Geographic Information System–Based Transportation Program Management System for County Transportation Agency

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A prototype geographic information system for transportation (GIS-T) that was developed for a suburban county transportation agency in metropolitan Atlanta is described. The main objective in developing the prototype was to design a system to help the county agency to better manage its transportation program. An organizational assessment was conducted to determine the different types of GIS-T applications that would most benefit the agency. These applications were ranked on the basis of greatest need, and five application modules were chosen for inclusion in the prototype to address these needs. The modules were: (a) an integrated accident record system, (b) traffic engineering, (c) pavement management, (d) transportation planning and land use, and (e) transit. The key finding of this project is that GIS-T provides a strong management decision support capability for officials in this agency. In particular, the prototype provides more than just a data management capability. It also provides a means by which various types of analysis can be performed more efficiently than they were in the past.

Transportation agencies are facing increasing pressures to manage transportation programs with fewer resources. For some years, many agency managers have examined the potential role that information systems technology could play in providing more productive program management. Such management information systems have become an important element of today's management process, although the level of importance varies from one agency to the next, depending on the type and magnitude of implementation. Geographic information systems (GIS) provide an important enhancement of these information systems, especially for those organizations, such as transportation agencies, that deal extensively with spatially defined services and facilities.

This paper describes a prototype GIS for transportation (GIS-T) that was developed for a suburban county transportation agency in metropolitan Atlanta, Georgia. In particular, this prototype system was designed to help the agency better manage its transportation program; a concerted effort was made to better understand the types of data currently collected in the agency, the manner of collection, and possible improvements in the use and handling of these data.

This project began with a literature search that examined the application of information system technologies to public works and transportation agencies similar in structure and function to the county transportation agency. Individual meetings held with agency personnel helped to establish the types of data and uses of information that existed within the agency. The responsible official for each unit within the agency was interviewed to determine current uses of data, desired types of data that should be collected, and possible software applications that would make the agency more efficient and effective. Where possible, standardized forms that are currently used to collect or input data, or both, were obtained.

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ORGANIZATIONAL ASSESSMENT

The county transportation agency consists of six divisions. The Traffic Engineering Division is responsible for safe and efficient traffic operations on county streets and highways through the design, installation, and maintenance of traffic control devices. The division is divided into transportation planning, field operations, and traffic engineering. One of the major tasks of this division is to analyze development proposals for their potential effect on the traffic operations of county roads. The Engineering Division is responsible for engineering design, design contract management, acquisition of right-of-way, construction management, and inspection. This division is organized into engineering services, right-of-way, and construction management. The Roads Division is responsible for maintaining 1,800 mi of county roads and 193 bridges under county jurisdiction. This division is organized into administration, construction, and maintenance sections. The division is expected to maintain accurate data on the costs of maintaining and repairing the county's roads and bridges. The Administration and Control Division is divided into general administration, project coordination, and archaeology. This division is responsible for the overall financial administration of the agency and for keeping track of payment requests; these are activities that lend themselves quite well to some form of automated information systems. The Transit Division is responsible for the short- and long-range planning of a suburban transit service as well as rideshare and vanpool operations. The Aviation Division is responsible for the operation of a small county airport.

The organizational assessment examined the current data management activities that were considered most important to the operation of the agency. The most relevant type of data were to be included as part of the prototype program management GIS. The following sections describe how data were collected and managed within the various divisions. A discussion is included on how data for the prototype GIS were obtained.

Traffic Engineering Division

The Traffic Engineering Division had two major types of information management activities that were important for this project: accident records and traffic signal management. For its accident records system, the Traffic Engineering Division uses a computer program for the input, management, and analysis of accident information. The data base was constantly updated using information provided from police accident reports. The system could perform statistical analysis and could produce a variety of hard copy reports. The system could also produce simple collision diagrams. Although the system adequately met the needs of the division from an efficiency standpoint, the system had a number of limitations. First, the display capabilities were limited. Diagrams produced by the system were limited to individual intersections. There was no capability to produce large-scale plots of collision diagrams at consecutive intersections on arterials. Second, only rudimentary analysis capabilities were possible with the system. Although it was possible to use the accident records system to list intersections of high accident incidence, there was no facility for producing a map that displayed various categories of accident incidence. Furthermore, there were no graphic capabilities that would make it possible, for example, to automatically create a pie chart for a particular intersection that displayed the percentage of accidents under various weather conditions.

The Traffic Engineering Division is also responsible for maintaining a number of traffic signals throughout the county. For each of the signalized intersections, the division keeps records for a variety of data, including hardware information, signal timing plans, intersection geometrics, and count data. However, not all of the signalized intersections in the county were under the jurisdiction of the county transportation agency. Some of the intersections fell under the jurisdiction of various cities.

The first type of data collected by the county to be included in the prototype GIS was the geometrics of the various intersections. For county intersections, these data were obtained in part through examination of bluelines, plans, and freehand sketches. Many of the signal plans were not available for some intersections. The geometrics for these intersections were developed from field visits.

The second type of data collected was the timing plan for each of the signalized intersections in the target area. Most of the intersection timings were available in digital form because these intersections were part of one of the 18 closed-loop systems connected to a central computer located in the signal shop. Timings for these intersections were quickly downloaded to diskette or to hard copy output. For those intersections not on the central system, timing plans were usually available on handwritten forms.

The third type of intersection data collected related to the various hardware at each of the signalized intersections. This included such items as controller type, inductive loops, and sensors. Many of the signal plans were either incomplete or out of date. Maintenance information was obtained for almost all of the intersections. The format of this information varied greatly between the different jurisdictions involved. One city had extensive maintenance data available on computer. Maintenance data provided by the county were in hard copy form and were limited. Additionally, traffic characteristics such as traffic count data and intersection levels of service were obtained from recent studies performed by a private consultant.

Engineering Division

In the Engineering Division, all data summaries and form handling were done manually. The most important data included the status and content of engineering contracts, right-of-way appraisals, information on right-of-way negotiations, and status of construction contracts. These documents were organized by project number and by funding category. If someone wanted to obtain information about a particular parcel of land, the division staff had to go to a file and manually retrieve the information. The specific type of information in these project files is extremely important for division managers and for the agency director to have retrieved in a timely manner. Right-of-way information was divided in parcel level information and included property costs, associated legal fees, appraisal fees and negotiation fees. Construction contract information included information on specific items, such as aggregate cost, and included a payment schedule. Engineering design contract information included similar types of data.

Roads Division

The only pavement distress information stored on-line was an aggregate score of pavement condition. All of the components that defined the aggregate score (i.e., alligator cracking, transverse cracking, oxidation, etc.) were kept in hard copy form only. Additionally, the existing computer data base had a lot of missing or incomplete information for many of the streets in the study area. Many streets in some parts of the study area were not in the data base and thus did not even have an aggregate distress rating. Another drawback of the data base, and the system in general, was a lack of segmentation for a number of streets. Streets 1 to 2 mi long or greater were listed in the data base as one continuous segment. Field investigations of several roads determined that the pavement surface varied substantially over the entire length of the segment.

Administration and Control Division

The Administration and Control Division included two data areas of interest: archaeology and project control. The county has an extensive inventory of historical artifacts. This inventory is augmented with site investigation and project management information to allow response to requests for archaeological and historical evaluation of projects. Different types of data exist in various formats, including hard copy and digital data bases. Some data, such as the location and characteristics of sensitive burial grounds, are classified. The archaeology section also reviews planning and zoning requests and all road projects. These reviews were done using a word processor. The projects control section mainly processes invoices for projects. This section recorded project financial information on forms that were filled out manually.

There appeared to be a great deal of similarity in the types of project information needed by this section and the Engineering Division. A project management system that monitored not only construction progress but also financial status appeared likely to be an important capability for both divisions.

Transit Division

The operating data for the transit system are collected by a private transit management firm. The data collection effort was very weak in maintenance costs and in socioeconomic and land use density data that would be necessary for the planning of any service expansions. Financial information came from the county finance department, but there was some concern that the information was not provided on a timely basis or that it was not categorized in a way that would be most useful for day-to-day management.

In summary, data acquisition techniques appeared for the most part to be manual and labor-intensive in nature. Standardized paper forms were completed by various staff members and circulated within the agency. The data collection appeared to be oriented toward business or accounting and did not include engineering data. Items such as maintenance records for existing facilities (roads, bridges, and traffic signals) were not computerized. Even within the financial section, various kinds of data or aggregation of existing data seemed absent. It was this status of data collection that led to the development of a prototype GIS that would help agency officials to better manage the transportation program.

PROTOTYPE GIS-T

A prototype GIS-T was developed for the county transportation agency using the TransCAD software. TransCAD was chosen for a number of reasons. First, TransCAD is designed for use on personnel computers and can be installed and tested on existing computers already available throughout the transportation department. Second, TransCAD has a number of specialized tools already in the software that are designed to address transportation-related problems. These tools include shortest-path algorithms, travel forecasting capabilities, and several tools to solve operations research problems related to transportation. Functional applications can be developed in a relatively short time. Furthermore, TransCAD is relatively easy to learn.

The roadway basemap for the prototype was developed by converting U.S. Census Bureau TIGER files into a TransCAD line data base for the entire county. A subset of this data base was used for the prototype. Because this prototype was intended to be used only to illustrate GIS capabilities, the line data base that represented the street system was not checked for accuracy. If the system were to be implemented for the entire county, one of the first major tasks would be to correct errors in the base map.

Using this line data base, it was possible to create additional data bases for signalized and unsignalized intersections, transit routes, bus stops, and accident locations. The only locational data that had to be digitized or entered manually were existing traffic analysis zone (TAZ) boundaries and future development sites.

The prototype GIS-T is divided into five application modules: (a) an integrated accident record system; (b) traffic engineering; (c) pavement management; (d) transportation planning and land use; and (e) transit.

Integrated Accident Record System

The prototype GIS-T has the capability to store, retrieve, and analyze accident data. The design of the digital data base is patterned after the existing agency accident record system. The various attributes for a particular accident record in the prototype GIS-T are listed in Table 1. The GIS-T data base was built by translating the existing accident system dBase files for 1990 into Lotus 1-2-3. TransCAD can import data directly from Lotus 1-2-3. All accident record data stored in the prototype are associated with an intersection. Accidents are described as being at an intersection or some distance away from the intersection along a particular approach.

The analysis and display capabilities of the accident module are extensive. A number of descriptive maps identifying, for example, those intersections with unusually high incidences of left-turn–related accidents can be generated using the prototype GIS. Another possibility is using the charting capability of the TransCAD to produce a pie chart that shows, say, the percentage of accidents that occurred at each intersection in the study area during 1990. Figure 1 shows a bar chart, also produced by TransCAD, indicating the various types of accidents that occurred in the study area in 1990.

Spatial queries and spatial analysis are capabilities unique to GIS technology. Examples of spatial queries that were tested in the prototype GIS-T included listing all accidents that occurred within a given distance from an intersection and producing a map showing the incidence of midblock left-turn accidents on streets with a two-way left-turn lane under the county agency's jurisdiction. Using spatial analysis techniques, it may be possible to identify trends in accidents. By cross-referencing accident incidence with other types of information, such as roadway inventory, a correlation may be found between high rates of accident occurrence with, for example, poorly maintained roadway pavement markings or missing signs.

Figure 2 illustrates a proposed integrated accident record system for the county. It proposes that the system be made up of three components, the first of which is the GIS-T. The accident module of the prototype GIS-T was designed to complement the county's current accident record system (called SCARS) rather than possibly replace it. The SCARS system represents the second component of the integrated accident record system. The purpose of SCARS would be to perform various statistical analyses on the accident data. Eventually, the analysis capabilities of SCARS could be programmed into the GIS-T, eliminating the need for the SCARS component.

The final component of the system is AutoCAD. Its purpose would be to produce detailed collision diagrams. Data from the SCARS or the GIS component would pass directly to AutoCAD, which would then generate the collision diagram.

TABLE 1 Accident GIS-T Attribute Fields

TRANSCAD FIELD	DATA TYPE	COLUMN WIDTH
Intersection ID	Number	12
Accident Date	Character	10
Time	Number	5
Vehicle,Injured, Killed	Number	3
Accident Number	Number	12
Route	Number	5
Direction-Distance	Character	5
County Node	Number	6
Site	Coded	3
Vehicle 1 Type	Coded	25
Vehicle 2 Type	Coded	25
Direction 1	Character	2
Direction 2	Character	2
Damage 1	Number	5
Damage 2	Number	5
Damage 3	Number	5
Vehicle-Pedestrian 1	Character	1
Vehicle-Pedestrian 2	Character	1
Description	Number	2
Movement 1	Number	2
Movement 2	Number	2
Location 1	Number	2
Location 2	Number	2
Event	Coded	25
Control	Coded	25
Lighting Condition	Coded	25
Surface	Coded	25
Cause 1	Character	3
Cause 2	Character	3
Road ID	Coded	25
Violation 1	Number	4
Violation 2	Number	4
North-South Street	Character	20
East-West Street	Character	20

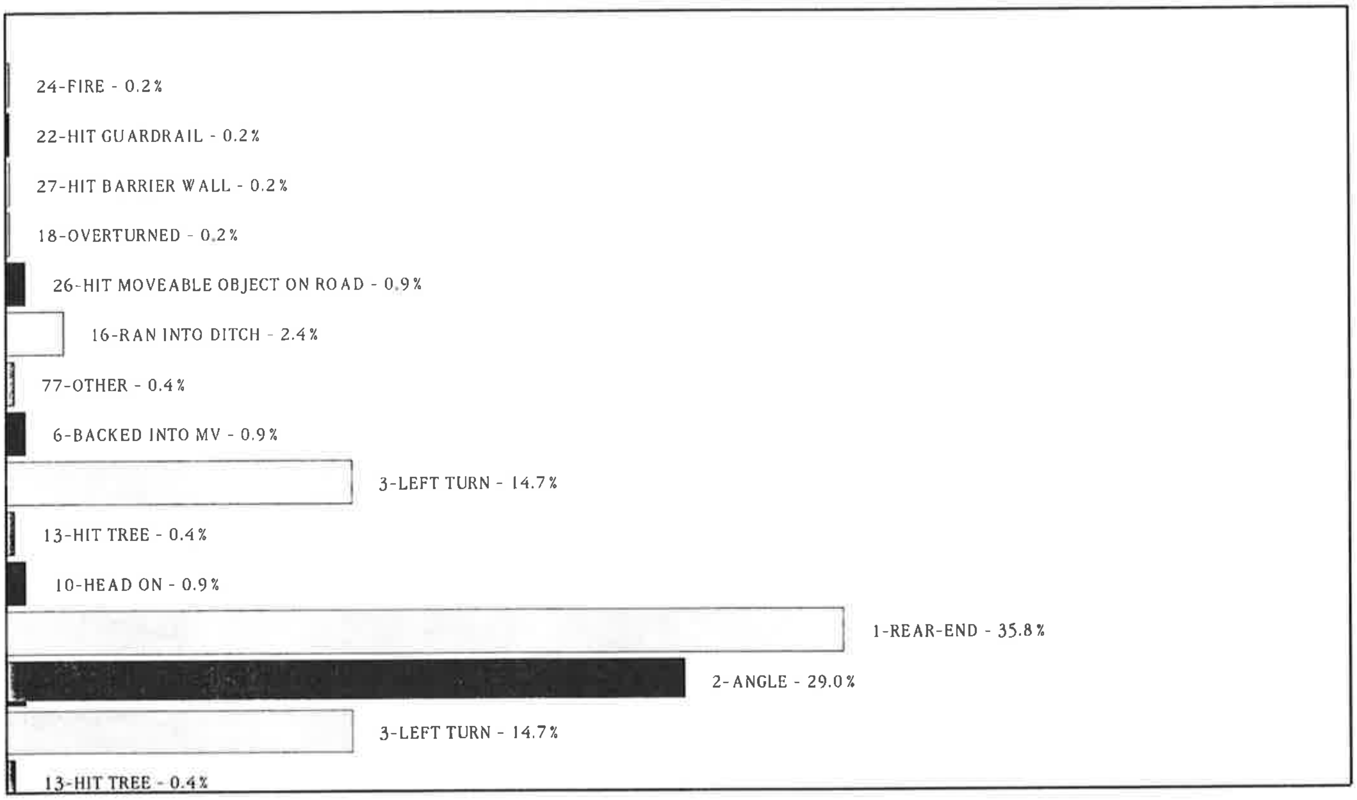

FIGURE 1 Accident records bar chart from GIS-T, all data (455 observations).

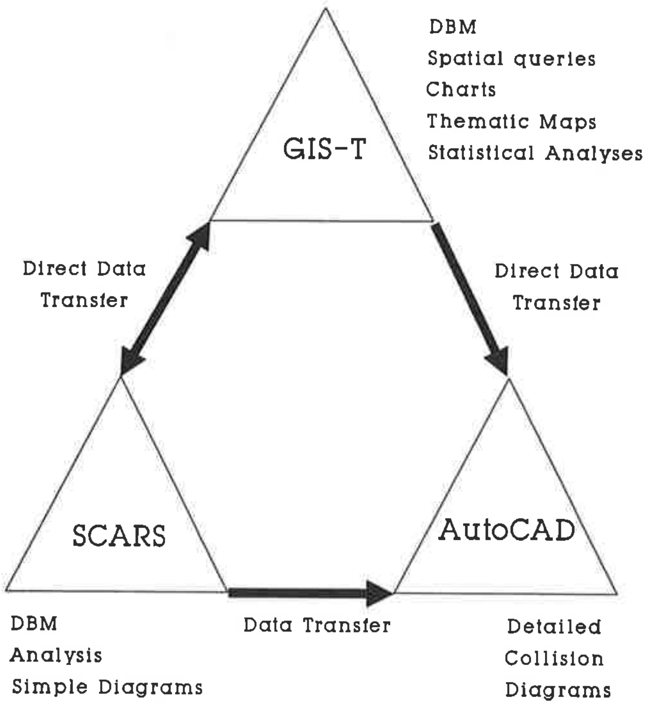

FIGURE 2 Integrated accident record system.

Traffic Engineering

Traffic Signal System Management

Specific information related to signalized intersections was incorporated into the prototype GIS-T. The intent of the signal module was to help automate the process of managing and maintaining the traffic signal system. The system provides a number of capabilities:

1. Provides quick and easy access to signalized intersection information.
2. Allows for swift identification of "troubled" intersections.
3. Keeps maintenance activities up to date to help spot problems before they occur.

The signal module of the prototype GIS-T is able to provide quick and easy access to signalized intersection information such as controller type, signal heads, detectors, sampling loops, intersection geometrics, and travel characteristics. Queries can be made simply by selecting an intersection from the map display. The associated text information that results from the query can be reviewed, printed, edited, or any combination thereof.

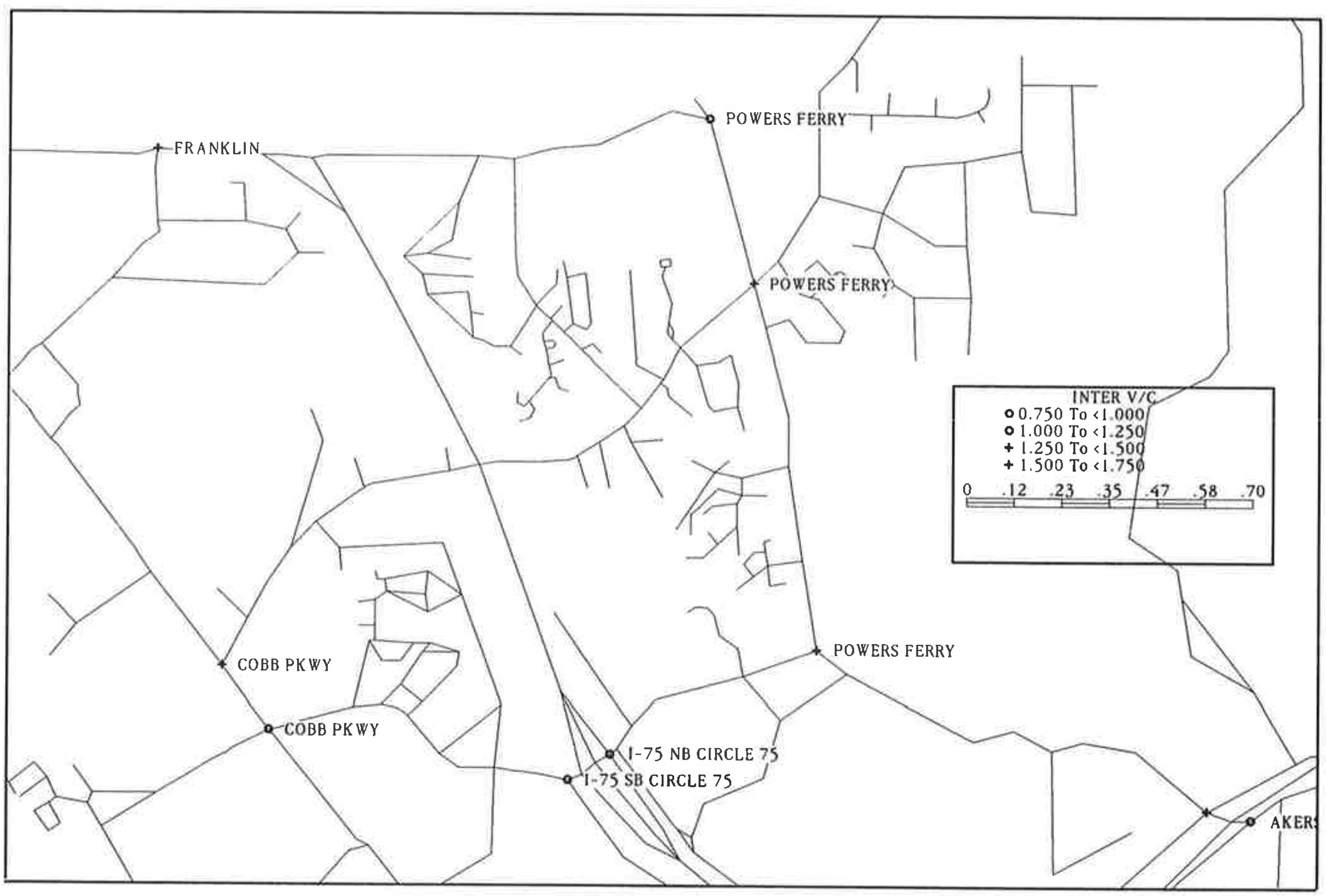

FIGURE 3 Thematic map showing *v/c* ratios.

The prototype GIS-T allows for swift identification of troubled intersections. These troubled intersections may be defined as those with large volume-to-capacity (*v/c*) ratios, enormous delays, unacceptable levels of service, intersections with a high number of maintenance activities in a relatively short period of time, or any combination of these variables. These troubled intersections can be displayed on high-quality thematic maps. Thematic maps are an intricate part of any GIS. A theme is a classification of entities in a layer based on the value of any one attribute. When users create a theme they also choose any or all of the following: colors, styles, or icons that are used to distinguish the classification on the map display or plotted output. An example of a thematic map produced by the prototype GIS-T that displays *v/c* ratios is shown in Figure 3.

If the user prefers maps with labels (which is normally the case when colored output is not possible), this is easily accomplished. Figure 4 shows a map of levels of service for the signalized intersections in the study area.

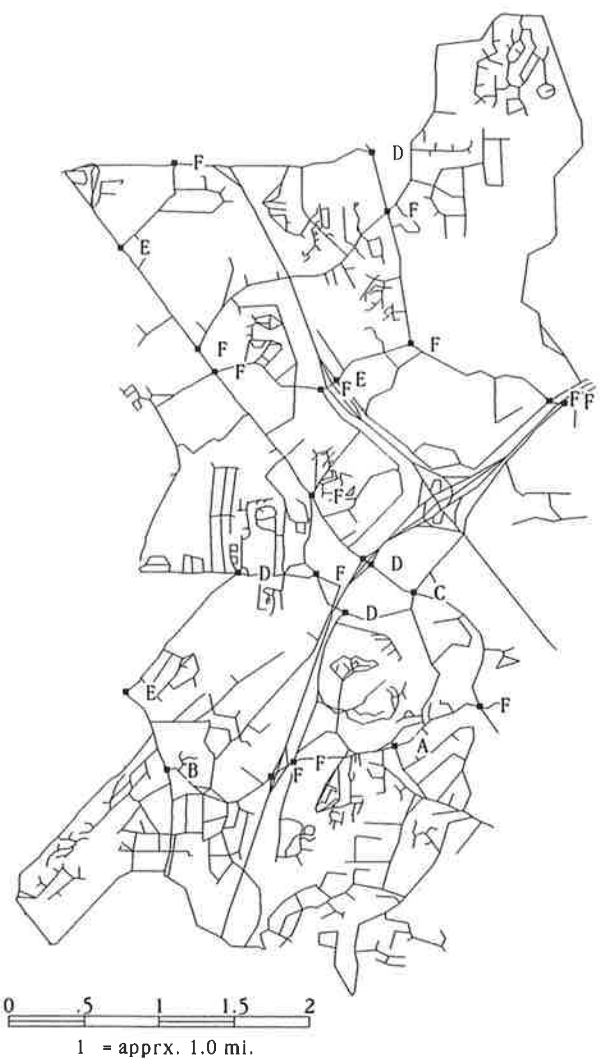

FIGURE 4 Thematic map showing levels of service.

Maintenance Management

The GIS-T prototype also keeps maintenance activities up to date, which can help spot problems before they occur. Included in the prototype is the type of last maintenance activity, date of last maintenance activity, and the number of maintenance activities in the last year. Using this information, it is possible to produce, for example, a map that identifies all intersections with more than four maintenance activities a year. A partial listing of information included in the signal prototype is as follows:

- *I.D. Number*—A three digit identification number that comes from TIGER files.
- *N-S Street, E-W Street*—name of the cross streets at the intersection.
- *Controller Type*—A description of the controller type at the intersection.
- *Plans Approved, Plans Revised*—Date (MMDDYY) that the signal plans were approved, revised, or both.
- *Signal Heads*—Character description of all types of signal heads from all directions at intersection.
- *Loops*—Physical description of loops actually located in the field.
- *Detectors*—Type or mode of loops at that intersection. Types are pulse, presence, pedestrian, and system.
- *Sampling Loops*—Number and location of loops used to sample traffic for occupancy and volume.
- *(NB-SB-EB-WB) Lanes*—Description of the approach lanes in each direction. Possible types are L-T-R-LT-TR-LTR-LR.
- *Study Date*—Date that the "field study" was conducted to gather filed data.
- *(NB-SB-EB-WB) (L-T-R) v/c*—Volume-capacity ratio for each approach lane in each direction. For shared lanes (i.e., LT or TR), the through (T) lane was used.
- *Intersection v/c*—Volume-capacity ratio for entire intersection.
- *(NB-SB-EB-WB) Delay*—Delay, measured in seconds.
- *Intersection Delay*—Delay, measured in seconds.
- *Intersection Lost Time*
- *(NB-SB-EB-WB) LOS*—Level of service for each directional approach based on directional approach delay. Levels of service are defined as follows:

LOS	*Delay (sec)*
A	0–5
B	5–15
C	15–25
D	25–40
E	40–60
F	>60

- *Intersection LOS*—Level-of-service for each intersection based on levels of service for all approaches.
- *(NB-SB-EB-WB) ADT*—Represents the 24-hr count of traffic for each directional approach on the specified study date.
- *Last Maintenance Activity*—A record of the last maintenance problem that occurred at the individual intersection. The possibilities are as follows:

Code	*Choice*
1	Bulb out
2	On flash
3	Defective loop
4	Replace controller
5	Signal head/pole hit
6	Rearrange/install signal heads
7	Preventive maintenance
0	Other

- *Date of Activity*—MMDDYY of the last maintenance activity performed at the individual intersection.
- *Number of Activities in Year*—Number of maintenance activities in the last year.

A potentially powerful tool that was developed as part of the prototype GIS-T is automating the process of signal coordination. Much of the information used by traffic signal coordination packages (e.g., TRANSYT-7F, PASSER) can be stored in a GIS. Software was developed that automatically accesses the GIS data base and generates input files for use in TRANSYT-7F (*1*,*2*). Implementation of this capability into an expanded countywide system will help make the process of coordinating signals more economical.

A desirable capability that is not possible with the current version of TransCAD is to be able to visually manage information at the intersection level. Although it is possible to access all of the attribute information for an intersection by scrolling across fields, this can be cumbersome. A better way would be to use a GIS intersection manager. This system would allow the user to visually see a wide variety of attribute information for an intersection on a single screen. For example, geometrics, turning movement volumes, signal head locations, and loop detector information could be included on a single graphical display.

Pavement Management

One transportation application of GIS that is getting a great deal of attention in public agencies is pavement management (*3*,*4*). Unfortunately for the demonstration project, pavement data were limited for streets located in the study area. Therefore, to better illustrate the capabilities of a pavement management GIS, imaginary data were added for those roads that lacked pavement data. Additionally, a number of fields were included in the data base even though data for these fields were unavailable. A list of the fields included in the pavement module are shown in Table 2.

One of the initial steps in the pavement management process is to collect and record the condition of roadway segments. The prototype GIS-T, with its visual display capabilities, can show the segments color-coded (e.g., a thematic map) by various attributes that would greatly facilitate the process of data entry and editing. Omissions in the data input would be immediately apparent from segments in the roadway showing no data. Furthermore, errors in measurement or coding would also be readily apparent. One such example would be where a long stretch of roadway that had recently been resurfaced included a segment that was coded as having severe transverse cracking. The prototype GIS-T can produce a series of color-coded map displays that would identify differing segments.

By using the conditional querying capabilities of TransCAD, it is possible to produce thematic maps that highlight distressed roadways. These maps can be used in system assessment. All of the graphical products produced as a part of the assessment can be easily understood by management, political figures, and citizen groups, helping to clarify issues and obtain needed support. Figure 5 shows a simple pavement rating map produced using the prototype GIS-T.

TABLE 2 Pavement GIS-T Attribute Fields

TRANSCAD FIELD	DATA TYPE	COLUMN WIDTH
TIGER File ID	Number	10
Length	Number	4
Direction	Coded	2
Street Prefix	Character	1
(i.e. N,S,E,W)Road Name	Character	25
Type (i.e. St.)	Character	6
Suffix (i.e. SE)	Character	2
Code	Character	4
Maintaining Jurisdiction	Character	10
Total Score	Number	3
Alligator Cracking	Number	3
Pothole/Patching	Number	3
Transverse Cracking	Number	3
Longitudinal Cracking	Number	3
Rutting	Number	3
Raveling	Number	3
Oxidation	Number	3
Bleeding	Number	3
Pavement Width	Number	3
Shoulder Width	Number	3
Functional Classification (i.e. Arterial,Collector)	Coded	2
Estimated ADT	Number	7
Pavement Evaluator	Character	20
Date of Evaluation	Date	8
Posted Speed	Number	3
Travel Time	Number	5

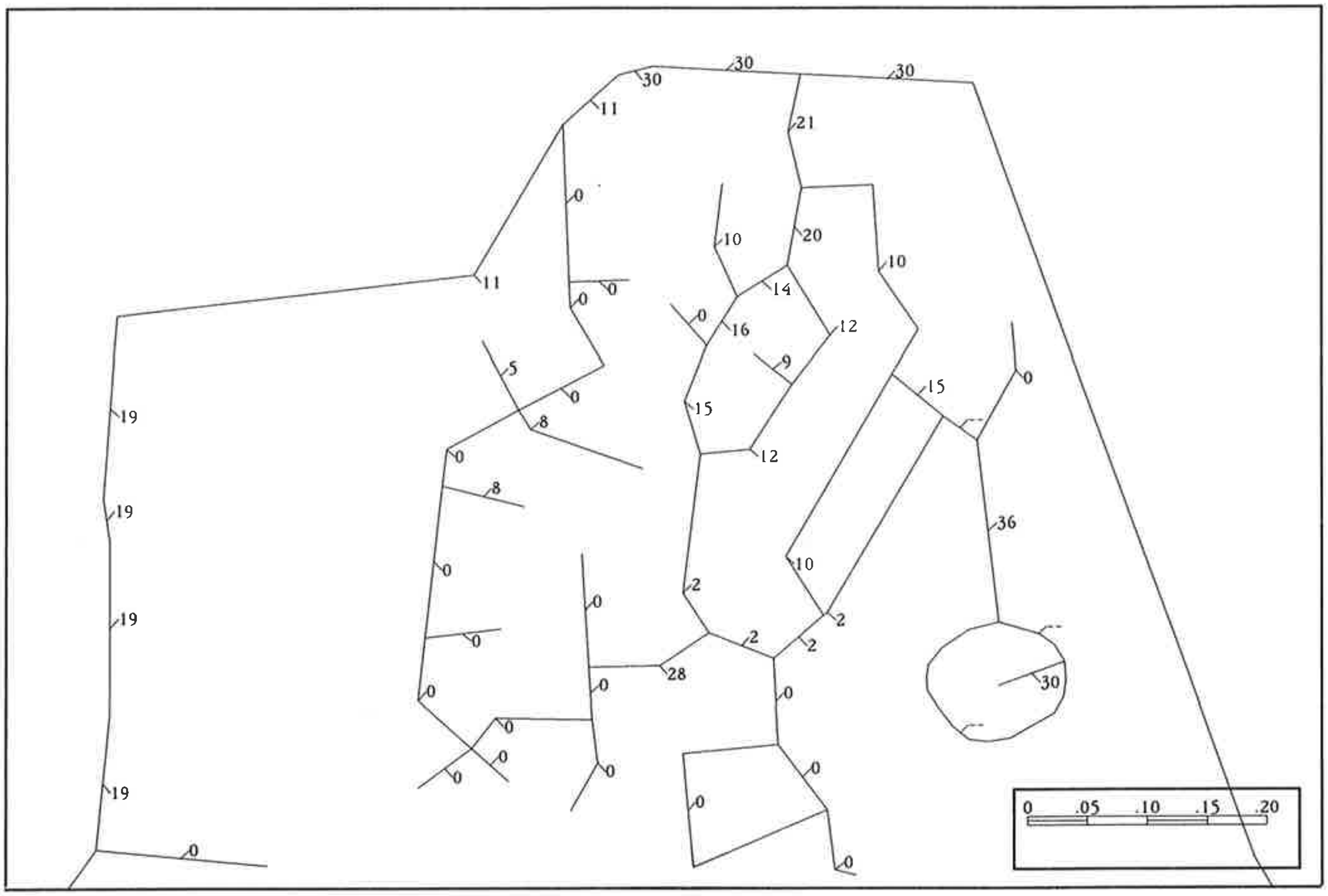

FIGURE 5 Pavement rating map.

One area of extension of the prototype GIS-T's capabilities is the addition of expert system technology to the pavement GIS. By adding "intelligence" to the GIS, maintenance strategies could be automatically identified on the basis of the types of distress of a particular roadway.

Transportation Planning and Land Use

Microcomputer-based travel forecasting usually involves the creation of lengthy ASCII files for input. The TRANPLAN transportation demand modeling package used by the county agency is one example of a travel forecasting software that requires ASCII text input files. Conventional data base packages are one means of simplifying the process of creating the ASCII input files. A characteristic of conventional data base packages that make them poorly suited to manage TRANPLAN input files is the cryptic nature of having to rely heavily on identification numbers (nodes, links, TAZs, etc.). Input file management is the perfect domain for a GIS because attribute information stored in a GIS is linked to spatial objects. Thus, it is possible to edit information for a TAZ by selecting the graphical representation of the TAZ from the computer screen. Likewise, link and node data can be edited by selecting the appropriate intersection or roadway from the screen. For the prototype GIS-T, a TAZ data base was developed to manage land use data.

As mentioned earlier, an ideal application of a GIS is to manage TRANPLAN input files. By developing certain procedures, it is possible to translate land use information that is included in the TAZ data base into productions and attractions that can be used by TRANPLAN. A translator can also be developed to extract link and node data included in the GIS and produce a network file compatible with TRANPLAN.

Transit

The transit module of the prototype GIS-T currently is very limited. Nevertheless, it can be used to illustrate a number of capabilities. The potential for additional capabilities is vast if more data fields were to be included in the data base.

Two layers of information are included in the transit module. The first layer contains bus stop information. The bus stops in the study area are shown in Figure 6. This figure was used for illustrative purposes only and does not necessarily represent actual bus stop locations. Ridership information associated with bus routes is included in the data base. Using this information, it is possible to produce a variety of descriptive thematic maps that can show, for example, those bus stops that have the greatest number of boardings and alightings during any period of the day.

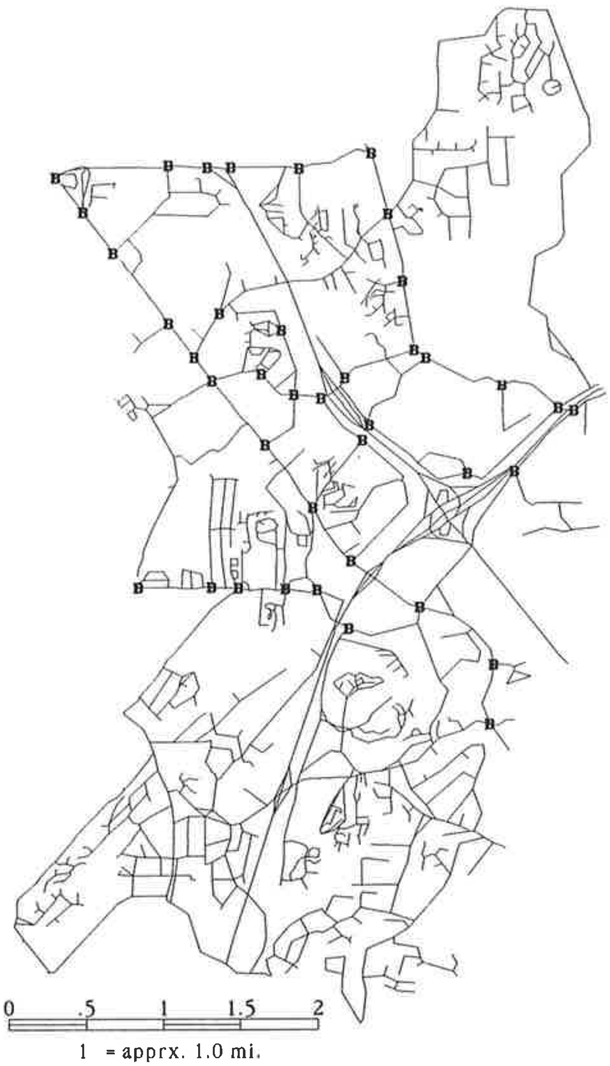

FIGURE 6 County bus stops.

FUTURE EXPANSION OF PROTOTYPE GIS-T

After an extensive evaluation of the prototype GIS-T, county officials have decided to implement an expanded GIS-T for the entire county. This GIS-T will be developed as part of an integrated multipurpose countywide GIS. The GIS platform (e.g., TransCAD/GisPlus, ARC/INFO, etc.) for this multipurpose GIS has yet to be determined.

In developing the prototype GIS-T, care was taken in the design of specialized functions (e.g., the TRANSYT-7F interface) to be as portable as possible to other GIS platforms. Thus, the programs were developed in the C programming language and designed to operate external to the GIS platform. The only functions that would be unique to a particular GIS platform would be how information is passed to and retrieved from the specialized functions. Information would probably be passed using customization tools built into the platform.

CONCLUSIONS AND OBSERVATIONS

This paper has described a prototype GIS-T that has been developed for a county transportation agency. The GIS-T provides a strong management decision support capability for the officials in this agency. In particular, it provides more than just a data management capability. As shown in the integrated accident records system, the development of TAZ input data into TRANPLAN and the automated development of input files for TRANSYT-7F, the prototype GIS-T is taking an important step in using GIS technology to provide more efficient analytical procedures. Clearly, given the current manual operation of the data collection and management procedures in the county agency, the GIS-T data management capabilities will also provide an important benefit to the agency.

The implementation strategy adopted for this project is also worthy of note. The project team consciously started with a small geographic area of the county to show the constraints that might be found in a countywide application, while at the same time illustrating in concrete terms what benefits could be obtained. This small-area prototype strategy has been well received by agency management and has been used to show midlevel managers the capabilities that could exist in their agencies.

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