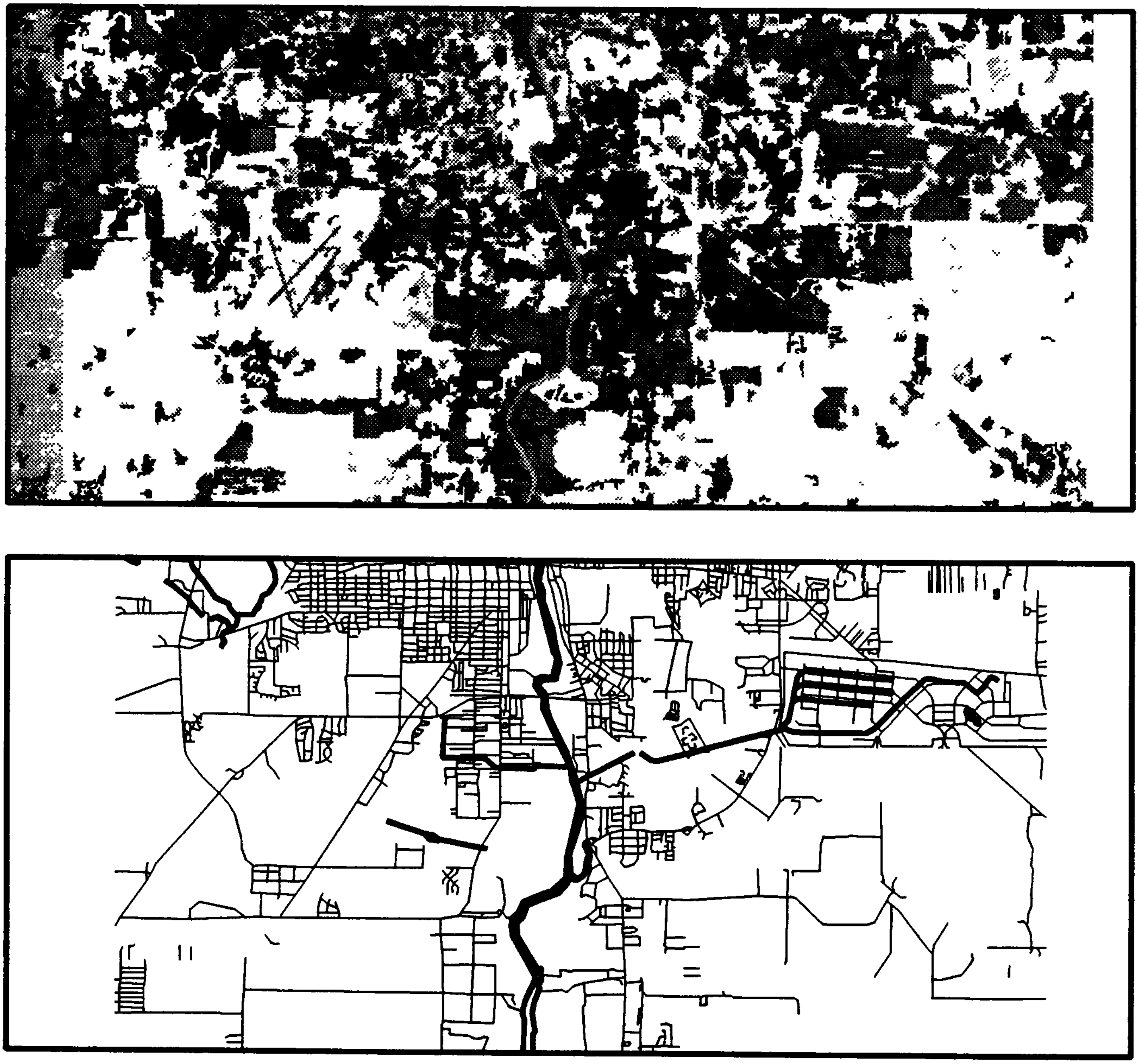

FIGURE 1 Sample raster map (*above*) and vector map (*below*).

operation). A GIS relies on the topology of its vector data structures to perform spatial analysis efficiently. Topology refers to the explicit definition of spatial relationships between entities. Thus, a roadway link "knows" what links it connects to. The importance of topology is illustrated in Figure 2, which shows how well-defined spatial relationships make it possible to efficiently calculate accurate distances through a network, perform logically consistent buffer analysis, and capture useful information about bordering or connecting spatial objects.

In addition to its spatial analysis capabilities, another fundamental GIS capability is geocoding—the assigning of coordinates to a spatial object. Address matching is one example of a geocoding operation in which the GIS is able to assign coordinates to a point entity by matching its address to an address range that is stored with street information already in the GIS data base. Through address matching, it is possible to perform a batch operation to geocode thousands of data records in a short period of time.

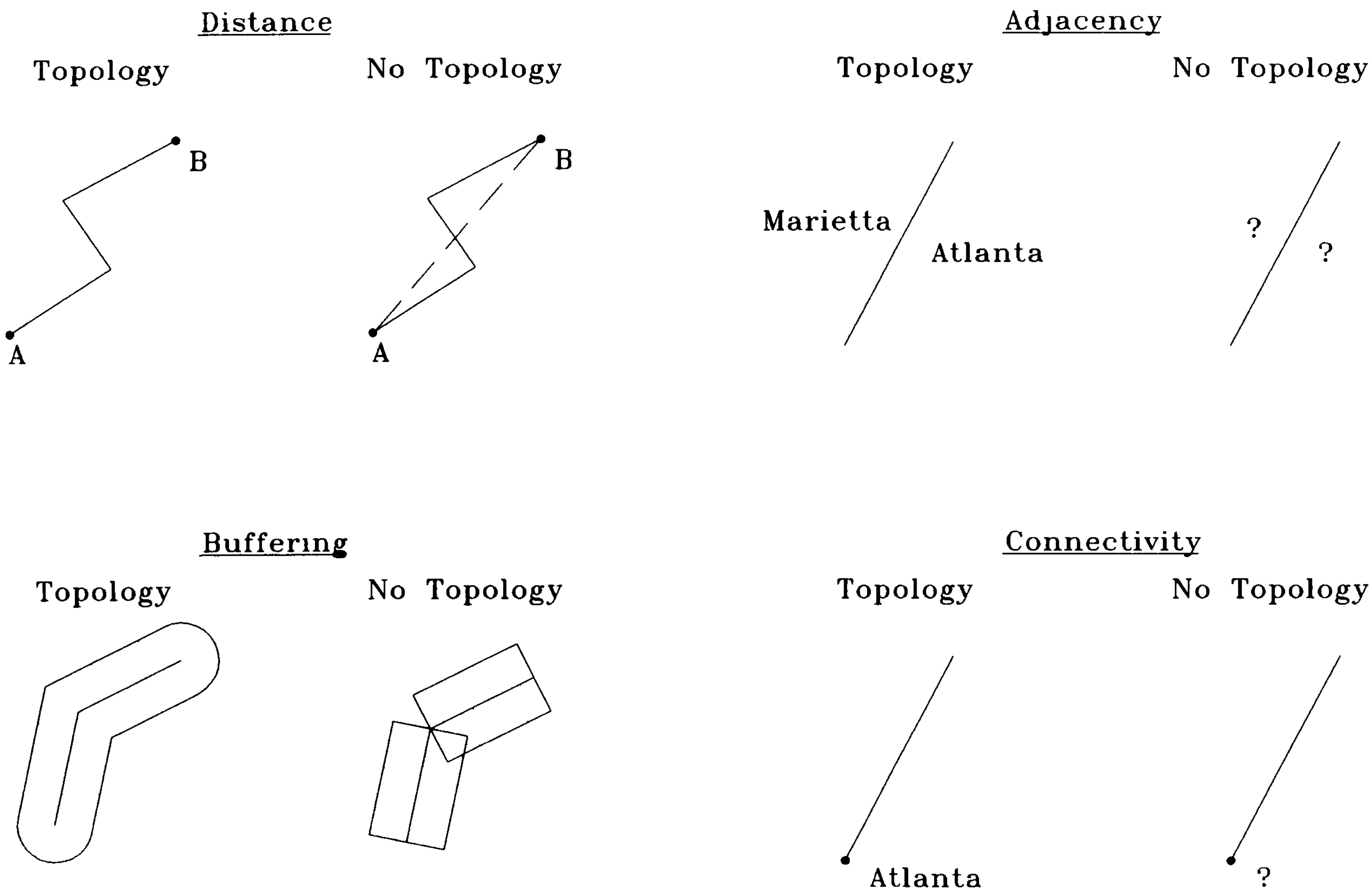

FIGURE 2 Importance of topology.

Use of GIS Technology in Travel Surveys

GIS technology has not been used extensively as an element of travel survey methodology. Hsiao and Sterling (*12*) describe how the use of GIS technology enhanced the accuracy and efficiency of origin-destination (O-D) survey data analysis and provided detailed spatial analysis results for evaluation of a new intercounty commuter rail service. Abdel-Aty et al. (*13*) describe how the geocoding and routing capabilities of a GIS proved useful in a survey conducted in Southern California. One of the objectives of this project was to compare actual route data with GIS shortest paths and conduct follow-up interviews with survey respondents to determine why their routes deviated from the shortest path. Shurbajji (*14*) showed how a GIS could be used to identify transit usage trends in the Atlanta metropolitan area based on the results of a geocoded transit origin-destination survey. As noted in this study, "GIS technology can provide effective means of analyzing service areas of potential transit services ... this technology can be combined with survey information which can be used in service analysis to enhance transit users and their behavior." By using the geocoded locations of the origins and destinations of respondents, the GIS was able to quickly and efficiently produce trip table information and socioeconomic variables by zone, which was extremely valuable to the planning process. The GIS thus provided a much easier and more effective platform to analyze survey data than previous approaches.

The following discussion is based on current literature and the authors' own experiences with using GIS technology for travel surveys. The benefits of using a GIS in travel surveys can be divided into several areas: input, processing and analysis, spatial display and query, and output.

Input

A GIS has a variety of methods for entering both spatial and attribute data. Spatial data either can be transferred from an existing digital format that includes positional information or can be geocoded. Because origin and destination data are usually locationally referenced by their addresses, a GIS's address matching geocoding tools make the system ideally suited for use in processing travel survey data. A drawback of address matching is that errors in the digital road network, such as missing address range information, misspelled road names, and, in some instances, missing roads, can lead to unsuccessful matches. To compensate for this, alternative methods for geocoding can be used. One possibility is to visibly locate spatial data, such as a trip's destination, on a digital road map. Using a GIS's graphical editing capabilities, the destination can be added to the data base simply by "picking" the approximate location on the display. This process is commonly referred to as "heads-up" digitizing.

Another limitation of address matching is that an origin or destination (e.g., identical street names that exist in two different cities) can be incorrectly geocoded. This problem can be alleviated somewhat by considering more attributes than just an address in the address matching procedure. In addition to the address ranges associated with road segments stored in the data base, other attributes such as city, county, and ZIP code can be used to ensure that the match is accurate. In addition to origins and destinations, trip routes can be geocoded as well. Routes that are stored in a spatial format (e.g., route data collected using GPS) can be transferred into a GIS directly.

The positional accuracy of point data and route data that are geocoded into a GIS depends on the quality of the underlying digital road network. A road network that is based on the Census Bureau's TIGER line file can be off by 100 ft or more at any one location. The impact of this error on travel survey data is not likely to be substantial.

Processing and Analysis

The process of translating travel survey data to final analysis format is generally recognized as labor-intensive and time-consuming. The ability of a GIS to manipulate spatial information and actually create new information can be valuable for processing travel survey data. Some especially useful capabilities are aggregation and overlay, routing, and statistical analysis.

Aggregation and Overlay

The Atlanta Regional Commission is currently conducting an O-D study for use with its 1990 Travel Demand Forecasting Model. The mail-in surveys include origin and destination addresses that are geocoded by a GIS. Once geocoded, the origin and destination data are overlaid with a TAZ polygon layer using GIS point-in-polygon operations. This process eliminates errors associated with manually placing origins and destinations with TAZs through visual inspection Once aggregated into TAZs, attribute data can be summed and the results can be reported at a TAZ level.

Routing

A significant use of O-D data is in the development of friction factors used in travel demand forecasting models The development of friction factors requires an accurate estimation of the distribution of travel duration by purpose Using routing algorithms, a GIS can calculate the time of travel from an origin and a destination at different times of day. However, the accuracy of these data depend on the quality of average and free-flow speed data included in the GIS data base. Comparison of GIS-generated shortest paths with actual survey data can be instrumental in understanding travel behavior (*13*)

Statistical Analysis

Most sophisticated GISs have the ability to perform statistical analysis. At a minimum, statistical summaries of TAZ data can be developed. This capability can be invaluable in developing trip generation models either through cross classification or multiple regression. In addition, the statistical analysis capability can identify important socioeconomic relationships that help planners better understand the travel phenomenon. For example, the transit service planning case described by Shurbajji used the statistical analysis capabilities of a GIS to define the household income, gender, ethnicity, and age distribution of those arriving at transit stations. Because such data were available by household location (through GIS geocoding), trip length distributions also were produced as part of the analysis.

Spatial Query and Display

GISs include a robust set of visual display capabilities that allow spatial data to be described in a format more powerful than tabular reports. TAZ maps that are color-coded by various attributes such as total number of home-based work trip origins can be developed. These visual displays can be easily understood by decision makers. Visual inspection of travel survey data also may make trends more apparent. Spatial query is another powerful GIS feature For example, a spatial query can be done, even with insufficient travel data, to identify TAZs, even though population for the zones suggest otherwise. This capability may be beneficial in identifying random sampling errors that may bias data.

Output

A GIS has a variety of output capabilities. In addition to being able to produce a wide variety of hard-copy maps, a GIS can produce tabular results. These results can be formatted to be compatible with other transportation tools, such as travel demand forecasting models.

GIS Disadvantages

The primary disadvantage of GISs is cost. A GIS's costs go beyond the cost of the hardware and software that support the system. A GIS is data driven, and data (especially highly accurate data) can be expensive. In addition to travel survey data, a great deal of spatial information is needed to support GIS use. Roadway centerline information is required to serve as a base map and provide geocoding capabilities. Other needed spatial information may include TAZ boundaries, census tract boundaries, and land use information. Spatial accuracy, completeness, and currentness of these data add to the cost of creating and maintaining this map information. Ideally, this information would already be available because of the existence of a GIS used for other applications It could be cost prohibitive if new spatial data (besides the travel survey information) must be developed. Another potential difficulty with using a GIS is lack of domain expertise. GISs are highly specialized and require a great deal of proficiency to be used effectively.

The Global Positioning System

GPS provides a means to obtain accurate positional information anywhere in the world, 24 hours a day. GPS is based on a constellation of 24 satellites orbiting the earth, and identifying a specific location is accomplished through satellite ranging. By measuring the distance from an object's location to the known position of GPS satellites, the object's location can be calculated through triangulation. GPS receivers, which communicate with the satellites, can perform these calculations automatically. Distances are determined by measuring the time difference between a clock internal to the receiver and signals received from the satellites. Typical GPS receivers can provide positional accuracies to within 100 m of actual locations. More advanced systems can provide accuracies within 2 cm.

There are two types of GPS surveys: static and kinematic. A static GPS survey is done solely for collecting the point positions of spatial features, such as a bus stop. Static point positions can be very accurate because averaging can be used to adjust multiple readings taken at the same location over a period of time (usually at least 180 sec). As the GPS receiver collects point information at a particular location, the user can enter attribute information about the point being collected into a datalogger or notebook computer linked to the receiver. A kinematic survey is performed when linear information, such as a travel route between a particular origin and destination, must be collected. The positional accuracy of kinematic GPS survey data is not as good as data from static surveys because averaging is not possible.

GPS Use in Travel Diary Surveys

GPS has been used successfully in a number of intelligent transportation systems (ITS) projects, including the Orlando TravTek project (*15*) and the Chicago ADVANCE and California Pathfinder projects (*16*). GPS also has been a key component in automatic vehicle location public transit projects (*17,18*). One of the areas in which GPS remains underutilized is travel surveys.

Transportation professionals and other users of travel survey data surmise that people often underreport very short trips when self-reporting methods are used. Other problems with self-reporting include the tendency to round travel times to 5- or 10-minute intervals. Similar tendencies to round may occur in reporting trip distances as well. Vehicle instrumentation with a GPS receiver can alleviate some of the problems associated with self-reporting. A GPS receiver can precisely monitor the time a vehicle leaves a location, the route the vehicle takes to get to a destination, any intermediate stops, the speed and acceleration characteristics of the vehicle while making the trip, and accurate distance information.

There are a number of advantages for using GPS technology in travel surveys. A GPS receiver keeps accurate clock time and can monitor a vehicle's movement without reliance on rough estimates that are common in self-kept travel diaries. Furthermore, all trips regardless of distance can be monitored. By downloading the GPS information to a GIS, specific route and other network attribute information can be linked to the monitored trip. This information can be verified with self-kept information that could be logged into an electronic device such as a notebook computer linked to the GPS receiver. A benefit of such a system is that all data can be directly downloaded, bypassing intermediate transfer through error-prone manual methods. Figure 3 illustrates a series of trips that were logged in a GPS receiver and dis-

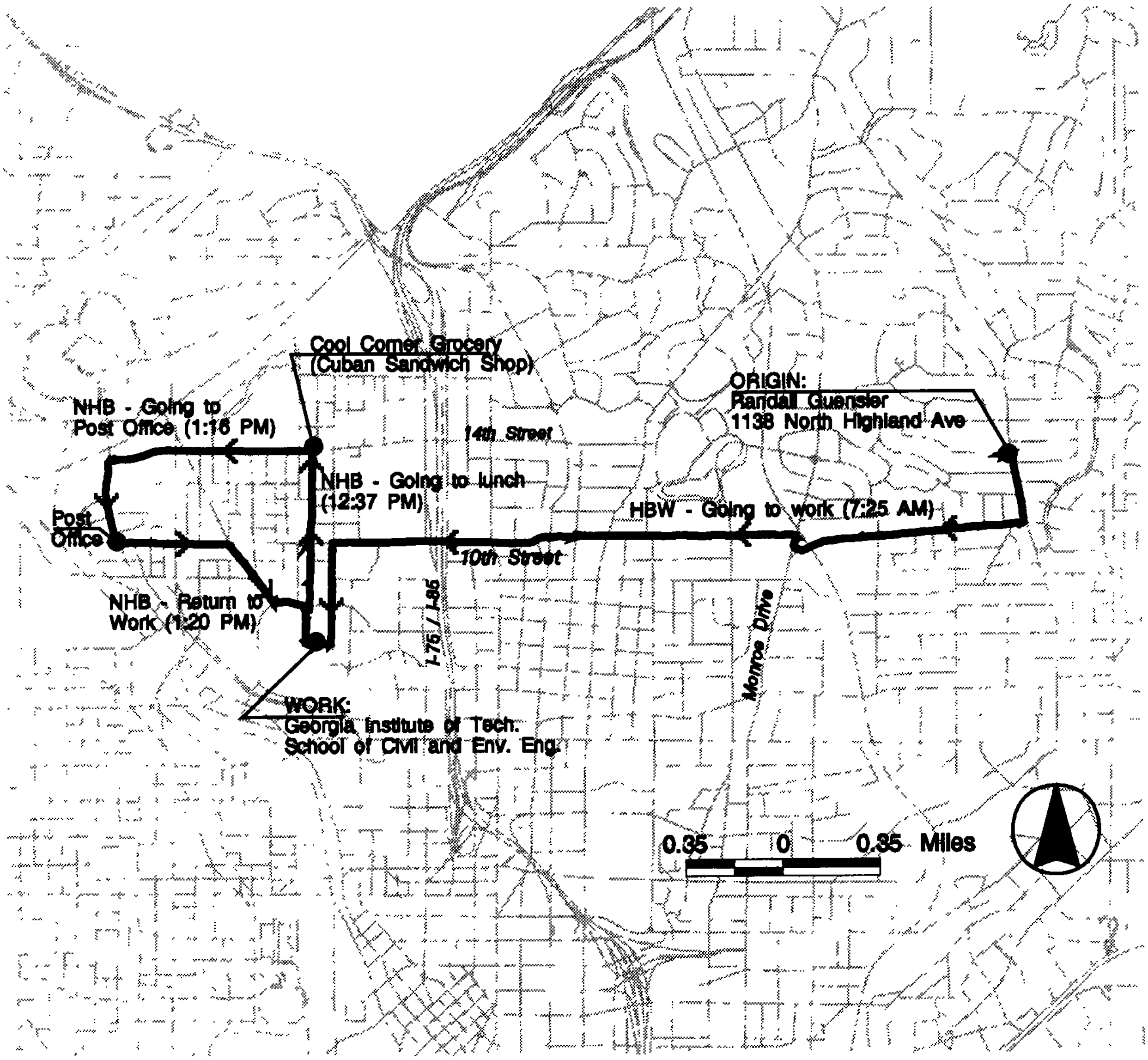

FIGURE 3 GPS travel diary data displayed in a GIS.

played in a GIS with selected attribute information. The trip has not been modified from its original raw data except through differential correction to improve positional accuracy

Georgia Institute of Technology is currently working on developing the next-generation mobile emissions model, which considers critical information that is not used in current emissions models. A vital component of this project is determining the travel patterns of a representative sample of drivers. By using GPS, it is possible to track a vehicle that is used by a study participant. Using a customized user interface on a notebook computer that is linked to the GPS receiver, the driver can enter critical trip attributes such as origin, destination, and purpose. The positional information collected by the GPS receiver is dynamically linked to speed and emissions monitoring equipment installed in the car. Once the survey is completed, the travel diary data can be imported into a GIS for processing and analysis.

GPS Disadvantages

Several disadvantages associated with the use of a GPS include cost, technological limitations, vehicle instrumentation, and lack of acceptance or misuse by study participants. The cost of the instrumentation can range from between $5,000 to $15,000 per vehicle. This cost includes a GPS receiver, a portable computing device such as a notebook computer, and associated software. Postprocessing equipment can add significant costs. These costs are decreasing and will continue to decrease with advances in technology and as the use of GPS becomes more popular.

Technical limitations primarily stem from errors associated with the positional inaccuracies of a GPS receiver. These errors are relatively small, especially if postprocessing is used to differentially correct positional information. The most significant disadvantage of using GPS occurs when satellite availability precludes the possibility of taking positional readings. A GPS receiver must be able to track four satellites at once to be able to pinpoint a location, otherwise no position will be recorded Several factors can limit the number of satellites that can be tracked. The most notable is the blockage of a GPS signal. Buildings, overpasses, trees, and the earth's topography can block the relatively weak signal from a GPS satellite. Because GPS can provide positions every second, the loss of a few seconds of data while passing under an overpass is unlikely to be a problem. The major difficulty arises when a study participant drives for an extended period of time in a location where satellite tracking is difficult or impossible. One example would be driving through a downtown area of a city.

The lack of acceptance or misuse of equipment is another disadvantage of using GPS. Requiring a driver to use instrumentation that is alien to the vehicle may influence the driver's decision to travel Furthermore, not using the equipment properly will undoubtedly lead to systematic errors. These problems can be alleviated somewhat by designing the instrumentation in such a way that user interaction is kept to a minimum.

Research Areas

This section addresses the research areas identified in the Household Travel Surveys Workshop Once identified, these areas were prioritized based on urgency, timeliness, and cost. The high-priority research items are

- Using GIS technology for sampling, including developing typology of urban form. The spatial aggregation and analytical capabilities of a GIS may prove invaluable in the stratification of demographic characteristics for travel survey purposes GIS technology also can be used to analyze demographic and socioeconomic data to help create standards for classifying urban form.
- Improving accuracy of travel behavior information by using GPS to track individual trips By using GPS in household travel surveys, all trips regardless of distance can be monitored. The improved accuracy resulting from the use of GPS may help transportation professionals better understand travel behavior
- Integrating GIS into a CATI system for on-line geocoding of origins and destinations. It is hypothesized that using on-line geocoding as opposed to postcollection geocoding can reduce respondent burden, increase the reliability of the coded trip end, and increase the "hit" rate in geocoding because nonhits can be clarified with the interviewee immediately.

The medium-priority items are

- Using CAPI for state preference research. This research proposes that a CAPI study be conducted either at households identified through a household survey or in focus groups to elicit results on interviewees' perceptions of the interview environment.
- Using CAPI for multimedia-assisted interviewing. The proposed research will investigate the value of including multimedia presentations on the CAPI hardware to help the interviewer obtain more accurate answers from respondents.
- Conduct a research synthesis on using GIS technology in household travel surveys. GISs offer many potential benefits in the conduct of household travel surveys. The purpose of this research is to develop a comprehensive synthesis on the use of a GIS as a tool for household travel surveys.

The medium-low priority and low-priority items in order are

- Route coding using a GIS in personal interviews,
- Using multimedia instruction as part of household travel surveys; and
- Monitoring personal travel with GPS body-pack units

Conclusion

Transportation planning by its very nature is data-dependent For decades transportation planners have developed regional data bases that continue to serve as the basis for transportation planning The effectiveness of this planning process is directly related to the quality of the data. As we head into the 21st century and as the profession assesses the types of modeling approaches it needs for the future, a close examination of cost-effective data collection strategies is needed.

The use of CATI, CAPI, GIS technology, and GPS as an aid in conducting travel surveys offers many potential benefits. These benefits include more efficient data collection, improved data quality, and more flexible output products. CATI and CAPI can provide real-time logical consistency checks that can help improve the accuracy of respondent answers. GISs provide spatial data manipulation capabilities to automate data processing tasks that historically have required a great deal of manual effort. The aggregation of travel survey data to TAZs is an example of a processing task that can be greatly simplified by using a GIS. The major benefit of GPS is in conducting travel diary surveys. GPS can alleviate some of the biases associated with conventional self-reported travel diary surveys because all trips including intermediate stops are monitored.

Perhaps the greatest potential for CATI, CAPI, GIS technology, and GPS is if they are used with each other in travel surveys. There are certain instances in which CAPI may be more appropriate then CATI (e.g., in cases where respondents do not have telephones) Likewise, in restricted access communities, CAPI may not be practical Both CATI and CAPI could benefit from the geocoding capabilities of a GIS. In addition, the combination of socioeconomic data and perceived travel characteristics (obtained from surveys) with real-time vehicle monitoring and location (obtained from GISs and GPS) can provide a powerful tool for transportation analysis. Of course, such a use presupposes that those subject to the surveys and vehicle monitoring activities will, in fact, participate. This human element of the analysis approach will be one of the real challenges in taking advantage of the potential of these technologies Even with this, however, recent advances in CATI and CAPI along with the spatial handling capabilities provided by GISs and GPS offer tremendous advances in the collection and analysis of travel survey data. These capabilities will go a long way toward enhancing the quality of transportation analysis in the years to come

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18 Sarasua, W *Final Report· MARTA Graphical Database Management System Exploratory Study* Metropolitan Atlanta Rapid Transit Authority, 1994

Steering Committee Biographical Information

Peter R. Stopher, *Chairman,* Educator and Research Administrator, received a B.S. in Engineering in 1964 and a Ph.D. in Engineering in 1967 from the University College of London. He was Research Officer, Greater London Council, 1967–68; Assistant Professor of Civil Engineering, Northwestern University, 1968–70; Assistant Professor of Civil Engineering, McMaster University, 1970–71; Associate Professor, Department of Civil Engineering, Cornell University, 1971–73; Professor of Civil Engineering, Northwestern University, 1973–79; Technical Vice President, Schimpeler•Corradino Associates, 1979–84; Director, Transportation Planning and Economic Studies, Evaluation and Training Institute, 1987–89; Principal and Chief Financial Officer, Applied Management and Planning Group, 1989–90; and Director, Louisiana Transportation Research Center, 1990–93. Dr. Stopher has been Professor of Civil and Environmental Engineering, Louisiana State University, since 1990.

Stacey G. Bricka, Research Associate, received a B.A. in Economics from Eckerd College in 1989 and an M.A. in Economics from the University of South Florida in 1991. She served as Research Associate at the Center for Urban Transportation, University of South Florida, 1990–94, and has been Research Associate at NuStats, Inc., since 1994 As Project Manager for Stated-Preference Surveys in Portland and Fort Worth, Ms. Bricka was responsible for the design, pretest, administration, and analysis of preference surveys for the transit agencies in these two cities. As Project Manager of the Los Angeles Earthquake Study, she conducted surveys to determine the impact of the January 1994 earthquake on travel by residents of Los Angeles and Valencia counties.

Mary Kay Christopher, Manager and Market Researcher, received a B.A. in Geography and Urban Studies from Elmhurst College in 1977 and an M.A. in Transportation from the University of Illinois, Chicago, in 1981. She served as Senior Planner, 1982–90, and as Manager, Service Oversight, 1990–94, at the Chicago Transit Authority, where she has been General Manager since 1994.

Robert E. Griffiths, Administrator, received a B.A. in Political Science from Drew University in 1973. His service with the Metropolitan Washington Council of Governments, which began in 1974, includes Transportation Planner and Chief of Computer Applications. He currently serves as Director of Technical Services and is responsible for directing the development of data and technical methods for analysis of regional transportation and growth issues. In 1981 Dr. Griffiths was awarded a fellowship to the Georgetown Center for Population Research. He has been a guest lecturer at Georgetown University and other universities on topics concerning innovative survey research techniques and population forecasting methodologies.

Herbert S. Levinson, Transportation Administrator and Consultant, received a B.S. in Civil Engineering from the Illinois Institute of Technology in 1949 and undertook graduate studies at Northwestern University in 1950. His professional experience includes the following. Bureau of Highway Traffic, Yale University, 1952; Traffic Engineer, Chicago Park District, 1949–51; Associate, Principal Associate, Vice President, and Senior Vice President, Wilbur Smith and Associates, 1952–80, Professor of Civil Engineering, University of Connecticut, 1980–86; and Professor of Transportation, Polytechnic University of New York, 1986–88. He has been Principal, Herbert S. Levinson, since 1990.

Hani S. Mahmassani, Transportation Educator, received a B.S.C.E. from the University of Houston in 1976, an M.S.C.E. from Purdue University in 1978, and a Ph.D. in Civil Engineering (Transportation Systems) from MIT in 1982. At the University of Texas, Austin, Department of Civil Engineering, he was Assistant Professor and Associate Professor from 1982 to 1992 and currently is Hayden Head Centennial Professor.

Nancy A. McGuckin, Planner, received a B.A. in Geography/Political Science from the University of Texas, Austin, in 1979 Since 1980 she has been Senior Associate, Barton-Aschman Associates, where she specializes in data collection, ranging from origin-destination for trip generation to attitudinal and stated-preference surveys of commuters and transit users.

Charles L. Purvis, Transportation Planner and Analyst, received a B.A. in Geography from California State University in 1979 and has served as Senior Transportation Planner, Metropolitan Transportation Commission, since 1988. At the commission, he is responsible for disaggregate and aggregate travel demand model development, preparation of regional and subregional travel forecasts, and transportation data analysis, including 1990 Household Travel Surveys and 1990 Census Journey-to-Work data. He served as Assistant Environmental Planner, Middlesex County Planning Board, 1980–81, and Teaching Assistant, Department of Urban Planning and Policy Development, Rutgers University, spring terms in 1980 and 1981.

Cheryl C. Stecher, Administrator, received a B.A. in Mathematics from Florida State University in 1972 and a Ph D. in Mathematics from the University of California, San Diego, in 1976. She was Director, Paratransit, Los Angeles County Transportation Commission, 1976–84, and has been President, Applied Management and Planning Group, since 1990.

Mary Lynn Tischer, Transportation Administrator, received a B.A in Political Science from Rosemont College, an M.A. in Political Science from American University, and a Ph.D. in Social Psychology Statistics from the University of Maryland, and currently serves as Policy Office Director at the Virginia Department of Transportation. She is a former Transportation Planner for the FHWA Urban Planning Division, where she was in charge of developing a research program in travel behavior and the dynamics of mode choice. As a Transportation Planner for the FHWA Operations Branch, Dr Tischer was in charge of a congressionally mandated study of the uniformity of state regulation of the interstate trucking industry

George V. Wickstrom, Transportation Consultant, received a B.S. in Civil Engineering from Cooper Union in 1953 and attended the Highway Traffic Institute at Yale University from 1953 to 1954. His experience includes the following: Traffic Engineer, New York City Department of Traffic, 1954–56; Deputy Director of Land Use and Transportation, City of

Philadelphia, 1956–68; and Deputy Director, Transportation Planning, Metropolitan Washington Council of Governments, 1968–94. Mr. Wickstrom has been a Consultant since 1994.

Robert M. Winick, Administrator, received a B S. in Civil Engineering from Cooper Union in 1964, an M S. in City Planning from Yale University in 1965, and a Ph.D. in City Planning from the University of North Carolina in 1968. He was Transportation Planner, North Carolina Department of Transportation, 1970–72; Senior Transportation Analyst, New York State Department of Transportation, 1972–74, and Chief, Transportation Planning Division for the Montgomery County Planning Department of the Maryland–National Capital Park and Planning Commission, 1974–92. Dr. Winick has served as Director of Transportation/Air Quality Analysis at Comsis Corporation since 1992.

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