Proceedings
of a Conference on

GIS in Transit

Using Geographic Information Systems to Enhance Transit Planning, Marketing, and Operations

CUTR
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Center for Urban Transportation Research
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Proceedings of a Conference on GIS in Transit
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The concept for a Conference on GIS in Transit evolved out of a growing awareness that Geographic Information Systems (GIS) could improve the planning, management, operations and evaluation of transit systems. GIS has evolved over the past decade as a field of information management that enables users to efficiently store, retrieve, edit, manipulate and graphically display spatially-referenced data and to integrate such data from multiple databases using both topological and attribute information.

GIS has the potential to significantly improve the quality of urban transportation planning data while reducing the cost of data collection and preparation. GIS also enables transit agencies and local planning organizations to share databases. The net potential impact of GIS applications is to enhance customer service and improve the cost-effectiveness of service delivery through more efficient planning and analysis.

The potential for more effective application of GIS in transit is great if current and potential future users share experiences. Although many transit agencies and MPOs use GIS, they rarely exchange information. Applications of GIS are diverse, and few agencies have been able to maximize its potential. To a large degree, vendors have driven the adoption of GIS by transit and transportation planning agencies -- a dozen different GIS software packages are currently in use by transit agencies and MPOs for planning and analysis.

While some networking does take place between individual transit agencies and MPOs, CUTR felt a forum for systematic discussion of benefits, issues and problems would offer an opportunity to accelerate the information exchange process. Furthermore, we felt that a national conference on GIS applications in transit would provide such a forum.

In planning this conference, it was our intent to bring together representatives from transit operators, planning agencies, the research community and vendors of technology to share experiences, perspectives and viewpoints on the subject. The conference format was developed to include:

- Speakers addressing both policy and technical issues
- Panel discussions on a selection of the topics proposed above
- Workshops on particular topics
- Vendor demonstrations of different GIS software packages

The conference was highly interactive and provided maximum opportunities for discussion and dialogue. In preparation for the conference, input on topics and format were solicited from professionals around the country. In order to better reach individuals with a potential interest in GIS in Transit, several organizations were invited to co-sponsor the conference. The presentation of the conference and production and dissemination of the proceedings were funded by the Research and Special Programs Administration (RSPA) of the U.S. Department of Transportation as part of the National Urban Transit Institute (NUTI) funds allocated to CUTR.
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Sunday, August 13

7:30 pm  Reception at Florida Aquarium

Monday, August 14

7:30 am  Continental Breakfast, Registration

8:30 am  ❖ Welcome (Ballroom)
          Gary Brosch, Center for Urban Transportation Research (CUTR)
          Sharon Dent, American Public Transit Association,
          Hillsborough Area Regional Transit (HART)
          Rosemary Mathias, Women’s Transportation Seminar

❖ Opening Plenary Session (Ballroom)
  Ronald Scheck, Center for Urban Transportation Research
  Keynote Speaker:
  Walt Kulyk, Federal Transit Administration

9:45 am  Break

10:00 am  Concurrent Sessions

❖ The Use of GIS in Public Transportation (Ballroom)
  Moderator: Diana Carsey, HART

"Overview of GIS in Transit"
  William Ball, CUTR

"Results from the National Transit GIS Survey"
  Larry Harman, L. J. Harman Consulting

"GIS as an Aid to Transit Planning from Vermont to Puerto Rico"
  James Wensley, Multisystems, Inc.

"Planning San Diego’s Transit Systems Using GIS"
  Linda Culp and Julie Jamarta, SANDAG

"Pinellas Suncoast Transit Authority’s Bus Stop Inventory"
  Dennis Hinebaugh, CUTR
Monday, August 14 (continued)

10:00 am  Data Base Design and Spatial Data
(Lancaster Room)
Moderator: Robert Aangeenbrug, Univ. of South Florida

"An Enterprise GIS Database Design for Transit Applications"
Zhongren Peng, Portland State University

"Use of FTA’s National GIS Transit Database for Guideway Transit Demand Analysis"
Young-Kyun Lee, Florida International University

12:00 noon  Luncheon (Terrace)

KEYNOTE SPEAKER:
Michael Dobson, Rand McNally & Company

1:30 pm  Concurrent Sessions

Trends in Software Technology (Ballroom)
Panelists: Jim Lam, Caliper Corporation
Bill Schuman, Intergraph Corporation
Marc Kratzchmar, ESRI
Ken Tozier, Int’l. Computer Works/MapInfo
Michael Sheldrick, ETAK

Case Studies of GIS in Action (Lancaster Room)
Moderator: Fredalyn Frasier, CUTR

"Minnesota’s Guidestar Project"
Melanie Braun, Minnesota Dept. of Transportation

"Combining Fixed Route Customer Information, Trip Planning and Paratransit Scheduling"
John Attanucci, Multisystems, Inc.

"GIS in Transit: Applications and Lessons Learned"
Joe Hagge, CUTR
Beverly Ward, CUTR
Monday, August 14 (continued)

"Metropolitan Atlanta Rapid Transit Authority's (MARTA's) Intelligent Transportation System: A Showcase for the 1996 Summer Olympic Games"
Wayne Sarasua, Georgia Institute of Technology

"Using GIS to Identify Locations with the Greatest Potential for Increased Transit Ridership"
Victor Henry, Baltimore Metropolitan Council

3:15 pm Break

3:30 pm Concurrent Sessions

❖ GIS and Public Transportation Management Systems (Lancaster Room)
Moderator: Steve Polzin, Center for Urban Transportation Research

"ISTEA Management Systems: Logical Modelling"
James Tucker, Graphic Data Systems Corporation

"The GIS-T/ISTEA Pooled Fund Study: An Approach to Transportation Planning"
Thomas Henderson, New Mexico State Highway and Transportation Department

"Dynamic Visualization of Network Flow in GIS-T"
Young-Kyun Lee, Florida International University

❖ Training Workshop: GIS Implementation (Ballroom)
Lyna Wiggins, Center for Urban Policy, Rutgers University

❖ Developing Standards for Transit GIS (Steele Room)
Moderator: Paula Okunieff, VIGGEN Corporation
Panelists: Robert Aangeenbrug, Univ. of South Florida
Bruce Spear, Bureau of Transportation Statistics
Wende O'Neill, Utah State University
Tuesday, August 15

8:00 am  ❖  FTA Special Sessions (Ballroom)

"FTA's Efforts in Context with USDOT's GIS Program"
Walt Kulyk, Federal Transit Administration

"Transit GIS Demonstration: Next Steps"
William Wiggins, Federal Transit Administration

"System Architecture and Connectivity"
Paula Okunieff, Viggen Corporation
Bruce Spear, Bureau of Transportation Statistics
Wende O'Neill, Utah State University

10:00 am  Break

10:15 pm  Concurrent Sessions

❖  "Issues and Applications for Large Transit Systems" (Lancaster Room)
Moderator: Lyna Wiggins, Rutgers University
Panelists: Nancy Neuerburg, Seattle Metro
          Bill Green, Delaware Valley Regional Planning Council
          Brenda Claybrook, DART

❖  "Issues and Applications for Medium Transit Systems" (Ballroom)
Moderator: Laurie Radow, APTA
Panelists: Linda Dowling, Suntran
          Jack Reilly, Capital District Transp. Authority
          Prianka Seneviratne, Utah State University

❖  "Issues and Applications for Small and Rural Transit Systems" (Steele Room)
Moderator: Larry Harman, L. J. Harman Consulting
Panelists: Boyd Thompson, ARC Transit
          David Gionet, Bloomington Public Transportation Corporation
Tuesday, August 15 (continued)

12 noon  ❖ Luncheon (Terrace)

  KEYNOTE SPEAKER:
  Richard Simonetta, APTA

1:45 pm  ❖ Results from Concurrent Sessions (Ballroom)
  Lyna Wiggins, Rutgers University
  Laurie Radow, APTA
  Larry Harman, L. J. Harman Consulting

  ❖ Planning vs. Operations: Areas of Coordination
  Melanie Braun, Minnesota Guidestar Project

3:00 pm  Break

3:15 pm  ❖ Transit CEO’s Panel Discussion of Next Steps in GIS
  Moderator: Walt Kulyk, FTA
  Panelists: Paul Toliver, Seattle Metro
            Richard Simonetta, MARTA
            Michael Townes, Pentran
            Paul Skoutelas, LYNX

4:15 pm  ❖ Conference Wrap-Up
  Walt Kulyk, Federal Transit Administration
  Ron Scheck, CUTR
  Larry Harman, L.J. Harman Consulting

4:30 pm  Adjourn
The full text was not available; however, following are representations of slides used in Mr. Dobson's presentation.

GIS-T
How Rand McNally Got Into the Mapping Business
- Trains, Timetables and Maps
- The Automobile
  - 1900 - 8,000 horseless carriages
  - 1910 - 1,000,000
  - 1915 - 2,000,000
  - 1908 - 1st paved street, one mile long, Woodward Avenue in Detroit

GIS-T
- 1907 - 1st pedestrian island SFO
- 1911 - 1st painted center line - M
- 1910 - 1st manual traffic signal, NYC
- 1914 - 1st electronic traffic signal, Cleveland
- 1915 - 1st no left turn, Buffalo
- 1913 - 1st drive-in gas station, Gulf, Pittsburgh
- 1914 - Gulf asks Rand McNally for maps
GIS-T

1909 - Photo-Auto Guides

1917 - Blazed Trails/Auto Trails

- Illinois AutoTrails Map was first to show numbered highways
- 1924 - first Rand McNally Road Atlas, and every year since
- 1925 - Uniform highway numbering

The Future

- We design the future the way we each want and expect it to be.
- We invent the future as we move toward it
- Under uncertain and dynamic conditions, you need two things before you can move forward:
  -- a sense of vision
  -- robust structure
- Today's talk will focus on the vision
- YOU must supply the structure

How May the Future Unfold?

- Legacy Systems - the long goodbye
- WorldNet - InterOperability
- High tech cornucopia
- The computer meets consumer/electronics
- Dominance of global technology/information/publishing keiretsus

What will be delivered?
In other words, what are the applications and markets that we might see?

Applications and Markets

- Electronic publishing/the Internet
- Electronic information systems
- Multimedia
- Intelligent transportation system
- Integrated messaging systems
- Advanced traveler information systems
- Personal and portable information systems
- GIS
Let's look at some of these markets that will influence GIS-T

The right place/right time?

To paraphrase the conventional wisdom used during the last election:

"It's money, school, and kids, stupid!"

Meaning?

- Households with children are more likely to have computers present than childless households
- PC penetration is highest among adult full-time students
- The actual income of the household influences the disposition toward PCs

More on Income

- Households with children:
  -- Above $25,000 - 50% likely to buy PC
  -- Below $25,000 - 70% not likely ever to buy PC
  -- 85% have a video game system
- No children
  -- 30% likely to buy PC
  -- 25% have video game systems
- Retired households
  -- 90% unlikely to buy PC

This Is A Problem

There are a lot of technophobes and even more people who cannot afford technology
What's the Installed Base?
- By 1997, it is estimated that 57 million homes will have PCs
- The majority of new PC sales are M PC ready, i.e. they have a double speed CD-ROM and a modem

What's the Market Profile?
- It is a pyramid capped by innovators (approximately .5M people), followed by early adapters (5M people) resting on regular buyers (50M people)
- The prevailing wisdom is that early innovators buy performance, the early adapters buy performance/value, and the remaining 90 percent of the market buys based on value/price

What's the market profile?
- It is believed in the software industry that this pyramid must be entered from the top

THIS is a problem, TOO!
- Technology is a classed society - how do we change that?
- Do people really understand how to use the technology?

Other Platforms
- The home as a market is thought to be divided into three segments:
  -- the game/play room
  -- the entertainment center
  -- the home office
- This means multiple platforms and multiple communications methods and lots of cost

Multiple Platforms?
This is also a problem
Information Superhighway

The Internet

- Based on the Internet:
  -- Begun by ARPA in late 1960s/
  primary responsibility today was
  NSF's and is now heading toward
  commercial service providers
  -- Purpose: to permit scientists
  working on federal research projects
  anywhere in the U.S. to tie into

- The Internet promises soon to be
  come the electronic foundation of
  the National Information Infrastruc-
  ture proposed by the Clinton admin-
  istration

- The principal use of the Internet
  was to transfer files from one
  location to another

- Usage patterns:
  - 45% research
  - 29% commercial
  - 10% defense
  - 7% government
  - 6% educational

- but do not overlook the significance
  of the web or of the use of MUDs and
  Moos

- The second greatest use was for
  electronic mail

- Today it is to sell things

- The goal for the system is to provide
  one gigabyte-per-second transfer rates
  (allowing one to transfer the complete
  Encyclopedia Britannica from New
  York to Sydney in one minute)

- And don't miss the MSN, AOL, or
  CServe connections -- editors are
  always needed

- Nobody is making money on the
  Internet. This is a problem, because
  it says technology is not as exciting
  to the general public as we think it is!
Integrated Communications Systems (ICS)

- A service that addresses the need to easily communicate and access information
  - private information and communication
    - database, FAX, e-mail, telephony
  - public information
    - on-line services
    - FAX, telephony, mail

Integrated Communications Systems, continued

- personal assistants
  - agents
  - service - banking, travel, traffic, shopping
- personalized
  - wireline
  - wireless
  - operating system and device choice

Integrated Communications Systems, continued

- Integrated
  - Single source for all messages and information
- Portable
- Dockable

Integrated Communication Systems

- And if you add GPS, you have the Killer App

How will all these things be delivered?

- Worldnet - global spanning digital highways
- RBOCS
- Cable
- Wireless - the realtime map update blues
- Wireline
- As today - in familiar places (but with batteries)

This is a problem, too, since you cannot buy a PDA that works

- Or find enough bandwidth to do anything interesting other than paging
In Familiar Places?
- The home
- The school
- The mobile office
- In your pocket
- Where you work

This Is Also A Problem
- Who is going to set these standards? Who is going to create these universal devices, develop open architectures? Who is going to provide access?

**ITS**

Architecture subsystems
- Remote access - kiosks, home or office computer, personal portable device
- Center - traffic/fleet management, ISP
- Roadside - traffic sensor, signal message sign, toll station
- Vehicle - mayday, navigation, toll, communications

**ITS**

Subsystem Terminators
- Users - center personnel, drivers, travelers
- Systems - roadside/vehicle systems
- Environment - environmental features such as air quality sensed by ITS subsystems
- Other subsystems - other vehicles, other centers

**ITS**

- Car nav/GPS 3 billion by 2000
- but the average compounded growth rate used to calculate these numbers is over 60 percent
- THAT'S A PROBLEM, TOO!

- The previous topics provide the rapidly changing environment within which GIS-T will either flourish or fail
- In large part, success depends on your ability to understand these trends and make products that work, FOR EXAMPLE:
**Beliefs—GIS-T will:**
- generate new activities not possible with previously existing technologies
- provide cost effective solutions to dealing with current problems
- enhance integrated problem solving
- make us more productive in current activities

But this will not happen unless we look at the world around us and understand what is happening and make products that work. We have looked at the world—let's look at products that work.

**PRODUCTS THAT WORK**
- Match customer needs
- Reduce customer anxiety
- Have these characteristics -- quality -- timeliness -- completeness -- utility

**HUMANS, GIS, AND COMPUTING**
Some speculations
- Ventriloquists - mediums - Fred the Agent and Harry the ventriloquist
- Pigeons and bad software design -- the fact that users will not give up a product or service should not be confused with proof that it is well designed

**HUMANS, MAPS, AND COMPUTING (HMAC)**
Some speculations
- The sensory and the intellect
- A computer is a television -- the part that computes is abstruse, it is a box that hums
- The balance between processing and image
• Universalists v. Particularists
  -- Universalists say that everything is driven by principle. Nothing happens by accident. There are no special cases.
  -- Particularists feel that the world is too complex to submit to simple rules. There are "distinguishing factors."

- This is why product interfaces are counter-intuitive and annoying
- And why they do not work the way you want them to
- And also why the GIS world is interested in "agents"
Some speculations (continued)
- One of the biggest lies technology causes us to believe is that there is only one way of doing things -- the way that the software is organized!
  -- This is called "flashcard memory"
  -- It leads to simplification and an inability to solve problems that do not meet the workflow

HMAC

Some speculations (continued)
- Interactivity
  -- Should be the distinguishing feature of electronic products since the computer is the only media capable of providing interactivity
    - But are error messages interactive?
  -- What would we want of useful interactivity?

HMAC

Some speculations (continued)
- Interactivity
  -- Should be the distinguishing feature of electronic products since the computer is the only media capable of providing interactivity
    - But are error messages interactive?
  -- What would we want of useful interactivity?

GIS

Some speculations (continued)
- What do we want in interactivity?
  - That's simple -- "we want"
    - Our expectation of control to be real
    - Creation of artificial personality

We Want GIS PRODUCTS That Act Like Humans

Dear Reader:

This is not the end of the story. The talk continues...
GIS

Concluding Issues
- Will GIS create specialists rather than generalists (point v. pattern)?
- Will GIS turn our attention from the task to the technology?
- Will GIS re-direct our competencies?
- Can we (as users) influence the course of GIS development? If not, we can answer "yes" to the questions above.

GIS

Concluding Issues
- Developers are twice as likely as the general population to be introverts and three times as likely to be classified as intuitive thinkers (Landauer 95)
- We are developers, you and me
- As developers, our job is to raise the productivity of the users we support.
Richard Simonetta

Chairman, American Public Transit Association (APTA)
General Manager of the Metropolitan Atlanta Rapid Transit System (MARTA)

I can't think of a more crucial time to hold a conference on the use of Geographic Information Systems to Enhance Transit Planning, Marketing, and Operations. We stand at a crossroads with respect to transportation policy issues and the technological advances of GIS. In fact, this topic is of such interest to our industry that Passenger Transport, APTA’s weekly newspaper, will devote most of its September 4 issue to transit agency use of GIS and other smart technology concepts.

The success of new light rail systems such as Metrolink in St. Louis, new commuter rail services, and innovative marketing as evidenced in Orlando demonstrates that transit can attract customers who would otherwise add to the congestion on the nation’s metropolitan-area roadways. Also, paratransit services associated with the Americans with Disabilities Act represent an expansion of our basic mission to serve the transit-dependent. But, growing numbers of elderly Americans will need improved transit service in the future, as will central city residents who want to reach suburban jobs and thousands who want to move from welfare to work.

How can today’s transit systems respond to this diverse range of customers needs when, with every new fiscal year, we are asked to do more with less? In an era of constantly rising customer expectations, how can we attract riders away from congested roadways? How can we reduce costs without sacrificing the quality that all customers demand? If transit agencies can incorporate the array of computer-driven technologies now at hand into an integrated system, we will be better prepared to satisfy this diverse group of customers more effectively than ever before.

The cost of GIS, which was prohibitive only a few years ago, has dropped enough to put this technology within reach of large and medium-sized transit agencies. Today’s general managers can no longer assume that this technology is reserved for the next generation of managers. We must recognize that GIS is here today. The question is not whether, but how GIS can serve the transit industry.

In addition to the drop in cost, we now understand that different computer-based technologies complement each other. We do not have to choose technologies independent from one another. It is not a question of GIS versus Intelligent Transportation Systems (ITS) or Integrated Intelligent Fare Systems. Rather, these can all be integrated components that work together.

One of transit’s marketing problems is that customers fear that we will waste their time. As planners, we know that if enough of our customers respond to this fear by driving alone, they will all waste more of their time stuck in traffic. With GIS, we can counter the auto’s perceived advantage in at least three ways. First, we can provide transit customers with real time information about the most efficient routes for their trips. Second, we can eliminate much of the uncertainty about how long they must wait for the next bus or railcar. And third, we can remind them about the traffic delays and tie-ups that they are avoiding by using transit.

What else can GIS do for transit systems? It can help us comply with federal legislation. Because it can manage location-referenced data, GIS can help us comply with requirements established under ISTEA, the Clean Air Act, and ADA. These laws require the integration of transportation data with
population, land use, and air quality models. Where previously transit systems needed limited sets of data, today no transit system can service without accurate extensive integrated data.

ISTEA’s call for major reforms in national transportation policy is one important reason we need to think about GIS. ISTEA strongly reinforced the need for transit systems to work with other agencies. With GIS and other computer-based technologies, transit systems can share and integrate data. The integrated data will allow the many local, regional, and state agencies to develop a coordinated implementation of the ISTEA management systems.

The application of GIS to ISTEA's management systems is just getting under way. GIS is also being applied to federal requirements under the Americans with Disabilities Act. ADA requires public transit systems to provide paratransit service for people who are unable to use regular fixed-route service because of their disabilities. A recent APTA survey found that the costs of providing ADA paratransit service is already more than $1 billion per year, and full compliance isn't required until fiscal year 1997. Original DOT estimates projected fiscal year 1997 costs at under $600 million. This is an expensive service. GIS will help many transit systems figure out how to transport people with disabilities more efficiently from paratransit origins to paratransit destinations. Improved productivity of ADA-related paratransit services can produce huge economic returns.

In addition to these public policy issues, in which GIS offers a location-based method to summarize many layers of information, it provides transit systems with a clearer way to communicate. There are several groups of people who benefit.

First are transit board members and other public officials. When discussing proposed schedule and fare changes, GIS provides a much more vivid depiction of anticipated results with the overlays of demographic zones, ridership levels, proposed new routes and other data categories. Answers can be given at the time the questions are raised, because the different layers of data are integrated and easily accessible.

Second, the public benefits. Changes in service are always difficult to rationalize and communicate to customers. When schedule changes are displayed as accurately as possible to include all portions of a route at different times of day and then overlaid with the route’s population, ridership levels and trip origins and destinations, it is easier for the public to understand the reasoning behind the proposed changes.

Third are transit agency employees. The new emphasis on customer service is just one facet of a new management approach that seeks to reduce the layers of authority and shift responsibility to employees who deal directly with customers. This approach depends on improved communication within the transit agency. Employees need to understand the kinds of information conveyed by GIS just as much as the public officials and customers do.

For all audiences, GIS has remarkable potential to move ahead in linking transit plans with regional growth plans, long-term land use, air quality, and other issues that are at the heart of ISTEA’s reform of federal transportation policy.

For GIS to be a successful management tool, it cannot be confined to a single office or department in a transit system. It must be developed across department lines, and reach out to agencies outside the transit system. Its integration capability enables GIS to serve as a valuable management tool.
According to Moore's Law, the information storage capacity of a state-of-the-art computer chip doubles every two years. The value of GIS technology for transit operations is sure to increase at a geometric rate as well. Just as networking turned personal computers from stand-alone number and word processors into much broader and more flexible management tools, GIS technology must undergo a similar transformation.

Under the heading of customer service, for example, many different departments produce individual databases. The coordination and integration of data allows faster response to customer inquiries. One department's digital base map of an agency's service area can be linked to bus schedules developed by another department. These layers can be combined with data from the local metropolitan planning organization or other unit of government. In the short term, customers receive more accurate and timely responses to their inquiries. In the long term, they benefit because transit agencies can do a better job of planning services and responding to needs.

A real-life, as well as real-time, example of a GIS application can be found in Atlanta's preparation for the 1996 Summer Olympics. Atlanta expects a large number of out-of-town visitors during the summer. MARTA's usual rail ridership of about 220,000 per day will increase to 600,000 or more during the 17 days of Olympic events. Plus, MARTA's peak bus operation will increase from approximately 60 buses today, to over 1500 buses during the games. For the Olympic Spectator Transportation System to work, MARTA must satisfy more customers more completely than ever before. We must get them to their events on time. We must transport them safely and securely. We must give them enough information to decide on the fastest route to each destination before they begin their trips. And we must provide this information in a way that is easy to understand and use. To help prepare for this surge of riders, we put our ITS project on the fast track. A project that would normally have taken several years to complete got underway earlier this year. It will be ready for testing next March and will be up and running in time for the July 19 opening ceremonies of the Summer Olympics. This $16.25 million ITS program includes five related efforts:

1. With the help of a Global Positioning Satellite system, MARTA planners are currently mapping 10,000 bus stops and 2,500 designated landmarks in Fulton and DeKalb counties.

2. Once this information is correlated with all Atlanta roadways for computerized mapping, MARTA's schedule information staff will be able to handle requests for route and schedule information more quickly and efficiently. This will be a way to test if we are meeting the rising expectations of our customers.

3. The same computer maps will be displayed at some 200 information kiosks that the Georgia DOT will install at visitor centers, rail stations, and other locations in Atlanta and throughout the state. These information kiosks will display information about congestion and accidents on Atlanta's major highways. Commuters can use the information to avoid certain areas or choose other routes. We will begin to train employees on the new system during the spring of 1996.

4. MARTA will install Automatic Vehicle Locators (AVL) in 250 of our buses so we can track them on the computer map to provide "real-time" information for passengers.

5. One hundred of the 250 AVL buses will have in-vehicle stop announcements, 15 buses will have automated bus passenger counters, and 10-15 bus stops will have changeable real-time message signs.
We know that not all of these efforts qualify as GIS. They comprise a range of new technologies that, integrated with GIS, will give the greater Atlanta metropolitan area an advanced, competitive transit system that responds to its customers.

Rather than duplicate GIS efforts now underway at MPOs and state DOTs or the efforts of other regional and state agencies, transit systems should, if at all possible, become part of a local or regional GIS consortium. Both voters and elected officials can appreciate the cost savings that result from this kind of coordination.

A consortium’s first effort may revolve around transportation. However, once the value of a regional cooperative effort is understood, there is no reason why a local GIS consortium cannot include information from the local agencies responsible to housing, employment services, health care, services for the elderly, veterans, and other needs.

Georgia DOT is taking efforts to develop GIS coordination on a regional basis, and MARTA is an active participant. One of the first and most critical policy issues is winning acceptance for GIS. Given the choice of purchasing a bus or a GIS system, transit managers and board members may choose the bus. It’s visible, and it reconfirms the agency’s primary goal.

It is hard to sell new, unfamiliar technology. The key is to explain how GIS manages and communicates information so that customers will receive better, more cost-effective service. With a system that ties GIS to AVL, transit vehicles can be tracked in real-time. Just as car phones provide a single driver with a direct link to the police and other emergency services, AVL offers bus drivers a direct link in case of emergencies.

The education of staff, not just management, is critical to implementing GIS and associated technologies. At MARTA, we have a process that involves a wide range of participants. This has lead to rapid acceptance and enthusiasm for the new technologies.

There are education requirements associated with any GIS effort. Often, the willingness of a transit system to initiate a GIS effort can be traced to the interest and dogged pursuit of one or a few staff members. However, once GIS is introduced into a transit system, the need for a highly technical, highly analytical staff will increase. GIS, with all its attributes, will require the staff managing it to know how to use these many layers of integrated data to the transit system’s advantage. General managers must make sure that transit GIS efforts incorporate the education of all staff to ensure its success.

We are just beginning to understand the policy aspects of GIS. This technology is pushing decision makers to look at information and make decisions differently. What is interesting is how relevant GIS is to three of the major developments that are driving transit today: establishing links between transportation and land use, responding to customers, and giving employees more responsibility.

A few years ago, APTA’s “Transit 2000” task force called on transit agencies to become managers of mobility. Transit’s success in taking on the broader mission will depend on its ability to use GIS, other computer-based technologies, and integrated databases. With these tools, we can successfully manage mobility in ways that benefit our economy, our environment, and the overall quality of life in our communities.
William E. Wiggins  
*Transportation Program Specialist, Office of Mobility Innovation, Federal Transit Administration*

The Federal Transit Administration (FTA) is making progress in its efforts to develop a National Transit Geographic Information System (GIS). In 1994, FTA launched a three-year effort to create a National Transit GIS. FTA's efforts in creating the National Transit GIS have fully supported the development of a GIS-based national transportation system for transit routes as a service layer element of a National Spatial Data Base Infrastructure (NSDI).

FTA's development of a national inventory of transit data bases will be available to the industry with basic route information. This information will consist of data on the fixed guideway and fixed bus route transit networks. The development of these spatial data bases will identify the geographic location and layout of transit guideway infrastructure (heavy and light rail systems, commuter rail, people movers, inclined planes, and high-occupancy vehicles (HOV) lanes), transit routes (fixed bus routes, and ferry lines), and intermodal transfer points (bus stops, stations, ferry terminals). Additionally, transit attribute data such as ridership, fare revenue, miles, and passenger miles will eventually be included in the system. These efforts will be the major components to the FTA's Transit GIS.

FTA projects the Transit GIS would offer transit managers the capability to perform peer group analyses and provide policy-makers direct and comprehensive data on existing transit inventories and project and program management information. As a management tool, FTA believes that the Transit GIS would augment its capability in transit planning, policy implementation and grant administration.

During FTA's Phase One development of the Transit GIS, the major thrust has been in identifying the public transportation assets of the country. FTA has collected a large volume of that information and has begun the process of creating the data sets that came from a variety of different formats, including paper maps and digital databases maintained by the transit agencies. Also during Phase One, and as part of a national outreach effort, FTA organized an industry steering committee to assist in its development efforts. FTA is also participating in a number of transit industry conferences and meetings to seek industry participation and support of the Transit GIS.
In Phase One efforts, FTA collected over 300 fixed route bus systems and completed the first version of the fixed guideway databases. The project has far exceeded the projected output, producing GIS databases for more than 2500 bus routes for over 140 transit agencies in the first two months. By July 20, 1995, transit bus networks for over 475 transit properties were represented in FTA's Transit GIS. By the end of this fiscal year (September 30, 1995), FTA expects to have transit bus networks for almost 600 transit agencies.

The fixed guideway data bases, which were completed earlier in the year, are being mailed to the industry for comment and review. When all the databases are completed, including the fixed guideways and transit bus networks, they will be provided to the local transit systems for their use.

For the first time, all the fixed bus routes of the country will have been converted to a standard digital map based on 1992 Topologically-integrated Geographic Encoding and Referencing (TIGER)/LINE files. There will be a GIS map available for all transit properties at the scale of the Census TIGER files. This will act as a base product that local agencies can "customize" further. The data could be offered in digital format.

For the first time, a transit GIS inventory has been completed. Transit agencies with and without bus route GIS databases have been identified. The types of GIS software being used and the nature of GIS applications being adopted at various transit agencies around the country are being identified and disseminated through this project. As that information becomes available, across the nation, transit properties will know, learn and benefit from each other's experiences in terms of GIS implementation.

FTA has used its GIS for a number of applications, including preparing situation maps on natural and man-made disasters that impact public transportation. It has also used its GIS to make national analysis of transit assistance and review compliance issues associated with the Americans with Disabilities Act of 1990. FTA has recently used the GIS to review the location of a number of demonstration sites to determine their proximity to other Federal assistance initiatives. In the area of transit planning, FTA is planning more integrated use of GIS.

FTA efforts in GIS have been designed to create a comprehensive, national inventory of public transit. This effort has also sought to put some identity on the mass web of public transit assets that exist and contribute to our national transportation infrastructure. GIS technology, a rather new tool, is proving to be an asset in transportation operations and planning. FTA's goal is to further its use and benefit to the transit industry.
Overview of GIS in Transit

by William Ball

Center for Urban Transportation Research

College of Engineering

University of South Florida

Significant potential exists for the use of Geographic Information Systems (GIS) in public transportation. Some transit agencies and transportation planning organizations have become extremely active in the use of GIS; however, the more active users have been typically within the largest transit systems and metropolitan planning organizations. Smaller planning organizations have been less likely to invest the resources necessary to establish a GIS that is adequate enough to result in significant benefits. This is primarily due to the fact that, in the past, the resources necessary to initiate and maintain a GIS system were rather significant. Only in recent years has the technology progressed to the point where basic GIS functions and applications have become more affordable for smaller agencies.

The creation of geographic databases for areas served by public transit can significantly enhance the transit planning capabilities of local transit systems, metropolitan planning organizations (MPOs), and other planning organizations. Potential benefits include cost savings resulting from increased efficiency in performing transit planning and analysis, increased precision in planning activities, the ability to assess the feasibility of more service alternatives, quicker response time for assessing the implications of service design and frequencies, more and better customer information for existing and potential patrons, and the ability to communicate the results in a format that can be readily understood by the public and decisionmakers, among others.

This presentation is based on a project conducted for the Florida Department of Transportation and was conceived to summarize and advance the state of the art in the use of GIS for enhancing the capabilities in transit planning and operations. Four major objectives were identified, including:
to identify uses for GIS in public transportation
• to compile an inventory of transportation-related GIS systems, databases, and applications in Florida
• to document uses of GIS in transit through literature review, survey results, and personal interviews
• to develop example uses of GIS that will be shared with transit agencies throughout Florida and the U.S.

The results of these efforts were summarized in the conference presentation. Copies of the technical report, "The Use of GIS in Public Transportation" (June 1995), also were distributed at the conference.
National Transit GIS Survey Results

by Larry Harman
L.J. Harman Consulting

In 1995, the Federal Transit Administration (FTA) conducted a survey of GIS use in transit by transit agencies and metropolitan planning organizations (MPOs) in the United States. The survey built up on a previous study conducted in 1991. The objective of the survey was to inventory the use of GIS in transit planning and operations throughout the nation in four areas:

• current use of GIS
• spatial data resources
• diffusion of GIS technology
• future plans for implementation

The 1995 survey greatly expanded the size of the population from the 1991 survey, but condensed the scope of the survey to a four-page interview instrument. In 1995, 269 entities were contacted, and 202 survey instruments were completed. This included 63 completed interviews from the original 71 contacts in 1991. The 1995 survey contacted all transit agencies and MPOs in urbanized areas with a population of 200,000 or above. In addition, 92 transit agencies without GIS were identified in urbanized areas under 200,000 and in non-urbanized areas of the country.

Responses to the question, “Does your agency currently use GIS?”, were grouped by fleet size (maximum peak hour vehicles). Nearly every transit agency (TA) with a very large fleet (500 and above) indicated that they were using GIS in some fashion. Below that threshold, GIS use dropped markedly. When questioned about future plans for using GIS, the picture did not change greatly. Particularly, small operators in the below-50-vehicle-fleet category showed nearly universal avoidance of GIS technology. Given the GIS products on the market in early 1995, their cost, skill level requirements, and supporting GIS data sets, it is easy to suggest why the GIS products have not penetrated the small bus operator market.

Of those operators and planning agencies indicating their use of GIS in the survey, the current and planned applications of GIS are extraordinarily diverse. In some cases, the application depends on the type of entity. Transit agencies predominate in areas related to transit operations, e.g. scheduling and run cutting, transit pass sales, fixed route and paratransit dispatching, and asset management (fixed facilities and bus stop inventories). MPO GIS uses are strongest in forecasting ridership, service planning, and development of map products.

An interesting pattern emerges when reviewing the TA and MPO future GIS implementation plans. The TAs show a strong interest in implementation of GIS across a broad spectrum of uses. Several areas are clear trend setters. All areas of operations planning are indicated in TAs future plans, especially service planning, run cutting, market analysis, and ridership forecasting. However, use of GIS in operations represents a strong departure from current use. These include customer information, paratransit scheduling and dispatching, fixed route dispatching, and automatic vehicle location and monitoring. The latter uses indicated the strong relationship between Advanced Public Transportation Technology (APTS) and GIS.
The sources of street data used by both the transit agencies and the MPOs show a great reliance on the Bureau of Census's TIGER line files, although there is a clear indication of both TAs and MPOs looking to other sources for street data.

The diffusion of GIS products into the transit planning market shows no domination of one vendor at this time. Clearly, ARC/INFO has a stronger presence in the MPO market, and TransCAD has a strong presence in the transit agency market. MapInfo sales have been equally strong in both markets. However, the numbers are too small, and too many product improvements are coming out in this highly competitive GIS market to make any far-reaching judgement about vendor preferences from this survey.
GIS as an AID to Transit Planning from Vermont to Puerto Rico

by James Wensley
Multisystems, Inc.

GIS has become an important analysis tool for transit planning, both for small and large transit systems and for a variety of modes and services. GIS aids analysis with graphical displays of information, including demographic and transit route ridership characteristics shown in conjunction with familiar map displays of the city and its roadways. In addition to graphical displays, GIS aids analysis by computing demographic characteristics for varying sizes of buffer areas around transit routes and stops. GIS aids in presentation of complex information for policymakers and the public because it is able to simultaneously show geographic location, color, and symbols to illustrate relationships.

The presentation included a variety of examples of GIS used in a series of transit planning studies throughout the U.S. All examples were produced using TransCAD 3.0. The examples included displays of census data done to aid service planning for small transit properties and examples of displays produced for major studies of fixed route services in San Juan and Cleveland and a study of alternative downtown rail terminals in New York. The New York example showed the use of Census Transportation Planning Package (CTPP) data to examine origins and destinations of work trips to Manhattan. An example from Boston illustrated the ability of GIS to access external data, in this case a database of survey results, and display travel patterns. Several examples from San Juan showed transit ridership data for route segments and stops on an accurate geographic display of one or more routes. The ability of GIS to aid in corridor planning studies was shown by examples of simultaneous displays of transit routes alongside the precise locations of major traffic generators or demographic data. Buffer areas of varying sizes then illustrate the locations within specified distances of transit. Finally, an example was shown of the use of GIS to generate transportation networks for demand modeling purposes.
Planning San Diego's Transit Systems Using GIS

by Linda Culp & Julie Jamarta
SANDAG

The San Diego Association of Governments (SANDAG) is the regional planning agency and the Metropolitan Planning Organization for the San Diego region. A major emphasis at SANDAG is to assist the region's transit operators in their planning and marketing activities by providing technical assistance and data including geographic analysis, survey research, and transportation modeling. For example, SANDAG integrates geographic information systems (GIS) and long-range transit planning models to produce passenger forecasts of light rail extension studies. Personal computer applications have also been designed to allow transit staff to directly analyze population and employment accessible to new transit lines. Most recently, SANDAG and San Diego's transit operators have been working together to design a desktop GIS application for direct use by individual operators. With this tool, operators have access to a variety of data which can be integrated for route planning, segment analysis, target marketing, and other applications. This paper presents two approaches to using GIS in transit planning. The first is a more centralized approach for planning applications such as transit ridership forecasting using SANDAG's GIS resources. The second is a more decentralized approach to short-range transit planning and marketing using desktop GIS directly by transit planners with the assistance of SANDAG.
Pinellas Suncoast Transit
Authority's Bus Stop Inventory

by Dennis Hinebaugh
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The purpose of this project was to develop a bus stop inventory database file to assist PSTA in responding to customer inquiries regarding the amenities and configuration of particular bus stops, and to aid in identifying ADA eligible bus trips. The first phase of the project included the collection of data at approximately 8,000 bus stops along 55 routes. This inventory included the collection of the following data:

1. Location
   - cross street
   - distance from intersection
   - nearside, midblock, farside designation
2. Distance between stops
3. Routes served by stop
4. Roadway characteristics
5. Bus Stop amenities
6. Pedestrian amenities

The project also included the entering of the bus stop data into a Lotus 1-2-3 spreadsheet, and the geocoding of bus stop location and route level data (headway, span of service) into MapInfo. The bus stop inventory data was also attached to the MapInfo file for easy access to the data while viewing the stop location.

Using MapInfo, bus route alignment and U.S. Census data were combined to show service area coverage, Title VI requirements, ADA requirements for service area, and a combination of elderly, low income, and zero-auto household data to show census tracts with a high propensity to use transit services. Other potential uses of the database and graphical representation include collection of Section 15 data, and the sorting of bus stop data by political jurisdiction.
An Enterprise GIS Database Design for Transit Applications

by
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Some advanced applications of GIS are emerging in the transit industry, such as automatic trip planning, paratransit scheduling, and real-time bus dispatch and control. Traditional project-oriented GIS databases that focus on individual applications are redundant and inconsistent. As more applications prosper in various departments of an agency, an institutional effort is needed to develop an integrative enterprise GIS to meet end-user requirements.

Although transit networks relate to highway networks, the relationships take a variety of complex forms. First, the level of transit service and the transit route layout must be specified. For the same route, not every segment has the same amount of service all the time. Transit service may deviate from the usual road links and may differ from time to time. Second, one stop may serve multiple routes, requiring a logical relationship among bus stops and various transit routes. Finally, many transit routes have express and limited services that bypass some transit stops. An enterprise GIS database has to be capable of handling the relational representations of spatial features such as routes, segments and stops, as well as the temporal service variations in scheduling. Furthermore, the transit network database has to relate to the underlying street networks, and may have to add non-street features, such as landmarks and shopping centers, through which the route may operate.

An enterprise GIS database has been developed in the Tri-County Metropolitan Transportation District of Oregon (Tri-Met). Our paper describes the development process of the general GIS database in Tri-Met while addressing those unique database design issues for transit networks. A mechanism to integrate spatial features of route, segments and stops, and temporal service variations is developed. The dual referencing systems of stops, linear referencing, and location referencing are addressed to link stops to different routes and to relate transit network information to the underlying street system. Dynamic segmentation used to relate distance-referenced stops to individual route paths is also discussed.
Use of FTA's National GIS Transit Database
for Guideway Transit Demand Analysis

by
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L. David Shen, Ph.D.
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Department of Civil & Environmental Engineering
Florida International University

The Federal Transit Administration (FTA) is conducting an ongoing, three-year project to develop a National Transit GIS Database. The National Transit GIS enables immediate access of guideway inventory and selected data on fixed guideway transit facilities.

Currently, the Lehman Center for Transportation Research (LCTR) at the Florida International University (FIU) in Miami, Florida is conducting a project to study demographic impact on urban guideway transit demand. We use TIGER/Line files from the U.S. Census Bureau, 1990 national census data, and FTA's preliminary National GIS transit database with TransCAD running on a microcomputer. Geographic boundaries of the census tracts are extracted from the TIGER/Line files, and demographic and socio-economic data are extracted from the census data on CD-ROM, while spatial information of guideway transit stations are provided by FTA's database.

In our paper, we present the current status of LCTR's project and discuss the hands-on experience with the preliminary FTA national transit database. We also discuss the wish lists for FTA's National Transit GIS project.
Case Studies of GIS in Action: Minnesota's Guidestar Project

by Melanie Braun
Minnesota Department of Transportation

Travlink is a one-year public transportation federal operational test that began in December 1994. It uses Computer Aided Dispatch (CAD), Automatic Vehicle Location (AVL), Global Positioning System (GPS), and Geographic Information Systems (GIS) to track 80 of the Metropolitan Council Transit Operations (MCTO) fleet of 800 buses. This is of great benefit to MCTO operations and planning efforts. For Travlink, it allows real-time schedule information and other traffic and transit information to be shared with commuters. This is done through electronic signs, computer monitors, interactive touch-screen kiosks and an on-line system for use in homes or offices. Part of the test includes recruiting several hundred commuters from Twin Cities western suburbs to use the on-line system.
Case Studies of GIS in Action:
Combining Fixed Route Customer Information, Trip Planning, and Paratransit Scheduling

by John Attanucci
Multisystems, Inc.

Multisystems, Inc. has recently developed and implemented an integrated Customer Information/Trip Planning, Paratransit Management and Scheduling, and GIS application package for the Greater Cleveland Regional Transit Authority (GCRTA). Based on a full-featured transportation GIS, this system is the first fully-integrated application in the transit industry to combine paratransit/ADA service management with fixed-route telephone-based customer information within a common modifiable GIS environment. The Cleveland package was developed using the newest release of TransCAD -- a Microsoft Windows version -- designed to allow third parties to use it as a development platform for building transportation GIS-based applications. The vast majority of the application was developed using TransCAD's "macro" programming language, which provides developers, and even users the ability to customize user screens, set-up new push button icons and dialog boxes, and produce reports using standard Windows application conventions.

The paratransit/ADA service management module was put into full production use at GCRTA in September 1995 while the customer trip planning database was being input for daily use in early 1996. The paratransit scheduling system allows a reservationist to automatically schedule a "dual-mode" trip (a fixed-route linehaul trip with paratransit feeder and distribution services) to more economically serve long crosstown ADA-eligible trips. Theoretically, the combination of fixed-route customer information with ADA reservations and scheduling could allow the telephone information/reservationist staffs to be combined within a transit agency.

TransCAD can also be used by an agency's transit planning staff to assist in service planning, ridership analysis, thematic displays, and is ideally suited for demographic analysis of service corridors. This GIS tool can also be used by various departments within the agency to track bus stop locations and amenities, produce custom marketing materials, provide internal and external performance monitoring analyses, and serve as a base map for an automatic vehicle location system. This next generation of GIS-based products represents a major leap forward in transit information technology.
Case Studies of GIS in Action:
GIS in Transit:
Applications and Lessons Learned

by
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Center for Urban Transportation Research
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The use of geographically referenced data and Geographic Information Systems (GIS) in transportation planning has undergone rapid expansion. This growth has been facilitated by the computer hardware and software technological advances that place the use of geographically referenced data at the convenience of virtually anyone with a personal computer. This proliferation of the use of geographically referenced data to conduct transportation analyses may be accompanied by a limited perception of the constraints associated with developing geographic analytical systems suitable for transportation planning. A better understanding of these constraints is paramount to the optimal use of such systems. GIS allows transportation professionals to view data in ways not previously possible. Viewing GIS as simply a new tool, however, is not appropriate. GIS is quickly becoming a way of thinking in a spatial and temporal manner which was not possible in the past.

Although GIS does represent data graphically, using such systems simply provides graphic information is an inefficient use of time. The distinction between geographically referenced data and geographic information systems is used to draw attention to a common practice of using geographic (geo-graphies) images. Geographic information systems have been described as "specialized computer and software designed to capture, integrate, analyze, synthesize, and present geographically referenced data." The true value of GIS is to be found in its capabilities of capturing, integrating, analyzing, and synthesizing data in a spatial context.

The GIS operations of the Center for Urban Transportation Research (CUTR) are developing at a brisk pace. At last count, there were 17 billable projects that involved significant GIS applications. The benefits of spatial data analyses include the capability of planners to view and analyze data in relation to the landscape over which it occurs. By making modifications to queries, the same data can be viewed in different measures of space, such as census tracts, traffic analysis zones, MPO planning zones, or other divisions. Through the simultaneous use of multiple layers of data, different data sets can be compared while using different divisions of space. Layering also make it possible to explore time and space relationships of data sets. Considerable tradeoffs between time, accuracy, and future utility of these applications have been made during the life of these projects.

The current applications of GIS in transportation can be compared to that of early word processing. In the move from typewriters to computers, word processing was viewed as a more efficient means of automating the writing process. Few users today speak of using computers to simply "type." Even the term "word processing" is being displaced by such terms as "word smithing" and "desktop
It is the capabilities of computer hardware and software applications that allow the user to manipulate written words in a manner that exceeds mere automation. Shoshana Zuboff, in *In the Age of the Smart Machine*, refers to this process as "informating." Likewise, the capabilities of GIS have expanded both how we learn and what we are learning.

This paper will discuss the GIS lessons learned at CUTR, a transportation research institute, as related to the various applications. Inherent in this learning process are several information management implications that will be of interest to other GIS users and other practitioners who are involved in data-intensive research and applications.

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2. Shoshana Zuboff, *In the Age of the Smart Machine*. 
Case Studies of GIS in Action:
MARTA's Intelligent Transportation System:
A Showcase for the 1996 Summer Olympic Games

by
Wayne Sarasua
Robert Awuah-Baffour
Diana Estrada
William Bachman
Georgia Institute of Technology

The Metropolitan Atlanta Rapid Transit Authority (MARTA) has contracted with a number of consultants to implement an Intelligent Transportation System (ITS). The purpose of this system is to create a showcase of technology which will be in place in time for the 1996 Summer Olympic Games and to leave with MARTA a legacy which will improve performance and increase ridership in the long term. The project focuses on putting in place at MARTA three areas of technology: 1) Advanced Traveler Information Systems that provide an automated means of assisting MARTA patrons with travel information, 2) Automatic Vehicle Location/Monitoring (AVL/AVM) for tracking bus positions in real-time, and 3) an interface with Georgia DOT's Advanced Transportation Management System (ATMS) so that up-to-date traffic and road condition information can be made available to MARTA. This presentation will describe the activities that have taken place to date in the planning, design, and implementation of the MARTA ITS. Particular emphasis will be given to the GIS role on this project, which is to provide support to the customer service application. The benefits of using GIS in this capacity will be addressed. Discussion on how Global Positioning System technology is being used in the development of the bus stop inventory will be provided.
Case Studies of GIS in Action: 
Using GIS to Identify Locations with the Greatest Potential for Increased Transit Ridership

by
Victor Henry
Baltimore Metropolitan Council
Stuart Sirota
Maryland Mass Transit Administration

Our paper presents how GIS was used in support of a marketing initiative to increase ridership on the Central Light Rail Line in Baltimore, Maryland. The primary objective of the initiative was to develop a marketing strategy that identified geographic locations in which to target marketing efforts. GIS was identified as an ideal tool to perform spatial analysis and yield the desired results. The analysis was performed by importing several existing data sources into the GIS. These data sources included passenger survey data, census data, and local demographic forecasts. Ultimately, the GIS was used to isolate individual transportation analysis zones that contained the greatest potential for new ridership. GIS also created dramatic color-thematic maps used to present the findings of the study to senior management.
The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) underscored the need for applying new technology to transportation decision support systems. Recognizing the urgency imposed by the legislation, Graphic Data Systems Corporation (GDSC) has developed an approach that provides for the timely development and implementation of integrated business models for the ISTEA management systems: bridge, pavement, safety, public transportation, intermodal, and congestion (traffic monitoring is also included). With the business models in place, transportation managers can develop comprehensive work plans to meet the ISTEA requirements -- work plans that eliminate redundancy and inefficiency and that recognize the integration requirements implied by the legislation. The business models are developed through a rigorous and systematic review of the processes and data currently used within the agency using time-proven tools and techniques of logical modeling.

Challenges

The challenges facing the agencies are many and include the following:

- Meeting the ISTEA Management System's deadlines.
- Having open database, GIS, and management systems without compromising accountability of persons responsible for each system area.
- Establishing criteria for infrastructure investment.
- Being responsive to citizens; urban and rural transportation needs.
- Providing old and new employees with system "ownership".
- Obtaining funding and financing for systems implementation.

The Business Model

The key to effective analysis is the building of a logical model of a system that meets the users' requirements and that takes into consideration the systems currently in place. This logical model, plus a statement of objectives and constraints, makes up a statement of requirements. The value of such a statement is that it expresses what the systems will be required to do without precluding how the systems should be physically implemented. Due to the simplicity of the visual presentation, the logical model also provides non-technical users with an overall understanding of the system and how the various components fit together.

This paper describes the process of logical modeling and workplan development for ISTEA requirements.
The GIS/ISTEA Pooled Fund Study:  
An Approach to Transportation Planning

by
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Geographic Paradigm Computing, Inc.
Thomas E. Henderson
New Mexico State Highway and Transportation Department
Juan Espinoza, Jr.
Sandia National Laboratories

The GIS-T Pooled Fund Study was initiated in November, 1993 to provide an integrated, modally unbiased, and jurisdictionally neutral approach to meeting the requirements of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) for management systems, metropolitan planning, and statewide planning. This was to be done within the context of GIS. The first phase of the study produced an information architecture that achieves this objective and goes beyond simply the ISTEA requirements to include the entire enterprise of transportation planning. The second phase moved a portion of that architecture into analysis and preliminary design using object-oriented modelling techniques. The final phase will produce a variety of demonstrations, simulations, and implementations, including incorporation of the information architecture defined by the study into an actual strategic plan for one department of transportation.

The study is sponsored by 40 states, the District of Columbia, and nine private sector firms or consortiums. New Mexico serves as the lead state. The private sector sponsors have played a key role by providing review and input during the study and by adapting the resulting architecture to their own products and services for demonstration purposes. An exhibition to demonstrate the use of the study results by both the public and private sectors were held in conjunction with the American Association of State Highway Transportation Officials (AASHTO) Annual Meeting in Norfolk, Virginia October 28-31, 1995.
Dynamic Visualization of Network Flow in GIS-T

by
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Sang-Ki Hong
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The Ohio State University

An enormous amount of road network flow data are generated from various sources on a daily basis under urban settings. Where there is a movement of people and goods, flow data are produced, and these flows occur through a series of nodes and links. The direction and the volume of these flows have great impact on the spatial organization of the places where the movements are taking place.

Public transit vehicles, with the exception of those running on exclusive right-of-way, share the same roadway network with private automobiles, and their operation is affected by network conditions. However, real-world networks consist of hundreds or thousands of nodes and links. This inherent complexity and the sheer volume of data make it very difficult to analyze and understand the processes behind these network flows. For a large data-set such as network flow on urban streets, visualizing various characteristics of the data has been regarded as one of the most efficient ways to explain and explore the data.

The need for visualization leads us to the relatively new area of dynamic visualization, which is a rapidly developing field aided by the explosive growth in computer technology and the recognition of human ability to process visual information. Effective visualization tools can benefit transportation engineers who are concerned with the network flows as a result of modeling procedures. We present how dynamic visualization can be implemented for network flow data on urban streets.
Issues and Applications for Large Transit Systems

Brenda Claybrook
Dallas Area Rapid Transit (DART)

The paper presented at the conference, GIS in Transit at Dallas Area Rapid Transit (DART), gives a general description of transit applications that can benefit from the use of GIS technology both as a standard operating platform and also as a management tool for analysis. Applications that are currently supported and/or in development at DART are detailed along with guidelines for development. Graphic and non-graphic data elements are discussed, along with sources for various data sets, data collection processes, maintenance of data sets, and data integrity and credibility. The need for standards (data and transfer) and the difficulties encountered when working with standards are explored, along with the challenges and benefits of implementing GIS in a transit environment.

For additional information, refer to the DART case study in the Case Studies section of these proceedings.

William L. Green
Delaware Valley Regional Planning Commission
Philadelphia, Pennsylvania

GIS offers an expanded opportunity to consider a number of important variables in planning transit service and routes.

Traditionally, population density has been most widely relied upon to suggest that an area is "transit friendly," and, thus, likely to have sufficient ridership to justify the service. This logic better served planners when employment and commercial destination were more predictably concentrated in relatively few areas. Current spatial disbursement of both employment and commercial activity to an increasing number of suburban centers suggests consideration of additional variables such as land use, employment and commercial center locations, and journey-to-work data. Such analysis of multiple, spatially-oriented variables is ideally suited to GIS technology.

GIS allows ready, super-imposition of existing and proposed transit service on land use to see if routes conveniently serve less dense but larger suburban residential areas. Combining this view with the location of employment/commercial centers and commuting patterns from journey-to-work data helps determine the answer to this question: Is the transit service accessible, and does it serve common and/or multiple rider destinations?

While the results of such analysis will vary in different parts of the county, clearly future transit service planning will need to better consider the spatial realignment of employment/commercial activity as well as less dense suburban residential locations. GIS is ideal and will likely become the transit planner's new "best friend."
The following are reproductions of the slides used by Ms. Neuerburg in her presentation.

**King County Metro Transit**
- Service area = 2,128 square miles
- 33 cities
- Service area population = 1.6 million
- Total active fleet = 1,141
- Annual ridership = 71.6 million

**Transit Service & Facilities**
- 200+ routes
- 2,500 route miles
- 40 million annual vehicle miles
- 9,000+ bus stops
- 1,200 bus shelters
- 90 park-and-ride lots

**Non-Transit Service**
- Vanpool van in service = 530
- Vanpool ridership = 2.7 million
- Ridematch applicants = 9,000
- Paratransit ridership = 480,000

**GIS History at Metro**
- 1982 - In-house GIS development
- 1990 - Obtained funding for new efforts
- 1991 - Reg. street map update project
- 1992 - GIS alternatives analysis
- 1993-5 - Core GIS built
- 1995+ - Additional use applications
GIS Development Phases

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<tr>
<th>Phase</th>
<th>Duration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain funding</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>TOTAL</td>
<td>42 mths.</td>
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</table>

Issues that Drive a Need for GIS

- Widespread use of geographic information in transit
- Redundant data management
- Inefficiencies due to multiple systems
- Higher Expectations for quality visuals and analyses
- Meeting new requirements cost-effective, e.g., ADA

Key GIS Application Areas

- Planning Examples
- Ridership
- Travel time
- Park-and-Ride lot usage
- Employer employee locations
- Survey results
- Census/demographics
- Facilities and right-of-way

Key GIS Application Areas

- Mileage tracking
- Vehicle tracking
- Operator driving Instructions
- Security incidents
- Accident locations

Organizational Issues

- Educational clients and decision makers
- Costs/benefits
- Internal and external support
- Effective project management structure

Organizational Issues: Strong internal and external alliances and support

- Regional and internal data sharing
- Create cost savings
- Create political successes
- Create "win" for all participants
Organizational Issues:
*Effective project management structure*
- Business client representative
- Information systems technical project manager
- Balanced business and technical needs
- Create "win" for all participants

Technical Issues
- Large data sets
- Data conversion
- Link to street network
- Design trade-offs
- Systems Integration
- Desktop set-ups

Technical Issues:
*Good, cost-effective design*
- Data can be maintained by most "vested" user
- Underlying network can be improved without impacting attributes and applications

Acceptance and Maintenance Issues
- Alignment of client and development team visions
- Agreement on test plans and acceptance criteria
- User interfaces and training
- Coordination of data maintenance

Top 10 Success Factors
- Educated clients and decision makers
- Clear rationale for investing in GIS
- Strong internal and external alliances and support
- Effective project management structure
- Common vision

Top 10 Success Factors
- Effective project planning and management
- Good, cost-effective design
- Training (developers, O&M staff, users)
- Communication and integrity
- Have fun!
Issues and Applications for Medium Transit Systems

Linda Dowling  
*City of Albuquerque  
Transit and Parking Department*

The City of Albuquerque Transit and Parking Department has joined with the Sandia National Laboratories (SNL), through the federal earmarking of funds, to use SNL's hazardous material tracking GIS software as the basis for a full-function, client-sensitive tool for the city's paratransit services.

The technical interest of this project is the great advance of technology expected as GIS-T is combined with the exotic dispatch and scheduling environment of a rapidly-growing paratransit function of the City. Paratransit, the door-to-door pickup and delivery of impaired individuals, is the mandate of the Americans with Disabilities Act (ADA). While commercial software tools exist, none have been identified to be simultaneously sensitive to ADA requirements and user-friendly.

The further scope of this project is to utilize these maps and city travel information to feed fixed-route deviated scheduling and ADA-authorized mainstreaming of paratransit clients. Expectations of the next phase include offering a neighborhood circulator system, without regard to ADA eligibility, as a fixed-route feeder system.

The project has a short-term emphasis, with completion slated for May, 1996. Successful completion should lead to future funding for more advanced, customer-accessible GIS for travelers in New Mexico and reaching out into the North American Free Trade Agreement (NAFTA) corridor.

Jack Reilly  
*Capital District Transportation Authority  
Albany, New York*

In early 1995, the Capital District Transportation Authority initiated a GIS project in cooperation with the New York State Department of Transportation, the Capital District Transportation Committee, the region's metropolitan planning organization, and the Capital District Regional Planning Commission. The objectives of the project were to support a number of policy, marketing, and operations planning functions at the agency. Further, the system was intended to compliment a number of other performance measurement systems used at the agency including ride check software, and the use of farebox data.

The project is partitioned into three phases. The first phase is data collection. In this task, we have created three databases. The first database is a bus stop database that includes a number of characteristics of each of our 4,000 bus stops, including location, routes that serve the stop, etc. We have prepared a route database that includes characteristics of our routes such as span and...
frequency of service and performance measures such as revenue to cost ratio. This dataset also includes the key generators on the route. Finally, we have a database of census data that includes a number of individual and household characteristics of each of about 500 traffic analysis zones in the transit district. This activity is nearly complete.

The second phase is data display. We propose to display the performance attributes of our routes on maps and boarding and alighting data by stop. Our objective is to develop traffic flow maps comparable to those used by highway planners. Further, we expect to develop a number of thematic maps showing key demographic variables of each of the traffic analysis zones.

For the third and final phase, we wish to use GIS to support the development of a number of social performance measurements of our transit system, including the percent of households with access to the transit system, the percent able to access a regional shopping mall, etc. This activity will drive the development of service standards for the transit system and assist in the development of a marketing plan.

The expected duration of this project is about one year.
Issues and Applications for Small and Rural Transit Systems

Boyd Thompson
ARC Transit
Palatka, Florida

ARC Transit's AVL project was funded by the Florida Department of Transportation in May, 1994 with $40,937 in state Service Development funds. Fourteen (14) vehicle modules, the AVL base station, and several vehicle radios were purchased with the grant. Management Analysts in Ormond Beach, Florida served as contractor with Hyperdyne of Alexandria, Virginia and Canyon Development Group of Tucson, Arizona subcontracted to Management Analysts.

The system consists of an onboard credit card reader, digital odometer, GPS receiver, and radio interface. Data is transmitted from the vehicle's radio to the transportation systems base station where it is received by the base PC 486 computer. Voice and data share the same channel.

In Florida, Medicaid recipients are issued a credit card identification. This card is scanned into the reader by the driver at the time that the Medicaid passenger boards and exists the vehicle. As a result, time, passenger identification number, vehicle number, latitude, longitude, and odometer reading are transmitted to the base computer. This data is then automatically collated in the billing computer with trip records, manually edited, and then transmitted on-line to Medicaid's fiscal agent.

For the use of dispatch, real-time position of the vehicle is acquired by the base station's automated poling of the vehicle roster. Every three seconds, the base computer and radio query the next vehicle on the roster to determine its location. In response, time, vehicle number latitude, longitude, and odometer reading are transmitted from the vehicle to the base computer and map displayed on the monitor.

Development of the system remained in the test phase through August, 1995. All project test objectives were met, and as of September, 1995, the system is being phased into operational use.

The GPS/card reader make it possible to monitor the duplication of vehicle time and mileage within a system. This level of duplication relates directly to the efficiency of passenger loading. By allowing for the correction of a system's performance figures to a standard m.p.h., cost allocation enables comparisons between urban and rural and between service formats. This makes it possible to accurately state what a given time and mileage should cost.

If we know that we have achieved the highest possible passenger loadings in conjunction with the lowest possible vehicle costs, we know that the service delivery system is at peak efficiency; we know that we have achieved coordination.
The Bloomington (Indiana) Public Transportation Corporation operates two services, Bloomington Transit fixed route bus service and BT Access demand response service for persons with disabilities. Bloomington is located in south central Indiana and is a regional government, industrial, and service center for the area. The city, one of the fastest growing in the midwest, has a population of 62,000 year-round residents, and is home to Indiana University, one of the largest in the country, with 35,000 students and more than 7,000 faculty and staff.

Bloomington Transit operates a fleet of 19 buses and provides about 600,000 miles of service per year. The system will provide a little more than a million passenger trips in 1995. BT Access is operated using four vans and will provide about 18,000 trips this year to the system's 500 registered users. The BPTC is managed by McDonald Transit Associates, Inc. headquartered in Fort Worth, Texas.

Indiana University also operates a bus service serving campus locations, and Monroe and Owen counties operate a third transit network to provide rides into the city from surrounding areas. Between the three operations, more passenger trips are made by local transit in Bloomington each year than in any other city in Indiana, except Indianapolis.

Over the past several years, the City of Bloomington, in combination with Monroe County and Indiana University, has developed a GIS database for the City and a fringe immediately outside the City's boundaries. The City chose Genimap software for developing the layers of data for its streets, parks, utilities, zoning, and a host of other areas. In addition, the system was designed to accommodate layers of data to be developed by the private sector, including such entities as telephone, electric, gas, and cable utilities. And of course, the City made available access to the GIS for local public services such as the BPTC.

Traditionally, most transit planning for the urbanized area has been performed by BPTC staff by a means of a pass through agreement with the local MPO for Federal Transit Administration 49 U.S.C. 5303 (Section 8) planning funds. In 1994, the BPTC added a GIS development element to that agreement. It was the idea of the BPTC staff that customer information accuracy could be measurably improved if bus schedule information were available by pointing at a bus stop on a computerized map instead of looking up key time points in a timetable and estimating the elapsed time to that street corner or stop. Additionally, such a system would drastically reduce training time for those new staff giving customer information over the phone. Or, more to the point, at Bloomington Transit where a lot of job sharing takes place, it would allow anyone the ability to answer a scheduling question with precision.

In the fall of 1994, the BPTC hired an Indiana University graduate student to digitize the system's fixed bus routes. First, the bus routes were mapped out in color coded fashion. Then, BPTC staff developed Microsoft Excel spreadsheets in which to code the bus stop and schedule data. Each street corner was named in a fashion to be recognized by Genimap and scheduled bus pickup times at each stop were figured to the minute throughout the entire day. Formulas were used where possible. Data fields were then transcribed via ASCII text file, and a user friendly menu system was designed.
In the meantime, hardware specs were developed for the new system. Because of cost and location constraints, the system would stand alone (and not be connected to the City of Bloomington's GIS network). The system operates on a Hewlett Packard 715 UNIX computer. Updates to the underlying map layer are simply transferred from tape. Updates to the Bloomington Transit application are done directly at the dedicated workstation.

The result was impressive. Users can look up a location by address, intersection, subdivision, major building name, or by point and click. Once zoomed in on, the user clicks on a node at the intersection, indicates bus route direction desired, and is presented with a list of all scheduled times for that route and direction to the exact minute. If desired, the user can then print a "personalized" bus schedule for the customer. Additionally, the user can tell the customer exactly how far the bus stop is from their dwelling, right down to the nearest foot.

Other applications the system is used for include the ability to query by specific address, whether that address is within the incorporated city and therefore within the BPTC's service district. This is important, because BT Access trips must be limited to the district. Also in development is an application using the GIS for inventory of bus stop signs, shelters and other "street furniture," and a permanent home for passenger count data by bus stop. In addition, entry of scheduling data for the three bus systems is in development, allowing for a central telephone information service with a cost sharing arrangement. Future uses also include easing transit route planning by using census and zoning data already encoded, and the addition at some point of a real-time AVL system to further improve the accuracy of customer information.

The cost to date of the entire system, including hardware, software licensing, software maintenance fee, and the labor cost for system development is about $12,000.
Transit CEOs' Panel Discussion:
Next Steps in GIS

In a panel discussion moderated by Walt Kulyk of the FTA's Office of Mobility Enhancement, executives of four transit agencies shared their views on the next steps needed to move GIS forward in the industry. Panelists included Richard Simonetta, Chairman of the American Public Transit Association (APTA), and General Manager, Metropolitan Atlanta Rapid Transit Authority (MARTA); Paul Skoutelas, Executive Director and Chief Executive Officer, LYNX, Central Florida; Michael Townes, Executive Director, Peninsula Transportation District, Hampton, Virginia; and Nancy Neuerberg representing Paul Toliver, Director, Transportation Department, Seattle Metro.

Simonetta placed GIS within the context of a transit system's decision-making needs. He noted that the industry has made great technological strides in the past 25 years and that GIS will allow transit to provide even better service in the future. He drew upon his experience at MARTA to show ways GIS can help the general manager set the organization's direction, ensure that staff members understand the agencies goals, and provide support to achieve those goals.

Simonetta talked about the role GIS plays in MARTA's strategic plan to show how new technology can benefit a transit agency. He described how GIS and Intelligent Transportation Systems can support each of the five major initiatives contained in the strategic plan:

- **Customer orientation** can be enhanced by using GIS to provide a database for understanding user travel behavior and desires. This information allows the agency to be more responsive to changing traveler needs.

- As part of outreach and education efforts to community leaders and groups, incorporating data into GIS and using other visuals can aid MARTA's *transit advocacy* initiative.

- The incorporation of GIS and ITS technology into the agency can contribute to *employee development*, lead to better understanding of agency operations, strengthen skills, and improve productivity.

- **Continuous quality improvement** can benefit from GIS monitoring of system elements, identifying weaknesses and taking follow up action to provide better service. By being focused, data collected from GIS can help ensure that MARTA is on target.

- GIS can play a role in *business management* by enabling policy boards to do a better job. Better reports produced in a timely manner can help decision-makers.

Townes also noted that system planning and monitoring has changed dramatically over the past 25 years and that GIS and APTS are two technologies that hold the promise of great benefits. The unique and rapid analysis capabilities of GIS are very useful to the general manager in dealing with situations as they develop. He cited the importance of carrying out a cost-benefit analysis before implementing GIS or APTS systems. At Pentran, GIS has hastened the response time to customers who call in for route and schedule information; improved scheduling of paratransit vehicles, which has increased the number of rides available to potential users; and enhanced analysis of demographic characteristics for planning and for service revisions and adjustments. He also stated...
that Pentran is exploring the possibility of using GIS/GPS real time data at information kiosks located at transfer centers.

Townes stressed that there is a need for standards to guide the implementation of GIS and that smaller systems, in particular, need guidance on GIS hardware and software. He cited the fast-paced change of GIS technology as being a major concern. Echoing Simonetta, Townes said that if GIS is to be a useful management tool, it must help transit systems meet customer needs, serve as an advocate for transit, and provide for continuous quality improvement, particularly in light of recent budget cuts.

Skoutelas stated that the transit industry has approached GIS and AVL with some skepticism, having been affected by previous wrong decisions on new technology. He also said that his system, LYNX, has perceived GIS as an integral part of their vision for the future. A major thrust of this vision is the development of a comprehensive transportation system for the three-county area LYNX serves (Orange, Seminole, and Osceola counties), whereby LYNX would be both a provider and coordinator of services, including bus and rail transit, paratransit, ridesharing, vanpooling, and perhaps even taxi and private charter vehicles.

Skoutelas addressed the question of how GIS contributes to the mission of his agency. He believes that the improved system performance will help ensure that LYNX is perceived as an important community asset. One of the planned uses of GIS/ITS is to provide real-time customer information based upon an AVL system. He further explained that he perceives GIS as contributing to the agency’s three major strategies: targeting and developing market niches; being non-traditional in designing and marketing services; and changing others’ perceptions of LYNX.

Neuerberg, who coordinates GIS operations for Seattle Metro, suggested that new and innovative strategies need to be explored. Incorporating GIS technology into route simulation for training of bus drivers was one example she discussed. Another example was combining AVL and GIS to monitor on-time performance information for operations management and for transit center displays of schedules and real-time information for customers.

The panelists pointed out that board members and the public may resist change. However, as GIS, ITS and other technologies improve service delivery and demonstrate benefits that justify investment, greater acceptance will, and has, resulted. Interest in, and support for, these technologies is growing. Financial limitations create the biggest resistance to incorporating GIS into transit operations. The general managers stressed that investment in GIS must be explained as a way to enhance service; improve cost-effectiveness; and contribute to better air quality, economic development, and overall quality of urban life.
Conference Wrap-Up

The conference concluded with brief comments from three of the original convenors: Walt Kulyk of the Federal Transit Administration (FTA); Larry Harman, formerly with EGG Dynatrend and now an independent consultant; and Ron Sheck, Senior Research Associate and Intermodal and Guideway Research Program Manager at the Center for Urban Transportation Research (CUTR).

Kulyk, who has led FTA's effort to build the National Transit GIS database, congratulated CUTR on holding an outstanding conference that resulted from a combination of good organization, quality of participants, and an atmosphere that encouraged an interchange of information, ideas, and viewpoints. Kulyk gave a federal perspective on several important points:

- The importance of "getting a handle" on standards, including common agreement on terms and data collected.
- The incredible strides vendors have made in the last year in developing software products or the industry. The need for us to encourage vendors to talk with each other and to meet the industry's needs.
- The need for better exchange of information among members of the transit industry to share the very innovative things they are doing, not just in the area of GIS, but of other APTS technologies. Continuous dialog is crucial to the improvement of our industry.
- The need for feedback and input on the National Transit GIS. When those in the industry help, we are better able to help you as an industry. There is a need to work together to develop a plan for maintaining this system.

Larry Harman presented a practitioner's perspective and raised these points:

- Ethics of the user and truthfulness emerge as issues to be balanced with a good, clear, concise presentation that is essential for senior managers and board members. Information must not be misrepresented.
- It is difficult to balance how much information is needed with limitations of budget and resources.
- Over 80 percent of the cost of using GIS is in getting data. A real challenge to our industry is to show we can improve and acquire data at a reasonable cost.
- We have new and powerful tools that are very user friendly. We must be aware of the danger of people using them without fully understanding or being trained in information systems or geography. We need to educate users on the proper use and misuse of these tools.
In the last decade, we have seen a re-invention of transit as a more customer-focused business, and GIS has been a helpful tool in achieving that. The National GIS survey has revealed that the leading application of GIS is in customer information, and vendors are providing us with tools for doing that.

Ron Sheck made these observations from a conference co-chairman perspective:

We need to continuously examine how we can use GIS most effectively to meet the customer's needs. As guest speaker Michael Dobson said, "the bottom line for the transit industry is getting the riders where they want to go."

Sheck stressed that strategic alliances are critical to the success of GIS:

- Internal strategic alliances - One is between the planning, customer information/marketing, and operations areas. Another is the technology alliance between GIS, AVL, and GPS.

- External strategic alliance - One is between the transit agency and other transit agencies or transportation providers, including intercity rail and bus, specialized transportation, local taxi operators, etc. Another is with community planning agencies such as MPOs, DOT's, cities, counties, special districts, etc.

- In forming alliances, think strategically about how you ally yourselves by theme, organization, and technology.

- Always involve the vendor.

Sheck concluded by raising the question, "Where do we go from here?" He stated that there has been significant interest in follow-up activity to the conference, perhaps another conference, an organization to continue the dialog, or other possibilities. Sheck urged conference participants to share their thoughts and ideas for continuing an open dialogue on GIS in Transit with him or Walt Kulyk at FTA.
Case Studies of Transit Systems Using GIS

Significant potential exists for the use of Geographic Information Systems (GIS) in transit planning, operations, and analysis. Some transportation organizations have become extremely active in the use of GIS; however, the more active users have been typically within the largest transit systems and metropolitan planning organizations. Smaller organizations have been less likely to invest the resources necessary to establish a GIS that will result in significant benefits. This is primarily due to the fact that, in the past, the resources necessary to initiate and maintain a GIS system were rather significant. Only in recent years has the technology progressed to the point where basic GIS functions and applications have become more affordable for the smaller agencies.

The creation of geographic databases for areas served by public transit can significantly enhance the capabilities of local transit systems, metropolitan planning organizations (MPOs), and other planning organizations. Potential benefits include cost savings resulting from increased efficiency in performing transit planning and analysis, increased precision in planning activities, the ability to assess the feasibility of more service alternatives, quicker response time for assessing the implications of service design and frequencies, and the ability to communicate the results in a format understandable by the public, and decisionmakers, and others.

This technical report was prepared to present a series of case studies of transit systems that have implemented a geographic information system. Many transit systems in the United States are using GIS currently, and much can be learned from their implementation experiences, as well as from the various applications for which their GIS is used. The case studies are presented for several transit systems and were selected to cover a range of system sizes. A brief discussion of GIS implementation issues is presented prior to the case studies.

IMPLEMENTATION ISSUES

GIS, as it is understood, today was initiated in the early to mid-1960s with the Canadian Geographic Information System and with systems developed by the United Kingdom Experimental Cartography Unit. Commercial turnkey systems began emerging in the early 1980s, with the early development of the software Arc/Info by the Environmental Systems Research Institute (ESRI). The first version of Arc/Info was released in 1982.1

The use of GIS has grown substantially in the 1980s and 1990s and is used commonly today in the public and private sector throughout the world. This is reflected in the 1994 GIS Industry Survey conducted by GIS World. Organizations from around the world responded to the survey, resulting in the identification of four hundred and eighty GIS products and service providers.2 Significant growth in this industry will undoubtedly continue into the next century.

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It is important to put into perspective many of the issues associated with GIS implementation. The implementation of a GIS is a significant commitment for any organization and is considered a costly, long-term undertaking. This was particularly true in the early development of the technology when GIS products were expensive and their benefits somewhat uncertain; however, as the technology continues to evolve, the cost of acquiring, operating, and maintaining a GIS is declining, and the quality and user-friendliness of the products are improving. As a result, what may have required a substantial investment and not been affordable only five years ago may be affordable to many of these same organizations today. Not only is it now affordable, GIS technology, including software, hardware, data integration, and training, has evolved to contribute further to the feasibility of GIS implementation.

The affordability of a GIS does not necessarily make the implementation process an easy one. As indicated previously, the decision to implement a GIS is a substantial commitment, not just from a monetary perspective. The GIS implementation literature is in agreement regarding one of the most important ingredients to successful implementation—the need for support from all levels within an organization, especially from management. In addition, success is usually dependent upon a single person who leads the charge in the development of the system. Implementation failures are usually a result of people problems and seldom a result of technological problems.

The message is clear. Even though GIS is fast becoming an affordable option for even the smallest organizations, agencies contemplating GIS investments should proceed with caution. It is recommended that organizations develop a strategic plan for the development of a GIS prior to investing in the technology. This plan may include coordinating efforts with other agencies in the area to enable the sharing of databases and other resources. It may be appropriate to seek outside assistance in the early stages of implementation to ensure that the organization has a sufficient understanding of relevant issues and applications. However, it is important that employees of the organization play an integral role in the planning and development of the system so they can carry on the efforts once the outside assistance is no longer available.

Some skepticism may persist in many organizations regarding the significance of GIS benefits in transportation planning. This skepticism may stem from a belief that GIS does not add anything new to the planning process that was not already handled in some other way in the past. Some even suggest that using GIS to perform certain tasks may take even longer than it did previously since it provides opportunities to produce more than is really needed to accomplish certain objectives. If at all possible, this skepticism should be addressed prior to implementation. This might be accomplished through a more formal feasibility assessment of a GIS program, including both qualitative and quantitative analyses. As is often the case when implementing new technologies, the agency pursuing GIS should have informed understanding of the cost and benefits, realistic expectations, an appreciation of the uncertainty, sound motions for pursuing the change, and a willingness to objectively assess and modify the program direction if necessary.

This is by no means a comprehensive discussion of GIS implementation issues. The intent is to identify many of the important issues to serve as background prior to the case studies of GIS implementation/application in transit systems in the United States.

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4Aronoff, p. 249.
SELECTION OF TRANSIT SYSTEMS FOR CASE STUDIES

Based on the preliminary results of a recent survey of transit systems regarding their use of GIS, several transit systems were selected to serve as case studies in this technical report. The primary criteria for the selection of systems included the following:

- **Active GIS Users** - The inventory of transit systems that indicate having and are using a GIS was reviewed. From this list, the more active users were identified and considered for selection as a case study site.

- **System Size** - The second criterion was used to ensure that the case studies included transit systems representing each of three system size categories, including the 50-200 vehicle category, 201-500 vehicle category, and the over-500 vehicle category.

METHODOLOGY

Methods for obtaining case study information followed a three-step procedure:

- Interview potential participants.
- Obtain written information pertaining to GIS implementation.
- Present draft copy of prepared materials for participants to edit and return.

Interviews

An attempt was made to contact at least two transit systems from each vehicle size category of active GIS users. Transit system participants were selected for phone interviews based on the following criteria, listed in order of importance:

- Transit systems known to have written materials documenting their GIS implementation process, i.e., a needs assessment.
- Geographically dispersed transit systems. If a metropolitan area had more than one transit authority, preference was given to the system with the most vehicles operated in maximum service. Subsequent to contact with the largest authority, preference was then given to another metropolitan area.

The phone interviews served two purposes:

- Identified the person(s) most knowledgeable about the GIS system and its implementation history.
- Identified which transit agencies had a GIS system sufficiently implemented to support a case study.

A secondary survey form was used to record responses to several questions, including:

- Describe the history of your GIS system implementation.
- Describe the benefits and obstacles encountered with your GIS system implementation.
- How have your GIS demands been met?
- What lessons have you learned regarding system implementation?
Obtain Written Information

When documentation was available, materials were requested. Respondents with recent written documentation were included in this report. Respondents without documentation, but with a sufficiently implemented GIS system were also selected as case studies. A "sufficiently implemented" system is defined, for the purposes of this report, as being at least partially functioning. However, because the purpose of selecting case studies was to determine what problems and pitfalls were encountered during implementation, preference was given to systems that were fully functional.

Present Materials for Editing

Finally, acquired information (phone and written) was compiled and returned to the case study participants for editing and additions. This helped insure greater accuracy and filled gaps inherent in phone and written sources.

Selection of case studies was further refined at the GIS in Transit Conference (August 13-15, 1995) in Tampa, Florida. Because written documentation of system implementation in small agencies was scarce, the conference provided an opportunity to examine at least one small agency's experiences in greater depth.

Table 1 lists the transit systems selected as case studies for this technical report. The case studies are organized into eight major sections:

- Overview of Transit System
- Overview of GIS at Transit System
- Hardware and Software Platform
- Spatial Data Resources
- Current GIS Applications
- Benefits of GIS and Obstacles to Implementation
- GIS Implementation Strategies
- Lessons Learned
## Table 1
**TRANSIT SYSTEMS SELECTED FOR CASE STUDIES**

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<th>Category</th>
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<td>King County Metro Transit Municipality of Metropolitan Seattle</td>
<td>Large</td>
<td>Wayne Watanabe</td>
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<td>Los Angeles County Metropolitan Transit Authority</td>
<td>Large</td>
<td>Paul Burke</td>
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<td>San Diego Association of Governments</td>
<td>Large</td>
<td>Linda Culp</td>
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<td>Dallas Area Rapid Transit</td>
<td>Large</td>
<td>Brenda Claybrook</td>
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<td>Milwaukee County Transit System</td>
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<td>Capital District Transportation Authority (Albany, Troy, Schenectady)</td>
<td>Medium</td>
<td>Thomas Gugisberg</td>
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<td>Bloomington Public Transportation Corporation (Bloomington, Indiana)</td>
<td>Small</td>
<td>David Gionet</td>
<td>19</td>
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<tr>
<td>Johnson City Transit (Johnson City, Tennessee)</td>
<td>Small</td>
<td>Gregory A. Plumb</td>
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* Operated in maximum service.
King County Metro Transit
Municipality of Metropolitan Seattle

OVERVIEW OF KING COUNTY METRO

King County Metro Transit in Seattle is one of the most active users of GIS among transit agencies in the United States. Over a three year period, Metro has invested nearly $2.5 million in capital expenses to develop a core GIS over three years. The system was completed in mid-1995. In addition, an estimated $225,000 is planned for GIS operating expenses in 1996. This case study illustrates a comprehensive implementation of a GIS.

Table 2
SERVICE AREA AND TRANSIT SYSTEM CHARACTERISTICS

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<tr>
<td>Annual Ridership</td>
<td>71.6 million</td>
</tr>
<tr>
<td>Routes</td>
<td>200+</td>
</tr>
<tr>
<td>Route Miles</td>
<td>2,500</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>40 million</td>
</tr>
<tr>
<td>Number of Bus Stops</td>
<td>10,000</td>
</tr>
<tr>
<td>Bus Shelters</td>
<td>1,200</td>
</tr>
<tr>
<td>Park-and-Ride Lots</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Transit Service</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanpool Vans in Service</td>
<td>530</td>
</tr>
<tr>
<td>Vanpool Ridership</td>
<td>2.7 million</td>
</tr>
<tr>
<td>Ridematch Applicants</td>
<td>9,000</td>
</tr>
<tr>
<td>Paratransit Ridership</td>
<td>480,000</td>
</tr>
</tbody>
</table>

Source: Wayne Watanabe, "Implementing a Successful Transit GIS," 1995 APTA Comutan Conference (Seattle: King County Metro Transit).
OVERVIEW OF GIS AT KING COUNTY METRO

Since 1982, King County Metro has been developing and using an in-house GIS called TransGeo. As of July 1992, TransGeo continued to be a critical feeder system to Metro's Automatic Passenger Counter system, ARIS/BUSTIME, Commuter Information System, Mileage Maintenance System, and the Radio Automatic Vehicle Monitoring/Location System. Although it served its purpose, TransGeo had several major shortcomings. First, it lacked many of the basic features available in commercial GIS packages now on the market. Second, it was not a user-friendly software program, and, as a result, widespread use of the system was not possible due to the lack of skilled staff. Third with only a few terminals available to access the software and only one user could use the interactive element of the software at a time. Fourth, accessibility was also a problem; it was difficult to upgrade and maintain TransGeo to remain compatible with other systems that have been upgraded throughout the agency. A brief history of GIS at Metro is presented in Table 3.

Table 3
GIS HISTORY AT METRO

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>In-house GIS developed (TransGeo)</td>
</tr>
<tr>
<td>1990</td>
<td>Obtained funding for next efforts</td>
</tr>
<tr>
<td>1991</td>
<td>Regional streetmap update project</td>
</tr>
<tr>
<td>1991</td>
<td>GIS feasibility/needs assessment</td>
</tr>
<tr>
<td>1992</td>
<td>GIS alternatives analysis</td>
</tr>
<tr>
<td>1993-95</td>
<td>GIS implemented</td>
</tr>
</tbody>
</table>

Source: Wayne Watanabe, "Implementing a Successful Transit GIS." 1995 APTA CompuTran Conference (Seattle: King County Metro Transit).

In 1991, King County Metro initiated a GIS project to assess the GIS needs of the agency, conduct an analysis of alternative GIS implementation strategies, assess the feasibility of implementing a GIS in terms of costs and benefits, and devise an implementation plan should a change in the current GIS program be recommended. A GIS project team was established to carry out this project.

A user needs assessment was conducted for several reasons, including:5

- to establish a basic understanding of the capabilities and limitations of a GIS.
- to summarize the current GIS environment at Metro.
- to establish the potential applications for a GIS.
- to identify major issues involving the application of GIS at Metro.

---

5 King County Metro, Transit Department, "Geographic Information Systems Project Phase I Feasibility Study, User Needs Assessment Document" (July 1992).
Ultimately, the objective was to determine whether GIS had appropriate applications in the day-to-day business needs of Metro. The answer to this question was positive. Geographic information is used widely and frequently throughout the agency to support many diverse needs.

Once the need for a GIS system was clearly justified, an alternatives analysis for the implementation of GIS at Metro was initiated. Three alternatives were presented:

- **Alternative #1 - Do Nothing:** In this alternative, status quo would be maintained at Metro with geographic needs being met primarily by TransGeo. Although this alternative is referred to as "do nothing," minor improvements would be necessary to meet the requirements of existing geographical functions.

- **Alternative #2 - Minimum Buy/Customize:** Under this alternative, Metro would acquire a commercial GIS software and customize the basic functions to meet the more important needs of the agency. A minimum "core" set of functions would be identified and included in this alternative to meet Metro's basic GIS business needs and to serve as a foundation for further GIS development.

- **Alternative #3 - Full Buy/Customize:** Similar to Alternative #2, Metro would purchase a commercial GIS software and would then customize the functions that are needed to meet Metro's most important business needs. However, in addition to the core functions and data included in alternative #2, this alternative seeks to be more exhaustive in the development of customized applications and databases.

Based on the results of the User Needs Assessment, the GIS team identified the minimum functional requirements and data that would be necessary to meet Metro's basic GIS business needs, and would serve as a foundation for further GIS development. The team recommended the implementation of a GIS with these minimum functional requirements in the form of Alternative #2 - Minimum Buy/Customize. The remainder of this case study is devoted to describing Alternative #2 since it is currently in the process of being implemented.

**HARDWARE AND SOFTWARE PLATFORM**

Hardware - The GIS infrastructure is illustrated in Figure 1 and the 1995 GIS hardware network is illustrated in Figure 2. Table 4 indicates the number of display devices and peripherals that are currently available, as well as the number of new devices required under the alternative being implemented.
Figure 1
GIS INFRASTRUCTURE AT KING COUNTY METRO

**Figure 2**

**1995 GIS HARDWARE NETWORK**

**NOTE:** Shading indicates existing hardware

---

<table>
<thead>
<tr>
<th>INFORMATION SYSTEMS</th>
<th>TRANSIT</th>
<th>TECH SERVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-terminal GIS Analyst</td>
<td>X-terminal BUS-TIME</td>
<td>X-terminal Water Resources</td>
</tr>
<tr>
<td>X-terminal GIS Analyst</td>
<td>X-terminal R&amp;MS</td>
<td>X-terminal Facilities Planning</td>
</tr>
<tr>
<td>X-terminal Project Mgr.</td>
<td>X-terminal Tran. Dir. Office</td>
<td>X-terminal Dept. Use</td>
</tr>
<tr>
<td>X-terminal Electronic Planner</td>
<td>Local Power</td>
<td>Dept. Use</td>
</tr>
<tr>
<td>X-terminal Intranet Planner</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Sys. Support</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Sys. Support</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Advanced Planning</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Power &amp; Facil.</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Mkt. Devel.</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal ADA</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal S&amp;CS Rideshare</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal S&amp;CS Info. Prod.</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>X-terminal Svc. Plng.</td>
<td>PC</td>
<td></td>
</tr>
</tbody>
</table>

---

**Source:** Metro, Municipality of Metropolitan Seattle, "Alternatives Analysis and Recommendation: Geographic Information Systems Project Phase I Feasibility Study," p. 34.

---

*Proceedings of a Conference on GIS in Transit*
Table 4
DISPLAY DEVICES AND PERIPHERALS

<table>
<thead>
<tr>
<th>Device</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer</td>
<td>50 (20 with x-emulation)</td>
</tr>
<tr>
<td>X-terminal</td>
<td>2</td>
</tr>
<tr>
<td>Workstation</td>
<td>2</td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>1</td>
</tr>
<tr>
<td>Plotter - electrostatic</td>
<td>1</td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td>1</td>
</tr>
</tbody>
</table>

Hardware Configuration - The hardware configuration is summarized in Table 5 and includes references to the host server, desktop access, hard copy output, and user access phasing.

Table 5
SUMMARY OF HARDWARE CONFIGURATION

<table>
<thead>
<tr>
<th>Host Server</th>
<th>System began with an existing ISD development machine (DEC 5500) with data being stored on a 6 gigabyte storage device. This was upgraded to a production server with capacity to support GIS and other large applications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop Access</td>
<td>Access to the GIS is available through PCS, Macs, X-terminals, and workstations connected to a Wide Area Network (WAN) and Local Area Networks (LANs). Core data and applications are available from any desktop access point. Non-core data are available only to those with proper authorization.</td>
</tr>
<tr>
<td>Hard Copy Output</td>
<td>One electrostatic plotter and two inkjet plotters are connected to the GIS. These plotters can be accessed through the WAN/LAN network. Local site printing also is available where printer and/or plotters are available.</td>
</tr>
<tr>
<td>User Access Phasing</td>
<td>Access to the GIS was phased in as capabilities were developed.</td>
</tr>
</tbody>
</table>

Software - No commercial GIS packages are capable of meeting all of Metro's needs as currently available. However, the software selection process concluded that ESRI's Arc/Info software could best be adapted to meet the GIS needs of Metro. Arc/Info is a high-end GIS with approximately
6,000 separate commands within seven separate modules. Using Arc/Info in its raw form would require an extensive training effort. As a result, one of the goals of the system was to develop a powerful but simple graphical user interface (GUI). This was accomplished using ArcView, a product that provides user-friendly query, display, and mapping capabilities for the more common GIS needs.

Table 6 illustrates the current software configuration. The estimated cost of this alternative is summarized in Table 7.

**Table 6**
CURRENT SOFTWARE CONFIGURATION, 1995

<table>
<thead>
<tr>
<th>Software Licenses</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc/Info floating seat license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Node-locked licenses</td>
<td>12</td>
</tr>
<tr>
<td>ArcView licenses</td>
<td>45</td>
</tr>
<tr>
<td>Arc/Info Tin license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Grid license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info COGO license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Network license</td>
<td>1</td>
</tr>
<tr>
<td>ArcCAD license</td>
<td>1</td>
</tr>
<tr>
<td>Ingres licenses</td>
<td>3</td>
</tr>
<tr>
<td>Geocoding package</td>
<td>1</td>
</tr>
<tr>
<td>X-emulation packages</td>
<td>20</td>
</tr>
<tr>
<td>Netware packages</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 7
ESTIMATED PROJECT BUDGET

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HARDWARE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desktop Access</td>
<td></td>
<td>$162,000</td>
<td>$16,000</td>
<td>$178,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>Main Host Disk and Memory</td>
<td></td>
<td>43,000</td>
<td>476,000</td>
<td>519,000</td>
<td>70,000</td>
</tr>
<tr>
<td>Plotter</td>
<td></td>
<td>60,000</td>
<td>7,000</td>
<td>67,000</td>
<td>7,000</td>
</tr>
<tr>
<td>TOTAL HARDWARE</td>
<td></td>
<td>265,000</td>
<td>499,000</td>
<td>764,000</td>
<td>97,000</td>
</tr>
<tr>
<td>SOFTWARE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software Licenses</td>
<td></td>
<td>94,000</td>
<td>23,000</td>
<td>117,000</td>
<td>17,000</td>
</tr>
<tr>
<td>PC Network</td>
<td></td>
<td>6,000</td>
<td>6,000</td>
<td>12,000</td>
<td>3,000</td>
</tr>
<tr>
<td>TOTAL SOFTWARE</td>
<td></td>
<td>100,000</td>
<td>29,000</td>
<td>129,000</td>
<td>20,000</td>
</tr>
<tr>
<td>STAFF LABOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit GIS Coordinator</td>
<td>1.00</td>
<td>70,000</td>
<td>70,000</td>
<td>140,000</td>
<td></td>
</tr>
<tr>
<td>WPCD GIS Coordinator</td>
<td>0.25</td>
<td>18,000</td>
<td>17,000</td>
<td>35,000</td>
<td></td>
</tr>
<tr>
<td>ISD GIS Project Manager</td>
<td>1.00</td>
<td>70,000</td>
<td>70,000</td>
<td>140,000</td>
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<tr>
<td>GIS Analysts</td>
<td>3.00</td>
<td>198,000</td>
<td>198,000</td>
<td>396,000</td>
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<tr>
<td>GIS Technician</td>
<td>1.00</td>
<td>56,000</td>
<td>56,000</td>
<td>112,000</td>
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<tr>
<td>Client Analyst - Transit</td>
<td>0.25</td>
<td>18,000</td>
<td>17,000</td>
<td>35,000</td>
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<tr>
<td>TOTAL STAFF LABOR</td>
<td>6.50</td>
<td>430,000</td>
<td>428,000</td>
<td>858,000</td>
<td></td>
</tr>
<tr>
<td>SYSTEM SUPPORT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Database Consulting</td>
<td></td>
<td>12,000</td>
<td>6,000</td>
<td>18,000</td>
<td></td>
</tr>
<tr>
<td>Arc/Info Contractor</td>
<td></td>
<td>60,000</td>
<td>60,000</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>Quality Assurance/Security</td>
<td></td>
<td>14,000</td>
<td></td>
<td>14,000</td>
<td></td>
</tr>
<tr>
<td>Documentation/TechSupport</td>
<td></td>
<td>30,000</td>
<td>30,000</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>GIS Consulting</td>
<td></td>
<td>35,000</td>
<td>35,000</td>
<td>70,000</td>
<td></td>
</tr>
<tr>
<td>TOTAL SYSTEM SUPPORT</td>
<td></td>
<td>152,000</td>
<td>131,000</td>
<td>282,000</td>
<td></td>
</tr>
<tr>
<td>TRAVEL/TRAINING</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training Classes</td>
<td></td>
<td>20,000</td>
<td>40,000</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>Conferences/Site Visits</td>
<td></td>
<td>12,000</td>
<td>12,000</td>
<td>24,000</td>
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<tr>
<td>TOTAL TRAVEL/TRAINING</td>
<td></td>
<td>32,000</td>
<td>52,000</td>
<td>84,000</td>
<td></td>
</tr>
<tr>
<td>TOTAL MATERIALS</td>
<td></td>
<td>16,000</td>
<td>5,000</td>
<td>21,000</td>
<td></td>
</tr>
<tr>
<td>ISD OVERHEAD CHARGES</td>
<td></td>
<td>42,000</td>
<td>42,000</td>
<td>84,000</td>
<td></td>
</tr>
<tr>
<td>CONTINGENCY (10%)</td>
<td></td>
<td>104,000</td>
<td>116,000</td>
<td>220,000</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>$1,140,000</td>
<td>$1,302,000</td>
<td>$2,442,000*</td>
<td></td>
</tr>
</tbody>
</table>

*Actual expenditure in 1995 was $2,010,000 **Actual expenditure in 1995 was $220,000

Proceedings of a Conference on GIS in Transit 79
SPATIAL DATA RESOURCES

As indicated previously, a minimum core data set was identified that would meet the basic business needs of Metro. The core data set can be placed into three primary categories, including Agency Core Data, Transit Core Data, and (WPCD) Water Pollution Control Division Core Data. The first two categories are summarized in Figures 3 and 4. The WPCD Core Data is excluded since it is not directly related to transit. Non-core data items also were identified but not included in the base system proposal.

Figure 3
AGENCY CORE DATA AND SOURCES
Figure 4
TRANSIT CORE DATA AND SOURCES

- Bus Stops/Zones (revenue only)
- Bus Stop Shelters
- Employer Sites
- Park & Ride Lots
- Route Footprints (revenue, school, deadhead)
- Timepoints
- Timepoint Interchanges (TPIs)

- Bus On-time Performance Data
- Ridership Data

- Vehicle Volumes

- Traffic Analysis Zones

CURRENT GIS APPLICATIONS

• Many applications were identified in the feasibility study as user needs that could be met using the Metro Core GIS. These applications are summarized in a series of categories, each of which is listed below, along with examples of applications that are included in each category.
• Capital planning and development - Display park-and-ride data against service patterns, volumes, and passenger volumes.
• Service planning - Produce maps of selected service areas, and display route proposals; display information related to ridership demand such as population, employment, travel patterns, population and employment densities.
• Market development - Display employer sites against available transportation services and information such as transit service, park-and-ride, etc.; display and analyze demographic, census data, etc.
• Accessible services - Geocode ADA applicant addresses and perform location related analysis.
• Coach and facilities maintenance - Provide route patterns maintenance (track mileage by vehicle and route).
• Sales and customer services - Use geocoding to create customer mailing lists for route-level marketing.
• Research and market strategy - Create displays and other test materials for focus groups; geocode respondents' origins and destinations to create a travel pattern database.
• Transit operations - Create quick information maps/guides for operators to help answer customer questions; provide timely and accurate maps for trainers and operators.
• Risk, safety, and security - Display and analyze accident locations by various attributes.
• Communications and community relations - Use GIS to convey information to decisionmakers and general public.
• Regional transit project - Calculate coverage of service against population (show what percentage of population in a subarea is within 1/4 mile of a bus route, calculate how much of a route's length is within a subarea).
• Environmental planning - Display environmental elements such as transit routes, sewer/storm systems; display environmental elements such as rivers, lakes, bays, housing patterns, etc.

OBSTACLES TO IMPLEMENTATION

Several observations were offered by King County Metro regarding potential obstacles to implementation. These are identified below according to technical and organizational problems that may hinder the implementation process.

Technical Obstacles

• Software Limitations - Individuals responsible for implementing a GIS should always be cognizant that every software has its limitations. King County Metro discovered limitations with Arc/Info that relate to the ability to handle a long continuous set of links and nodes, which are necessary for many of the transit routes that run throughout the service area. Metro is working directly with Arc/Info to remedy this problem.
• Street Network Maintenance - The street network in a GIS must be maintained over time
to ensure that applications are developed using an accurate base network. Determining who is responsible for this maintenance can be a significant obstacle to implementing a GIS. Currently, King County Metro is handling maintenance for the base network which gives them control over the process but also burdens them with the cost of maintenance.

• **Consistent Financial Support** - Metro believes they are fortunate in that they have had significant and consistent funding to establish their GIS. However, this also was a result of significant efforts by staff to sell the benefits of GIS throughout the agency.

• **Data Integration and Conversion Issues** - The process of integrating and/or converting data into a GIS is arduous and time-consuming and can present a significant obstacle in the implementation process. One standard might be to assume that a task will almost always take four times longer than anticipated originally.

**Organizational Obstacles**

• **Desire for Quantifiable Benefits** - There is a tendency for management and decisionmakers to want the benefits of GIS quantified and compared against the costs to determine if an investment in GIS is worthwhile. Metro suggests that this should not be done since too many of the benefits cannot be quantified. Their approach was to present the costs, identify what they will get for this investment, and then ask management if they want these capabilities.

• **"Scope Creep Factor"** - An important element of developing and GIS is sharing evidence of progress throughout the implementation process with management and decisionmakers. This will likely keep them interested in the GIS project and will maintain support for the effort in the future. However, this also can result in what is termed the "scope creep" factor. Efforts made to show progress along the way often will result in the expansion of the original scope to meet new demands and include new elements. This will likely contribute to the project effort falling behind schedule and over budget.

**GIS IMPLEMENTATION STRATEGIES**

In a recent presentation by Wayne Watanabe of King County Metro, the top ten success factors for the implementation of a transit GIS were identified from the perspective of Metro Transit. Each of these factors is identified and discussed below.

**Educated Clients and Decisionmakers**

An extensive education process was conducted with clients and decisionmakers regarding GIS uses and capabilities. The process took approximately four months and included over 50 formal presentations. In addition to this effort providing the foundation for conducting the future GIS needs assessment, it also helped "sell" the GIS to individuals throughout the organization.

**Clear Rationale for Investing in GIS**

A convincing argument must be made to justify investment in a GIS. In particular, decisionmakers must be sufficiently sold on the idea to garner support for the development of a GIS, as well as for ongoing operations and maintenance associated with a GIS. This will likely require significant emphasis on the intangible benefits of a GIS. This confirms the need for some type of needs assessment and an objective consideration of alternative GIS investments.
Strong Internal and External Alliances

Cooperation and coordination among and within agencies in a region will contribute to sharing resources and data. This can potentially result in cost savings, political successes, and a win-win situation for all agencies participating in such a cooperative arrangement.

Effective Project Management Structure

The need for an organized and effective project management structure is evident and should include a business client representative and an information systems technical project manager. The structure must balance the needs of the business and technical perspectives.

Common Vision

Understanding and agreeing upon a common vision for GIS within an organization is essential. A "vision" exercise is recommended for consideration to help clients and the development team reach a common understanding as to how GIS should evolve. This should include a formal agreement on requirements, test plans, and acceptance criteria. The shared vision for King County Metro covered numerous issues, including the following:

- budget, resources, and organizational support
- training for users, developers, and maintenance
- data: shared, accurate, easily used
- tools and applications meet needs
- System linkages and integration
- multiple distributed access points

Effective Project Planning and Management

Effective project planning and management is essential and should involve considerations such as allowing time for the expansion of the scope, including intermediate milestones along the way to show progress and maintain support, and assuming that data conversion and system integration always takes longer than anticipated.

Good, Cost-Effective Design

The database must be designed in a manner that allows for a maintenance process that is as cost-effective as possible. For example, a necessary component of the database design is the ability to improve the underlying network without impacting attributes and applications.

Training

The importance of training at all levels cannot be overstated. Training should be provided at varying levels for development staff, operations and maintenance staff, and the end users.

Communication and Integrity

Constant communication will increase coordination and cooperation among users of the system.
Los Angeles County
Metropolitan Transit Authority

The Los Angeles County Metropolitan Transit Authority (LACMTA) is the largest transit system examined in the >500 vehicle category. However, unlike Seattle and Dallas, the LACMTA just recently began implementation of its GIS system. Although hardware implementation began in 1991, GIS applications for transit planning did not begin until 1993. Implementation is ongoing and completion is expected in 1996.

The project is one of the largest GIS-based transportation development initiatives by a metropolitan planning agency in the nation. It is, however, shadowed by the Southern California Association of Governments (SCAG) ACCESS project, which will link over 185 cities to the SCAG Los Angeles County office. Ultimately, the intent of the LACMTA project is to establish an enterprise-wide GIS that will link several MTA departments and other agencies.

OVERVIEW OF TRANSIT SYSTEM

Transit system characteristics for the LACMTA include two distinct service types: Contract Services and Directly Operated Services. Characteristics of both service types are outlined in the following tables.

Table 8

<table>
<thead>
<tr>
<th>TRANSIT SYSTEM CHARACTERISTICS FOR LACMTA CONTRACT SERVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area (sq. mi)</td>
</tr>
<tr>
<td>Service Area Population</td>
</tr>
<tr>
<td>Total Fleet</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
</tr>
</tbody>
</table>

Table 9
TRANSIT SYSTEM CHARACTERISTICS FOR LACMTA
DIRECTLY OPERATED SERVICES

<table>
<thead>
<tr>
<th>Service Area (sq. mi)</th>
<th>1,433</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area Population</td>
<td>7,154,679</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>2,378</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>1,964</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>1,537,778,291</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>83,981,460</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>645,191,746</td>
</tr>
</tbody>
</table>

(01/01-12/31/98)
Source: U.S. Department of Transportation,
Data Tables for the 1993 National Transit Database, Section 15 Report Year.

OVERVIEW OF GIS AT LOS ANGELES COUNTY METRO

History of GIS Implementation

The evolution of Los Angeles County's GIS system began in two separate agencies: the Southern California Rapid Transit District (RTD) and the Los Angeles County Transportation Commission (LACTC). These agencies later merged to form the Los Angeles County Metropolitan Transportation Authority.

Prior to the merger, (1991-1992) the LACTC acquired two IBM RS/6000 computers and the RTD acquired a VAX system which included two RISC machines. The LACTC staff focused on map production and spatial queries using pre-existing databases and ArcInfo 5.0. The RTD staff had just started using their GIS to produce maps and some crude analysis when the two agencies merged.

Although two discreet systems were acquired, the VAX system is used primarily for operations and the IBM system was used for transit planning. The primary VAX application is transit operations dispatch in real time, specifically bus schedule tracking and route analysis. A computer-aided dispatch (CAD) system links the GIS with an automatic vehicle system (AVL) for maintaining and updating bus service routes. Although the VAX system is not a true GIS, it supports both a customized real-time system and ArcInfo 5.0. The ArcInfo module is used to update route patterns from the IBM system. The patterns are then fed into another application...
that permits tracking of fleet vehicles in real time. The AVL system is currently not in use fleetwide. Operations (now part of MTA) plans to begin AVL use on a portion of the fleet by November, 1995.

Originally, the LACTC used non-GIS software for transit demand modeling, shortest path routing, and other transit operations. Maps were also produced, but true GIS applications were not performed. Needs were identified for updating databases and addressing inadequacies of the existing systems. Analysis of these needs justified design, development, and implementation of a comprehensive GIS.

In April, 1993 a merger of the two agencies occurred to form the Los Angeles County Metropolitan Transportation Authority. Shortly after the merger, the planning machines were combined into one cluster and several other machines were eventually added. Unix ArclInfo was acquired for the IBM system, which is primarily dedicated to rail and highway planning. The system uses both ArclInfo and TRANPLAN software on a Token Ring network located at MTA's downtown headquarters. TRANPLAN is used for transit modeling and ArclInfo is used for GIS analysis of modeled forecast results. This case study focuses on the IBM system only.

During the first year of implementation, GIS services were available to several groups within LACMTA including Transportation Modeling, Planning, Scheduling and Operations, and Benefit/Assessment. However, it was felt that expansion of GIS service was necessary to provide more comprehensive service to end users, particularly MTA planners (Benefit Assessment) who were not intimately familiar with the high end software. With this in mind, desktop mapping software (ESRI's ArcView1 and later ArcView2) was chosen to facilitate easier viewing and analysis of available spatial datasets to end users. The Benefit Assessment planners use ArcView to track the payment status of several thousand commercial property owners. These property owners are assessed a fee for their anticipated benefit derived from their proximity to the Metrorail subway. This stage of implementation is expected to be completed in 1996.

HARDWARE AND SOFTWARE PLATFORM

The GIS at LACMTA consists of a networked (Ethernet) Unix based system that is loosely connected to the rest of the in-house PC network through a TCP-IP bridge. The LACMTA PC network operates in a LANMAN environment which connects more than one hundred PCS. The Benefits Assessment department has two high-end PCS and plans on using ArcView2 for front-end access to GIS databases. Full connectivity is expected to be completed in the near future.

Two software packages were chosen for planning applications: TRANPLAN and ArclInfo. TRANPLAN (Urban Analysis Group, Danville, Calif.) is used for transportation modeling and ArclInfo is used for GIS applications. At the time of this writing, eight staff members use the system: four full time GIS analysts, and the remaining alternate between ArclInfo and TRANPLAN.
Table 10
HARDWARE DEVICES AND PERIPHERALS

<table>
<thead>
<tr>
<th>Device</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer</td>
<td>5</td>
</tr>
<tr>
<td>X-terminal</td>
<td>2</td>
</tr>
<tr>
<td>Workstation</td>
<td>11</td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>0</td>
</tr>
<tr>
<td>Plotter - electrostatic</td>
<td>1</td>
</tr>
<tr>
<td>Calcomp 68436</td>
<td></td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td>2</td>
</tr>
</tbody>
</table>


Table 11
SOFTWARE LICENSES AT LACMTA

<table>
<thead>
<tr>
<th>Software Licenses</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc/Info Node-locked licenses</td>
<td>5</td>
</tr>
<tr>
<td>ArcView licenses (1 Unix, 5 PC expanding to 8 PCS)</td>
<td>6</td>
</tr>
<tr>
<td>Arc/Info Grid license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Network license</td>
<td>1</td>
</tr>
<tr>
<td>SAS</td>
<td>1</td>
</tr>
<tr>
<td>TRANPLAN</td>
<td>1</td>
</tr>
</tbody>
</table>


SPATIAL DATA RESOURCES

The LACMTA uses a diverse selection of data sources, many of which are modified for GIS use. For their basemap, the LACMTA uses a street network leased from Thomas Brothers, a mapping software vendor based in California. Annual updates and a data dictionary are provided as part of the lease contract. Other spatial data and corresponding sources are listed in the table below.
Many data source layers used in the LACMTA’s GIS are modified versions of existing databases. Parcel data from the City Engineering department was obtained, post-processed, and modified to obtain property units. Parcels were selected within 0.25 miles from planned red-line stations to calculate assessment charges. Some lots were further subdivided to reflect sub-leases as well as actual properties.

Bus routes were derived from DIME files and modified with tables from RTD’s Computerized Customer Information System. These routes are maintained by the MTA (Customer Information and Operations) and other transit operators. Customer Information maintains the routes as DIME file derivatives and Operations maintains the routes on the Thomas Brothers street basemap. The LACMTA also conducts ridership surveys which are thematically mapped. Transit patronage data is collected by Operations and is related to the digitized bus files.

CURRENT GIS APPLICATIONS

A Two-Tiered Approach

In addition to an enterprise wide strategy for system implementation (horizontal), the LACMTA also intends on implementing two (vertical) levels of GIS access. The ArcInfo/TRANPLAN marriage will be centrally maintained, and ArcView 2 will be available to planners for accessing, viewing, and analyzing spatial datasets.
This case study examines the IBM RS/6000 system and its use. As discussed earlier, this system employs TRANPLAN and ArcInfo for transit planning applications. The two packages are linked with data conversion software provided with TRANPLAN. With this link, the modeling team can seamlessly access both packages from the same workstation. Urban Analysis will soon offer TRANPLAN to ArcInfo data conversion routines, which will hopefully improve dynamic linking.

ArcInfo's spatial analysis capabilities are used to merge data sources with modeling scenarios in a graphic environment. Transportation zone models are developed with ArcInfo and then transferred to TRANPLAN for analysis. The resulting models are fed back into ArcInfo, displayed, thematically mapped, and plotted. By linking modeled output to the GIS, results such as future road congestion and projected patronage on a proposed subway are easily visualized. When this data is overlaid on other population and demographic data, relationships begin to appear that may otherwise be difficult to extract from text reports.

Because Los Angeles County has serious traffic problems, transportation planning has emphasized congestion reduction solutions. This involves obtaining comprehensive knowledge of travel demands in terms of time, place, and traveler identity. Bus service and light rail systems offer limited relief. Potential solutions are derived from combining transportation modeling information with geographic base maps to chart commuter patterns.

Analysis is performed in two stages. First, new transportation zones are created from existing models. Second, trip analysis studies are performed within the zone models. Minimum zone to zone travel times are displayed and mapped. A number of thematic maps are also created to accommodate requests from other groups within the LACMTA. These include transit corridor analysis, local and regional transportation balancing, mobility studies, smart signals, freeway improvements, bus and rail lines, station location and rail analysis, and high-occupancy vehicle (HOV) lane studies.

Individual departments within the LACMTA also use the GIS database. For example, the Customer Information Services department uses an interactive routing and scheduling tool for responding to customer inquiries. When citizens call to get travel information, customer service representatives visually display route information and can print optimal bus routes and schedules.

ArcView 2 is currently in limited use within the Benefits/Assessments department as a pilot program. Within the LACMTA, the Benefits/Assessment department is using ArcView 2 for tracking and assessing industrial and commercial properties to support the Metro Rail program. This project requires gathering and merging information from multiple departments and agencies including the County Assessor's Office (parcel maps), the Los Angeles Building and Safety Department (permits), and the Department of Engineering (digitized city maps). Because over 12,000 parcels are used, inter-agency access capabilities will greatly facilitate efficiency.

BENEFITS AND OBSTACLES TO IMPLEMENTATION

Los Angeles County has had mixed success with their system implementation. Some success was realized with increased mapping efficiency and advances in analysis. However, some major obstacles remain for Los Angeles County:
Interfacing

Interfacing refers to improvements in database entry, access, and management. One of the biggest remaining challenges is planner access to GIS data. Decision makers need to easily access this information, display it graphically, and perform queries. As mentioned earlier, a decision was made to acquire ArcView 2 software to facilitate this goal. However, implementation is slow. Obstacles include acquiring hardware, network logistics, user training, and budget cuts.

Data Source Compatibility

Data source compatibility refers to the challenge of conforming different data source formats to work with the GIS system. Perhaps the biggest obstacle encountered by Los Angeles County was merging the existing proprietary database with the GIS system. Methods for updating the database were antiquated and clumsy. Demands could be better met with visual references for database entry. This might be accomplished with an ArcInfo workstation for database entry personnel. Moreover, the GIS system needs to be optimized for speed.

Avoiding Redundancy

Avoiding redundancy is another implementation challenge. One suggestion is to make an attempt at reusing macros and developing a better database management system. Macro reuse can be particularly helpful when plotting maps.

Changes and Reductions in Personnel

Personnel reduction and turnover is common, particularly with GIS personnel. The LACMTA has changed consultants three times since implementation began. The lack of continuous expertise and training has meant that keeping the databases updated is a challenge. Sources for updates are not always consistently available. The LACMTA would like to work towards developing a GIS that is less staff dependent. The Benefits/Assessment pilot program demonstrated that implementation of Arcview2 would be beneficial. However, the current environment requires a network specialist every time a link is necessary for an outside system connection.

Other Hindrances

- Lack of coordination between departments with GIS needs
- Staff divided between two buildings (soon to be resolved)
- Multiple management structures for GIS staff and equipment support

The Customer Information staff at LACMTA would greatly benefit from a GIS tool for maintaining route data. Currently route updates are performed as text edits. This means that staff members need to type in coordinates to define route changes. These coordinates occasionally need to be estimated by interpolating between two known coordinates. As an enterprise-based GIS, a procedure should be developed at LACMTA to centralize route editing and then distribute route updates and delivery schedules in various formats as needed.
GIS IMPLEMENTATION STRATEGIES

Enterprise-Wide Implementation

The ultimate goal at LACMTA is to implement an enterprise-wide GIS system. The biggest benefit of GIS implementation at this scale will be long range planning designed to reduce Los Angeles’ dependence on automobiles. A 20-year, $183 million plan is being outlined for reducing the number of automobiles on County freeways. This plan has recently been scaled back to approximately $75 billion. This is a cooperative effort among several LACMTA departments including Capital Planning and Operations, Benefits/Assessment, and Transportation Modeling. Anticipating and meeting County-wide transportation demands is the overall goal. Through GIS implementing, each department is helped to understand current and predicted traffic demands and develop workable alternatives within the framework of the overall plan.

GIS is a tool to help facilitate decision making. Because transit data is inherently spatial, geographic analysis is a natural extension of this concept. At LACMTA, the GIS process consists of several parts: centralized data maintenance, analysis tools like TRANPLAN, and the ability to test options to make recommendations.

Through the Multi-Modal Planning Department, Area Teams are assigned a specific region of the Los Angeles County area. Each team assesses the transportation status of a particular area and then develops alternative scenarios to resolve specific problems. Plan suggestions must include multi-modal elements. Transportation demand studies are also performed by Area Teams.

After suggested plans are outlined, the GIS staff maps each plan and ranks its potential success. All current projects are entered into a database, analyzed and presented to planners with low and high cost alternatives. The solutions obtained from the GIS include a variety of transportation types. For example, a low cost alternative may add a traffic signal on an arterial road and a HOV freeway lane. A high cost plan may include a rail line. Teams meet weekly to evaluate plans for each region in an attempt to form a comprehensive solution.

Because of the immense scale of integration and implementation, a GIS consulting firm was hired. Third Wave Corporation serves as LACMTA’s Management Information System (MIS) department. Development of an enterprise wide GIS depends on coordination between previously independent agencies and satisfying the needs of end users in each department. Inter-agency coordination necessitated the development of a local area network within LACMTA, and wide area network for outside agencies. Implementation of Arcview2 remains a critical element in enterprise wide implementation.

LESSONS LEARNED

The majority of lessons learned at the LACMTA are generic to information system development. However, the larger an operation becomes, the more crucial investment in data management becomes. Some general principles shared by the LACMTA GIS staff include:

• Anticipate needs--Anticipating some needs would have enhanced the speed and efficiency of implementation. For example, anticipation of delays in basemap acquisition
may have facilitated overall system implementation. These delays were not necessarily better because the issue was who was going to pay for acquisition

- **Formalize and review GIS needs regularly**--Another recommendation made by LACMTA was to review the needs assessment more frequently. Two years is perhaps too long for large system implementation.

- **Emphasize software support**--Software specialist support for the proprietary database would have better facilitated compatibility with the GIS system.

- **Facilitate inter-agency cooperation**--Because the LACMTA frequently relies on City data, an agreement on an update schedule would help both parties. However, complication can arise from differences in update needs.

- **Include end-users**--The long-term GIS plan is to allow more planners to access GIS data. Currently, planners who want GIS data must make requests and physically pick up data coverages in disk form.

GIS implementation costs have not been formally calculated by LACMTA and are difficult to extrapolate. However, less than $50,000 is attributed to annual GIS maintenance (maintenance for Thomas Brother's products, the IBM system, Calcomp plotters, and ArclInfo licenses). This figure does not include staff, hardware capital costs, or data acquisition.
San Diego Association of Governments (SANDAG)

OVERVIEW OF TRANSIT SYSTEM

Transit service within the San Diego region is provided by seven fixed route operators who work with SANDAG to coordinate fares, transfers, public information and all major public transportation studies for the area. The San Diego Association of Governments (SANDAG) is both the regional planning agency and the Metropolitan Planning Organization for the San Diego region. SANDAG also acts as a regional technical and informational resource for 18 incorporated cities and the County of San Diego government.

Several divisions operate within SANDAG, including a research division. Emphasis in the research division is placed on GIS services and the Assistance to Operators (ATO) program. Planning and marketing assistance is provided for transit operators in the form of data and technical help. ATO projects include data collection and management, survey research, geographic analysis, and transportation modeling.

Table 13

<table>
<thead>
<tr>
<th>1994 SERVICE AREA CHARACTERISTICS FOR SAN DIEGO COUNTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area (sq.mi)</td>
</tr>
<tr>
<td>Service Area Population</td>
</tr>
</tbody>
</table>


OVERVIEW OF GIS AT SANDAG

SANDAG has been using ArcInfo since 1985, and has developed an extensive collection of spatial databases. These include census tracts and blocks, jurisdictions, freeways, local roads, transit routes and stops. A diverse sample of applications are employed by SANDAG including ridership forecasts, ADA analysis, FTA Title VI requirements, transit ridership volumes, address-matching, Short Range Transit Plan needs, and demographic analysis for user-defined areas.

Transit planning and marketing are key functions of SANDAG's GIS. Regional growth forecasts are compiled for cities and communities for the years 2000, 2010, and 2015. Databases of population, housing, employment estimates, crime statistics, and land use are maintained and used to produce historical, current, and forecasted profiles. Transit operators often request SANDAG GIS staff to integrate and analyze data from these sources to produce a variety of alternatives for their specific geographic area. Examples include questions about a future light rail corridor or areas surrounding particular bus stops.
HARDWARE AND SOFTWARE PLATFORM

In the late 1970s, SANDAG developed a mainframe-based census data retrieval program to analyze population and employment accessible to new transit routes. The program, called TRANES (Transit Network Evaluation System), was converted in the early 1980s to a short-range transit planning PC application called STOPS. STOPS allowed direct access for transit operators to determine population and employment within walking distance to proposed transit lines and convert this information into transit demand.

As software sophistication progressed, spatial analysis at SANDAG became centralized. For the past ten years, SANDAG has used ESRI's ArcInfo 6.1.1 product on a Novell network of Unix workstations. GIS applications at SANDAG have historically used macros developed in ArcInfo's programming language, Arc Macro Language (AML). SANDAG also uses ERDAS software to provide image processing and raster GIS capabilities. Integration of raster imagery and vector data is provided by ERDAS-ArcInfo Live Link. Additional software includes a Fortran compiler, SPSS 3.1 (statistical analysis), and TRANPLAN (transportation planning software).

Significant improvements in personal computers have recently allowed SANDAG to decentralize some GIS applications. SANDAG maintained databases are now networked and accessible to transit operators. The following tables briefly highlight SANDAG's hardware and software infrastructure.

Table 14
HARDWARE PERIPHERALS AND DEVICES

<table>
<thead>
<tr>
<th>Device</th>
<th>Existing</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minicomputer (Prime 9955 II)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Personal Computer</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>X-terminal</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Workstation</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Other Printers (2 HP4si,</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>1 SPARC, 1 line)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Figures are for hardware peripherals and devices used by SANDAG GIS staff only.
Table 15
SOFTWARE LICENSES AT SANDAG

<table>
<thead>
<tr>
<th>Software Licenses</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc/Info floating seat license</td>
<td>7</td>
</tr>
<tr>
<td>Arc/Info Node-locked licenses</td>
<td>6</td>
</tr>
<tr>
<td>ArcView licenses</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Tin license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Grid license</td>
<td>2</td>
</tr>
<tr>
<td>Arc/Info COGO license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Network license</td>
<td>7</td>
</tr>
<tr>
<td>Geocoding package (ArcInfo, ArcView)</td>
<td>-</td>
</tr>
<tr>
<td>X-emulation packages(PC Xware)</td>
<td>1</td>
</tr>
<tr>
<td>Ingres licenses</td>
<td>16</td>
</tr>
</tbody>
</table>


SPATIAL DATA RESOURCES

General Coverages

SANDAG collects and maintains a variety of GIS coverages for geographic areas and features, including census tracts, jurisdictional boundaries, special districts, freeways, local streets, and natural resource areas. Coverages fall into five major groups: general use jurisdictional and census tract boundaries, sensitive lands and natural resource coverages, special districts (fire and sewer), land use coverages (constrained lands), and cross-reference files. Table 16 illustrates the variety of data sources used at SANDAG.
Table 16
GENERAL GIS COVERAGES AT SANDAG

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
<th>Update Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base map</td>
<td>DIME (U.S. Census)</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Road Network</td>
<td>DIME (U.S. Census)</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Passenger Counts</td>
<td>SANDAG Passenger Counting Program</td>
<td>Annually</td>
</tr>
<tr>
<td>Public Ownership</td>
<td>SANDAG</td>
<td></td>
</tr>
<tr>
<td>Demographic Data</td>
<td>U.S. Census</td>
<td>Annually</td>
</tr>
<tr>
<td>Regional Activity Centers</td>
<td>Various local sources, collected and address-matched by SANDAG</td>
<td>Annually</td>
</tr>
<tr>
<td>Special Districts (State Assembly,</td>
<td>County sources, Registrar of Voters,</td>
<td></td>
</tr>
<tr>
<td>Congressional, fire, school, sewer,</td>
<td>Department of Public Works, Department of Education</td>
<td></td>
</tr>
<tr>
<td>judicial, water, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political Boundaries</td>
<td>Local Agency Formational Committee</td>
<td>Annually</td>
</tr>
<tr>
<td>Rail/Trolley</td>
<td>USGS maps</td>
<td>As built</td>
</tr>
<tr>
<td>Land Use</td>
<td>Air Photos, Satellite Images, local jurisdiction community plans, misc. sources</td>
<td>Periodic (approx. years)</td>
</tr>
<tr>
<td>Crime Data</td>
<td>ARJIS</td>
<td>Annually</td>
</tr>
</tbody>
</table>


SANDAG is also the designated Regional Census Data Center for the San Diego region and maintains complete census data. Regular requests are made for demographic profiles for areas ranging in size from individual transit stop accessibility to district or regional characteristics.

Transit Data Sources

Much of SANDAG’s transit and transportation data is collected through numerous quantitative surveys. Transit databases at SANDAG include:

- Regional On-Board Transit Survey - Trip-making characteristics are determined, including
purpose, fare, mode of access, and origin/destination information. Demographic characteristics are also obtained, including age, gender, income, occupational status, number of vehicles available, household size, area of residence, and frequency of public transit use.

- Regional Transit Passenger Counting Program - Boarding and deboarding data are tabulated by stop. The program also provides on-time performance information for all routes within the region.
- Resident Transit Public Opinion Survey - Measures public use and non-use of public transit and level of familiarity with services. The results are used in planning and marketing transit service.
- Trolley Ridership Estimation Program - Vendomat information is combined with survey information collected on-board the vehicles by fare inspectors. This produces a monthly estimate of ridership by fare payment type and by line.

**Transportation Data Sources**

Transportation databases used by SANDAG include:

- Average Daily Traffic Volumes - Conducted by each jurisdiction for vehicle counts on local streets and arterials. Regional freeway counts are performed by CALTRANS (California Department of Transportation). Annual reports are made available to SANDAG.
- Bicycle Use Survey - Identifies directional bicycle volumes at major street intersections and is conducted approximately every two years. The information collected is used by local government agencies for facilitating regional bicycle use as an alternative commuting means.
- Border Surveys - Information gathered helps assess the ability of the transportation system to accommodate international tourism and commerce as well as to identify deficiencies in the infrastructure.
- Level of Service Analysis (Freeways) - Current and historic weekday LOS data from 61 locations along 11 freeways are maintained by CALTRANS. Long term monitoring of traffic conditions helps to identify areas with the most critical levels of congestion.
- Level of Service Analysis (Arterials) - Data is compiled that quantifies existing operating conditions for approximately 93 arterial roadways which includes approximately 600 one-way miles of roadway in the San Diego region.
- Transportation Networks - This database contains existing and proposed transportation facilities and is maintained by SANDAG, CALTRANS, transit agencies, and local jurisdictions.
- Travel Behavior Survey - A survey conducted in Spring, 1995 is used to calibrate trip generation, trip distribution, and mode split models that comprise part of the regional transportation modeling package.
- Vehicle Occupancy and Classification Survey - Three surveys conducted in 1981, 1985, 1990, and Spring 1995 are used to evaluate facility needs, mode splits, vehicle emissions, and fuel consumption. Occupancy counts over time can indicate the effectiveness of programs that encourage higher vehicle occupancy through ridesharing.
Table 17
TRANSPORTATION MODEL COVERAGEs

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing and planned transportation network facilities</td>
<td>DIME Network, Local Circulation Plans, Regional Transportation Plan</td>
</tr>
<tr>
<td>Existing local streets</td>
<td>DIME Network</td>
</tr>
<tr>
<td>Transit routes</td>
<td>Transit Operators</td>
</tr>
<tr>
<td>City of San Diego traffic count stations</td>
<td>City of San Diego</td>
</tr>
<tr>
<td>County of San Diego traffic count stations</td>
<td>County of San Diego</td>
</tr>
<tr>
<td>CALTRANS traffic count stations</td>
<td>CALTRANS</td>
</tr>
</tbody>
</table>


CURRENT GIS APPLICATIONS

SANDAG has taken a two-fold approach to GIS integration and transit planning. The first is a centralized approach in which transportation modeling services are provided by SANDAG ATO staff to various operators on request. This approach provides sophisticated analysis of complex transit related queries using large databases. Powerful software applications required for this type of analysis tend to require extensive training time and are typically not user-friendly. The centralized approach is common with large systems. However, recent improvements in personal computer capability has allowed SANDAG to decentralize access to its GIS databases.

The second approach endorsesthe use of PC workstations linked by a network to the main system. This decentralized approach is becoming increasingly popular with large GIS systems and provides several benefits. Once implemented, planners (end users) can easily access spatial databases with little or no formal GIS training. This approach can also reduce the volume of commonly requested queries. Budget restraints often dictate reductions in staff and decentralization can offset potential loss of efficiency. Furthermore, because networked systems are increasingly common, interoperability between and among agencies is facilitated. SANDAG uses ESRI's ArcView2 for user-friendly access to their GIS databases. The following paragraphs highlight SANDAG's GIS applications as they relate to the two approaches.

Transit Modeling

ArcInfo is used as the principal transit modeling tool at SANDAG. Because ArcInfo does not have transit modeling capability, TRANPLAN is used for transportation planning and modeling. TRANPLAN is used to evaluate the traffic impacts of proposed development and improvements to the region's existing and future highway and transit systems. Person or trip movements between areas can also be analyzed with TRANPLAN.
Fortran programs are used for linking TRANPLAN with ArcInfo. First, ArcInfo files are fed into TRANPLAN. Calculations are performed in TRANPLAN and the results are then fed back into ArcInfo for map and report generation. An extensive master transportation coverage is maintained and contains both existing and planned network related features. These include: freeways, ramps, high occupancy vehicle (HOV) lanes, general plan circulation streets, streets used by public transit, local streets necessary for network connectivity, highway access links, and rail lines. Approximately 42,000 arcs and 34,000 nodes are included in this master transportation coverage.

In preparation for running the model, updates to routes and alignment changes are coded into ArcInfo. These changes are digitized and built using the Network module of ArcInfo. Coding is currently being updated from a point-by-point method to an arc method. Using ArcInfo 7.0's dynamic segmentation feature, route coding efficiency and accuracy near rail lines will improve. Models are updated with information obtained from travel behavior surveys and on-board transit surveys. The transit ridership forecasting models are used for determining future ridership in corridor improvement projects.

Transit planning questions are also addressed using SANDAG's GIS. Network buffer analysis is a common request. Census data such as total population, minority population, and dwelling units are summarized for user-defined buffers. Recent work includes the development of transit flow maps, which provide users with a simplified visual representation of ridership volumes by route. Decisions regarding where to expand or reduce service can be assisted by these maps and plots.

Desktop GIS Applications. The second approach focuses on decentralizing access to SANDAG maintained databases through the use of desktop GIS applications. Specifically, SANDAG has developed View2Transit (V2T), a customized application using ArcView2's programming language, Avenue.

The main objective of View2Transit development was to allow transit operators and planners to use a GIS with minimal training and expense. A V2T development committee was established and several key needs were identified. Table 18 details six base transit applications identified by the development committee. Prior to implementation of V2T, many of these applications were performed by SANDAG GIS staff per operator request.

Users of V2T can directly access commonly used SANDAG maintained information. Geographic analysis can be performed at scales ranging from less than one city block to entire service areas. A central feature of V2T is data integration. For example, transit operators can query a variety of spatial databases, join databases with common geography, and display the output as a map, table, or chart.
### Table 18

**BASE APPLICATIONS FOR DESKTOP GIS AT SANDAG**

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Category</th>
<th>Database</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Service Potential</td>
<td>Using a definition of potential transit ridership including employment, income, low auto availability, renter, age, and other variables, define areas underserved or unserved by transit</td>
<td>Planning/Operations</td>
<td>Census data</td>
<td>Currently done with SANDAG’s GIS</td>
</tr>
<tr>
<td>Socio-economic profiles of areas surrounding transit</td>
<td>Socio-economic profiles of areas surrounding stops, routes, route segments. Allows staff to buffer an area within a specified distance to a stop or route</td>
<td>Planning/Operations/Marketing</td>
<td>Census data</td>
<td>Currently done with SANDAG’s GIS</td>
</tr>
<tr>
<td>Physical characteristics of transit</td>
<td>Maintains physical characteristics of bus/trolley stops, displays ADA accessible stops, etc. (i.e., What is the distribution of accessible bus stops?)</td>
<td>Planning/Operations</td>
<td>SANDAG and operator bus stop inventories</td>
<td>Currently done with SANDAG’s GIS</td>
</tr>
<tr>
<td>Route analysis</td>
<td>Analyze existing and planned routes by stop activity, capacities, analysis of passenger loads by route segment</td>
<td>Planning/Operations</td>
<td>Transit coverage, route alternatives, Passenger counts, surveys</td>
<td>Currently done by individual operator</td>
</tr>
<tr>
<td>Title VI evaluation</td>
<td>Identify minority areas, transit accessibility, and minority routes for FTA/Title VI requirements</td>
<td>Planning</td>
<td>Census data, Passenger counts, Transit coverage</td>
<td>Currently done with SANDAG’s GIS</td>
</tr>
<tr>
<td>Future Growth areas</td>
<td>Identify areas of forecast growth and relate these changes to transit (current and planned service). For example, what is the expected population growth within the service area of a planned light rail line?</td>
<td>Planning/Operations/Marketing</td>
<td>SANDAG population, employment, land use forecasts, Transit coverage</td>
<td>Currently done with SANDAG’s GIS</td>
</tr>
<tr>
<td>Transit use by time</td>
<td>Identify route activity during peak versus non-peak hours, identify possible turnarounds</td>
<td>Planning/Operations</td>
<td>Passenger Counting Program, Transit Coverage</td>
<td>Not yet developed</td>
</tr>
</tbody>
</table>


### OBSTACLES TO IMPLEMENTATION

The main obstacle encountered by SANDAG was a two-year delay in project implementation. Half of this delay was due to the delay in the release of ArcView2. This meant that the development committee was put on hold after a strong start. However, the delay actually allowed time for SANDAG staff to develop the required databases in preparation for software acquisition.

Another obstacle was the task of ensuring that transit staff members actually used V2T. To overcome this, SANDAG and transit operators formed a user group. The user group met regularly to discuss problems/comments, new applications, and new databases for use with V2T.
GIS IMPLEMENTATION STRATEGIES

The primary implementation strategy for View 2 Transit was discussing the needs and requests of the transit operators before any programming or development began. Prior to any software development, a development committee of SANDAG staff and transit operators was formed and regular meetings were scheduled for several months. Discussion topics included applications, data needs and sources, agency responsibilities, development scheduling, testing and evaluation, and other project aspects.

A second key success strategy was training of transit operator personnel in ArcView and View2Transit. Lastly, establishing the user group to obtain regular progress reports from the operators helped ensure continued use and monitored ongoing problems/needs.

LESSONS LEARNED

A clear lesson learned by SANDAG staff during View2Transit implementation was that good project management skills are needed by staff, particularly when dealing with a range of computer and technical expertise among transit operators. One challenge noted by SANDAG was keeping the staff members interested in GIS while attempting to keep their level of GIS understanding minimal. Not only was SANDAG staff responsible for developing a system for non-GIS users but they were seeking advice from non-GIS staff members for assistance in the design stage.

Additionally, it was important to keep the transit operators informed as to project status, particularly while waiting for the software to arrive. Updates and reminders regarding the scope of work were regularly sent to the development group after ArcView2 was received.
Dallas Area Rapid Transit

OVERVIEW OF TRANSIT SYSTEM

Dallas Area Rapid Transit (DART) was formed in 1984 and provides public transit to Dallas and 13 member communities. Service is provided by buses, vans, and a planned light rail system. A modified transit development plan was approved in 1989 which called for 65 miles of light rail, 35 miles of HOV lanes and 18 miles of commuter rail. Construction began in 1992 on a 20-mile long light rail starter segment serving the downtown area. The line, connecting downtown Dallas to Park Lane and Oak Cliff, is expected to open in mid-1996.

By 2010, population is expected to climb 25 percent, employment is expected to increase 44 percent, and total vehicle miles traveled is expected to increase 38 percent. DART’s GIS is a critical planning and management tool for anticipating network service needs, and, therefore, for improving existing and future ridership.

Table 19
TRANSIT SYSTEM CHARACTERISTICS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area (sq. mi)</td>
<td>695</td>
</tr>
<tr>
<td>Service Area Population</td>
<td>1,771,150</td>
</tr>
<tr>
<td>Member Cities</td>
<td>14</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>1,011</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>842</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>179,752,804</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>26,538,006</td>
</tr>
<tr>
<td>Average Riders per Day</td>
<td>175,000 - 189,000</td>
</tr>
<tr>
<td>Bus Routes</td>
<td>135</td>
</tr>
<tr>
<td>Bus Stops</td>
<td>10,612</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>118,932,320</td>
</tr>
</tbody>
</table>

OVERVIEW OF GIS AT DART

GIS applications at DART are used in numerous divisions of the agency, including Paratransit, Automatic Vehicle Location, enhanced customer services (Trip Itinerary Planning System), Bus Stop Inventory Management, service planning, data collection, service scheduling, and federal reporting efforts.

The genesis of DART’s GIS began in 1986 when an existing CADD (computer aided design and drafting/CAES (computer aided engineering systems) was replaced with a GIS called Graphic Data Systems (GDS). Both systems were designed by Electronic Data Systems Corporation (EDS). Because the basemap and other construction drawings already existed in EDSs CADD system, transition to GIS applications development required no additional capital outlay.

Purpose and Structure

The purpose of developing and implementing a GIS at DART was to respond more quickly to customer requests, effectively track route changes, and to determine required additions and modifications of transit lines. DART’s GIS is used primarily for service planning, customer assistance, and map and schedule production. Project Management also relies on the base map for its AVL program.

DART’s GIS division acts as a service arm of the Information Systems Department and responds to various mapping and spatial analysis requests. The staff consists of a manager, a design analyst, two programmer analysts, and a data collection/data entry specialist. The GIS division develops applications and eventually transfers the responsibility of daily operations and maintenance to end-user departments.

SPATIAL DATA RESOURCES

Basemap

DART’s basemap consists of corrected and enhanced TIGER files for the agency’s five-county service area. A significant amount of corrections were needed to increase the accuracy of these files for geocoding and AVL/GPS purposes. The corrections were first made by a subcontractor who produced a map that delivered approximately 90 percent accuracy. In-house enhancements increased the address accuracy to 94 percent.

Spatially accurate and aesthetic considerations were also issues with the TIGER files. Because DART’s AVL/GPS integrated radio system delivers locational information on over 800 vehicles to within 30 feet, the spatial accuracy of the original TIGER files (60-200 ft) was not acceptable. To increase visual attractiveness and spatial accuracy, the TIGER basemap was then linked to a “dumb”, but aesthetically pleasing, map provided by the Texas Department of Highways.

Scheduling information is stored in tables managed by an ORACLE database management system and linked to the basemap. Bus stop source and destination information is related to demographic information and traffic survey zone data provided by the Bureau of the Census and the area Council of Governments. These tables are geocoded to the street centerline database (enhanced TIGER) and form the core of DART’s Trip Itinerary Planning System (TIPS). TIPS is the customer service component of DART’s GIS.
### Table 20
DATA LAYERS AND SOURCES

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Centerline Database (Basemap)</td>
<td>TIGER, Texas Department of Highways, ETAK, GDT</td>
</tr>
<tr>
<td>Bus Stop Inventory</td>
<td>Internal Sources</td>
</tr>
<tr>
<td>Bus Route Database</td>
<td>Internal Sources</td>
</tr>
<tr>
<td>Route Timing/Scheduling Database</td>
<td>Internal Sources</td>
</tr>
<tr>
<td>Origin/Destination</td>
<td>ETAK, GDT</td>
</tr>
<tr>
<td>Land Use Mapping</td>
<td>North Central Texas Council of Governments, Consortiums</td>
</tr>
<tr>
<td>General Demographic, employment data, transportation data sampler</td>
<td>Bureau of Transportation Statistics (BOTS), COG or MPO, U.S. Census Bureau (STF3A, STF1B, CTPP)</td>
</tr>
<tr>
<td>Hazmat DB, Aerial DB</td>
<td>Department of Information Resources (DIR)</td>
</tr>
<tr>
<td>Digital Orthophotos, parcel data, Digital Elevation Models</td>
<td>Other public entities (municipalities and appraisal districts, consortiums)</td>
</tr>
<tr>
<td>Meteorologic, biologic, geologic resource data, water data, socio-economic data</td>
<td>Texas Natural Resources Information System (TNRIS)</td>
</tr>
</tbody>
</table>


**Bus Stop Inventory**

DART’s Bus Stop Inventory (BSI) contains 10,526 stops and all routes serving each stop. The BSI is a graphics/tabular dataset that describes the locations of all bus stops, amenities, and maintenance items (benches, shelters, phones, trash cans). The BSI also includes the sequence of stops within routes, associated timepoints, and schedule information.

**Demographics**

Census Block Group drawings for DART’s service area were obtained from North Central Texas Council of Governments (NCTCOG) datasets. This data was loaded into the ORACLE RDBMS for analysis to be driven from within the mapping environment. Analysis is performed at three levels of aggregation: Census Block Group, Traffic Survey Zones (TSZ), and Traffic Analysis Patterns (TAP). The years include 1980, 1986, 1990. Projections for 2000 and 2010 are also included.
Current data and transfer standards at DART include the following:

- ASCII - fixed format or comma delimited
- TIFF - 36 flavors graphics images
- DLG - vector exchange formats
- DXF - vector exchange formats
- TX State Plane Coordinate System - NAD27, NAD83
- Lat/Long
- UTM

HARDWARE AND SOFTWARE PLATFORM

GDS is a proprietary package that employs an object-based data structure that embodies objects for storing and managing complex data relationships from numerous sources. For storage of attribute data, DART uses the ORACLE RDBMS system. GDS has the ability to make calls to the Oracle RDBMS. Applications developed using the "C" programming language are used for interfacing the system with external programs. Visual Basic is also used extensively for end-user applications where map display is not required.

The current hardware driving DART's GIS includes a VMS cluster of two Digital Equipment Corporation VAX6000s and one VAX4000. Four VAXstation 3100 workstations are linked to the system, and 35 486 terminals emulate an X-Windows environment through a Digital Pathwork network. Table 21, depicts DART's current hardware configuration.

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Device Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-computer</td>
<td>VAX 6000-510</td>
<td>2</td>
</tr>
<tr>
<td>Hard Disk Drive</td>
<td>HSC-70 (32Gb total)</td>
<td>2</td>
</tr>
<tr>
<td>X-terminal</td>
<td>PCS with X-Window emulation</td>
<td>35</td>
</tr>
<tr>
<td>Server</td>
<td>AlphaServer 2100 (40Gb disk space)</td>
<td>1</td>
</tr>
<tr>
<td>Workstation</td>
<td>VAXstation 3100-76</td>
<td>4</td>
</tr>
<tr>
<td>AXP Workstation</td>
<td>DEC 3000-400</td>
<td>5</td>
</tr>
</tbody>
</table>

DART plans to replace the VAXstations with Alpha stations while shifting the singular VMSCluster currently in place to a two-cluster system, each consisting of three subsystems. One of the two VMSClusters will be dedicated to GIS/CADD/Development, and the other will be dedicated to Paratransit, Customer Service, and Rideshare applications. This system will use an ORACLE database to provide access to tabular datasets from all clusters.

CURRENT GIS APPLICATIONS

GIS applications at DART fall into five categories:

Customer Service / Assistance

DART's Customer Assistance Division handles approximately 2 million telephone requests annually. Prior to GIS implementation, customer questions about schedules and routes were handled by perusing printed bus schedules, referring to notices reflecting schedule changes, and using a variety of maps. Approximately 5,000 customer inquiries are received daily. High call volume at the Customer Assistance Division, created a significant incentive to automate the process as well as an internal willingness to change. One objective is to reduce call durations from a pre-GIS average of 1.5 minutes to one minute or less.

In March, 1993, DART began implementing TIPS, which allows information operators to access a trip's origin or destination by inputting an address intersection or landmark. The system geocodes the location and searches for the closest bus stop to that location. TIPS reports all routes that stop at the location and displays the schedule information. The final version of TIPS can calculate the customer's entire trip and provide alternatives.

Specialized Applications

The GIS division at DART has developed an interactive graphic maintenance application for updating spatial attributes on bus stop maps and associated tabular datasets. This was done by developing "C" programs to read the schedule data from the PC-based Teleride-Sage run-cutting system used in the scheduling department.

Two copies of the Bus Stop Inventory are maintained for both stops and routes: one that reflects current system configuration and a second set of tables that store changes that will take effect at the next markup. This allows for modeling of future changes without changing the production dataset. Route datasets are particularly useful in generating graphic plots for the route revision public meeting and the markup processes. The creative services department also uses the route and basemap files for generating public timetables. A separate Operator's Route Guide is produced by the service planning department using these datasets.

Service Planning

DART's GIS service planning applications include a variety of analysis functions: travel demand, route optimization, rail alignment, demographic analysis, and "what if" studies. Frequent requests include transit route analysis and demographic analysis. Polygon, linear, and point, buffer commands are used for demographic analysis.
An application was developed by DART’s GIS staff that allows interactive graphic demographic data analysis for the creation of study polygons, and analysis of intersections of underlying Census polygons. Demographic reports are produced for the following fields:

- Age / Sex
- Educational Levels
- Ethnicity and Population
- Mean Housing Value
- Median Income
- Persons per Household
- Mean Rental Value
- Vehicles per Household
- Population and Employment
- Intrazonal HBW Trips
- Mode of Travel to Work
- Number of Workers in 1989
- Projected Ridership
- Origin / Destination “starbursts” (TSZ level and study district level)
- List of street names and address ranges

The application also allows the end-user to model proposed routes or extensions to existing routes and calculate projected ridership generate desired “starburst” plots depicting origins and destinations of home-based work trips, and generate listings of street names and address ranges that fall within the study area.

Four times each year, DART evaluates route productivity and examines service needs in relation to operating budget. As a result of this analysis, new routes and schedules are generated and then presented to DART’s board of directors and the general public.

System-Wide Analysis

An extension of service planning applications includes the ability to see transit usage trends and modify network design accordingly. DART is in the process of redesigning its network from a radial, spoke-and-hub system (most buses traveling into the downtown corridor) to a more grid-like system. This system is described as a “daisy chain” that include multiple hubs that fan out over the service area. GIS analysis revealed a need for transit service to become more responsive to needs in outlying areas. DART successfully implemented cross-town routes in response to an increasing trend of suburb-to-suburb travel. Conversely, DART uses GIS to plan for service reductions. By examining year-to-year ridership comparisons, trends based on passenger-per-mile ratios are revealed.

Similar analysis was performed when evaluating potential light rail corridors. GIS was used extensively to perform a series of studies examining three different rail alignments in north Dallas. Current and projected population and employment densities were overlaid and buffer analysis was performed (.25 mi).
Paratransit, Ridesharing, and AVL/GPS

These applications serve as GIS sources for route overlays, the basemap (street centerline), and the bus stop inventory used in all applications, including geocoding. Starburst origin/destination maps are used for ridesharing, car pooling, and van pooling strategies.

GIS IMPLEMENTATION STRATEGIES

General Strategy

DART’s implementation of its GIS was a conscious decision based on recognized needs. However, the decision to go with a proprietary software vendor was the result of economic pragmatism. The GDS software package currently used by DART’s GIS staff was originally purchased by the Engineering Department as a design support tool for light rail implementation. In 1988, when a bond referendum to obtain more funding for DART failed to pass, the design and construction phase of the light rail project was subcontracted to area consultants. Many of these consultants used different CADD systems.

Because thousands of engineering drawings were developed during the first two years of the project, translation to and from these other systems was necessary. Light Rail Transit coordinators developed a set of scale and map projection standards to facilitate data sharing so that the drawings could be used by DART during the operations and maintenance phases.

Application-Specific Strategy

Perhaps the most successful GIS application at DART is TIPS. The primary reason for its success stems from early participation and management support from the end-user department. DART charges the customer service staff with updating and maintaining all landmark data, and verification of all schedule changes for errors prior to initiating a mark-up (service charge). Because the customer service department has the greatest vested interest in the data, it is the most likely group to take responsibility for data updates and maintenance.

OBSTACLES TO IMPLEMENTATION

The largest challenge in developing a GIS at DART has been balancing data collection, enforcement of data standards, and data integrity, with the need to provide an accessible, friendly gateway to spatial datasets that serve the needs of various end-user departments.

Other GIS challenges at DART include the following:

- Clean up and audit tasks
- Maintenance
- Data credibility
- Inefficient procedures or processes that have outgrown their usefulness and are only continued because, “that’s the way we have always done it.”
- Conflicting standards (feet versus meters, NAD27 versus NAD83)
- Not all standards are well developed or adhered to
• Some issues are difficult to resolve and alternatives need to be developed
• Production and Development datasets

LESSONS LEARNED

DART has established several rules of thumb based on their implementation experience:

• Avoid proprietary standards and protocols - Proprietary standards and protocols limit flexibility and opportunities to share data. Proprietary standards also eliminate competitive bidding and flexibility in terms of software solutions.
• Only implement what can be maintained - Data maintenance is critical to GIS quality and subsequent decision making. Data may be incomplete or incorrect, missing, not applicable once obtained, and/or too costly to obtain. Useful information is a function of data quality. If data are not high quality, decisions based on data are not going to be high quality.
• Maintain the integrity of your data source - Develop a means of updating and passing enhanced data back to the originator, benefiting all parties. This includes adding “key” fields for relating to other sources and then back to the original source. Another advantage of this approach is that it disperses the data maintenance burden while enhancing the data for all users. Moral: the sum of the parts is greater than the whole.
• Acquire data as close to the source as possible - This increases the opportunity to acquire accurate data while decreasing errors. The primary user (one who has the greatest vested interest in the integrity of the data) should maintain the data.
• Share data where possible - The benefits of data sharing include:
  -- Concentrates maintenance among a few and benefits to many.
  -- Eliminates or decreases disagreement over who has the correct data.
  -- Focuses data maintenance on the proper “owner”. This allows you to focus on your area of expertise rather than maintaining other parties’ data.

DEVELOPMENT STANDARDS

Addressing the issue of developing standards may facilitate application of the lessons learned by DART. Some suggestions outlined by DART regarding development standards include:

• Naming conventions - for all database objects (tables, columns, indexes, views, etc.) for all application objects (application names, forms, reports, menus)
• Standard screen layout
• Standard report headings, layouts, and breaks
• Standard key functionality, i.e., F1 key = help
• Standard data modeling methodology
• SQL forms library
• Standard directory structure
• Production/Test/History Systems

Benefits can be realized by developing and maintaining datasets in one centralized location rather than multiple areas. This also dramatically improves data integrity and credibility.
Milwaukee County Transit System

OVERVIEW OF TRANSIT AT MILWAUKEE COUNTY

The Milwaukee County Transit System (MCTS) is operated by Milwaukee Transport Services, Inc. Table 22 highlights some characteristics of the MCTS.

Table 22
MILWAUKEE COUNTY TRANSIT SYSTEM CHARACTERISTICS

<table>
<thead>
<tr>
<th>Service Area (sq. mi)</th>
<th>243</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area Population</td>
<td>990,700</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>543</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>425</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>150,423,158</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>17,445,622</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>80,263,938</td>
</tr>
</tbody>
</table>


OVERVIEW OF GIS AT MILWAUKEE COUNTY TRANSIT SYSTEM

The core of Milwaukee County Transit’s GIS is a newly installed computer-aided dispatch (CAD) and automatic vehicle locator (AVL) bus system. The Westinghouse system, called “SmartTrack,” provides reliable two-way radio communications and enables MCTS dispatchers to identify the location and schedule adherence of any on-duty bus. The radio system operates from repeaters located in the 42-story Firstar Center in downtown Milwaukee and the Muridale water tower.

History of Implementation

Milwaukee County’s consideration of a GIS system stemmed originally from its need to replace an antiquated radio dispatch system (over 20 years old). The replacement process started in 1985 and did not include a GIS as part of the update. However, during the years over which implementation took place, AVL technology became an option. Although a formal needs assessment was not completed, the primary need identified was a locator system. Milwaukee County needed to:
• Know where the buses were at any given moment
• Monitor on-time performance

Because GPS technology was just beginning to surface at that time, consideration was given to Signpost and Loran-C systems. In February, 1992, the Milwaukee County Board of Supervisors approved the purchase, and MCTS contracted with Westinghouse Corporation and Motorola to provide a GPS trunked radio system. At that time, MCTS received $6.3 million in federal funds and $1.6 million from Milwaukee County for system implementation (total cost: $7.9 million). Because the radios share infrastructure with other county agencies, overall costs to the county were reduced. Some aspects of the system are not yet fully operational and final payment will be made upon completion of implementation.

The MCTS GIS is comprised of three interfaced subsystems:

• 800 MHZ Motorola trunked radio system
• Westinghouse Computer-Aided Dispatch System (CAD)
• Westinghouse Automatic Vehicle Location System (AVL)

Milwaukee County is currently beginning stage two of a three-phase acceptance program. The Phase I acceptance test mandated Westinghouse to demonstrate that the system would perform as specified for 15 vehicles. The Phase II acceptance test expanded the mandate to include the full fleet. Following the Phase II acceptance test, Westinghouse is to demonstrate that the system will perform as specified for the full fleet and for a minimum of 30 days without any major problems or downtime.

Maintenance of the system is performed by Transportation Management Solutions, who purchased the fleet communications business from Westinghouse. Prior to the MCTS project, Westinghouse began installation of a radio/locator system for Denver’s Regional Transportation District. As a result, MCTS was able to learn from Denver’s experience and made several changes and upgrades to improve the system.

HARDWARE AND SOFTWARE PLATFORM

Milwaukee County's AVL system runs Trimble and UMA Trapeze scheduling/mapping software and ORACLE databases on a Unix HP9000 platform. Four stations are networked for dispatching. The route map interface is passed daily to the Westinghouse system. Timepoints are checked by monitoring 380 unique locations with 525 logical checks.
### Table 23
**HARDWARE DEVICES AND PERIPHERALS**

<table>
<thead>
<tr>
<th>Device</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer (366/25)</td>
<td>1</td>
</tr>
<tr>
<td>Host mini computer (HP9000, Model 8275-650)</td>
<td>2</td>
</tr>
<tr>
<td>X-terminal</td>
<td>0</td>
</tr>
<tr>
<td>Workstation (HP-720)</td>
<td>2</td>
</tr>
<tr>
<td>Color Printer (HP-Paintjet XL)</td>
<td>1</td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>0</td>
</tr>
<tr>
<td>Plotter - electrostatic</td>
<td>0</td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td>0</td>
</tr>
</tbody>
</table>


### Table 24
**SOFTWARE LICENSES AT MILWAUKEE COUNTY**

<table>
<thead>
<tr>
<th>Software Licenses</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP-Unix</td>
<td>2</td>
</tr>
<tr>
<td>SmartTrack</td>
<td>7</td>
</tr>
<tr>
<td>Trimble IVLU</td>
<td>1</td>
</tr>
<tr>
<td>Trapeze MAP</td>
<td>1</td>
</tr>
<tr>
<td>Trapeze SCHEDULE</td>
<td>12</td>
</tr>
<tr>
<td>Oracle-ENGINE</td>
<td>2</td>
</tr>
<tr>
<td>Oracle REPORTS</td>
<td>2</td>
</tr>
<tr>
<td>Oracle FORMS</td>
<td>2</td>
</tr>
<tr>
<td>Oracle SQL</td>
<td>2</td>
</tr>
</tbody>
</table>

SPATIAL DATA RESOURCES

The street network was derived from TIGER files then imported into the Trapeze mapping module. The basemap is maintained by transportation department personnel. Bus routes were digitized and are also maintained by transportation department personnel. These maps are then exported into SmartTrack for modification.

Table 25
DATA LAYERS AND SOURCES

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
<th>Update Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basemap</td>
<td>TIGER</td>
<td>As needed</td>
</tr>
<tr>
<td>Bus Routes</td>
<td>Existing Maps</td>
<td>As needed</td>
</tr>
<tr>
<td>Bus Stops (timepoints)</td>
<td>Existing Maps</td>
<td>As needed</td>
</tr>
</tbody>
</table>


CURRENT GIS APPLICATIONS

GIS applications at MCTS are currently limited to the CAD/AVL system. Information from SmartTrack helps drivers and dispatchers proactively manage fleet operations and maintain arrival/departure schedules.

The AVL component of the system operates in a loop fashion. Schedule information gets transferred to the AVL system every evening. Every morning, bus operators enter batch, route, and run numbers into data terminals, and the AVL system downloads data necessary for scheduling buses. As the bus travels, the system checks route and time adherence every 45 seconds. This information is then sent back to the AVL system for dispatchers to monitor.

The CAD component of the system is comprised of a number of features. Communications equipment has been installed on all 543 buses as well as 61 route supervision/support vehicles. Locator equipment is currently installed in all buses and 59 support vehicles. Control units were installed in each bus near the driver's seat. Dispatchers at a central monitoring system track bus locations on CRT's. Icons representing buses move on route maps indicating bus locations. The icons also change colors, indicating the number of minutes a driver is behind or ahead of schedule. Dispatchers can identify if bus stops are missed and if buses deviate from the route.

This locator function also helps dispatchers provide pinpoint information to emergency services in cases of breakdown, security problems, and medical emergencies. When a bus operator requests security assistance, priority is automatically given, enabling immediate response from dispatchers. Additionally, each bus is equipped with a concealed microphone and an automatic police assistance feature. Operators can request police assistance without speaking to a dispatcher by activating the microphone. Dispatchers are able to hear events taking place on-board and can relay this information to police.
Administrative support for dispatchers is also provided by the system. Daily activities such as bus operator requests for vehicle repairs and security assistance are tracked. Summary reports are automatically generated and printed. Timepoint and route adherence information is also logged into a database so that the scheduling department can monitor trends in on-time performance. Reports are also generated so segments and schedules can be adjusted if necessary. Ultimately, the intent is to increase on-time performance. At the time of this writing, MCTS's AVL/CAD system has not in place long enough to determine whether implementation resulted in increased on-time performance.

Future applications include the following:

- Installation of Automatic Passenger Counters are planned for fifty buses by 1996.
- "Investigating options for the purchase of mapping/census software for the Planning Division.
- Schedule adherence information will be available to planners for review of schedule running time.

BENEFITS AND OBSTACLES TO IMPLEMENTATION

Two implementation obstacles were noted by Milwaukee County. Because vendors sometimes use subcontractors for system installation, implementation can be delayed. Second, greater monitoring capabilities have complicated system operations. Bus operators need to input more data into the system on a daily basis. Operators also need to request permission to talk on the system. Prior to implementation, requests were not necessary. Some resistance to change occurred.

Milwaukee County has been very satisfied with system performance in terms of equipment reliability. Although the system was originally set as a 1.5 year project, implementation is in its third year. Most of the delay was valid and related to Westinghouse and MCTS working together to design a system that met the needs of MCTS. Some delays were caused by third-party vendors not providing hardware and software as quickly as anticipated.

LESSONS LEARNED

Advice from MCTS is limited to CAD/AVL system implementation. MCTS offers several tips for agencies considering implementation of this type of system:

- Make sure that needs are clearly specified in the contract language. Bases need to be covered in the initial stages of specification identification.
- Be sure to see a prototype of the product (if available) before committing to buying it. If possible, visit users of equipment to see what problems may be avoided. For example, Milwaukee County discovered that a control head was not readable in sunlight. Had another agency/company been using the control head, early discovery of the problem might have been possible. Additional costs and time delays associated with replacing these items may have been avoided.
- Do not underestimate the complexity of a full CAD/AVL system. Numerous technical components must work together before the system functions properly.
- Choose a reliable company for the main contractor. This may help assure company cooperation if a problem arises.
• Be prepared to devote a large amount of technical and dispatcher staff time to project implementation. Do not let the vendor create and install the system without the transit operators active participation.

The Milwaukee County Transit System case study illustrates that the nature of GIS implementation is specific to individual agency/operator needs. That is, development of a GIS varies depending on the specific needs of the transit system. At Milwaukee County, the use of GIS as a planning tool was not the primary impetus for implementation. Rather, GIS development and implementation driven by operations needs.

Capital District Transportation Authority, 
Albany, NY (CDTA)

The Capital District Transportation Authority's district consists of Albany, Rensselaer, Saratoga, and Schenectady counties. The CDTA is considered a medium-size transit agency.

OVERVIEW OF TRANSIT SYSTEM AT CDTA

| Table 26 |
| TRANSIT SYSTEM CHARACTERISTICS |
| Service Area (sq. mi) | 2,261 |
| Service Area Population | 779,718 |
| Total Fleet | 247 |
| Maximum Number of Vehicles Operated | 201 |
| Annual Passenger Miles | 55,120,601 |
| Annual Vehicle Miles | 6,380,014 |
| Total Annual Operating Expenses | 23,353,638 |

Source: U.S. Department of Transportation, Data Tables for the 1993 National Transit Database, Section 15 Report Year.

OVERVIEW OF GIS AT CDTA

Within the Capital Region, several organizations have collaborated to form a regional GIS consortium as a forum for implementation. Participants are listed in Table 26. Implementation is currently in the early stages and is using a GIS demonstration project as a development model. Because the majority of GIS development will be performed as part of ongoing regional and transportation activities, inter-agency coordination will act as a testing ground for demonstrating the use of GIS for a number of transit policy and planning applications. General applications include spatial data display and spatial analysis, with an emphasis on service standards.

Inter-agency GIS coordination began with the adoption of a GIS-T research demonstration project in January, 1995. Members included the New York State Department of Transportation’s Transit Division, the CDTA, and the Capital District Transportation Committee. In June, 1995, the Capital District Regional Planning Commission added a regional geographic information inventory.
Although the CDTA’s GIS is relatively new, a significant number of data layers have already been acquired. The demonstration project is effectively functioning as a needs assessment. Although the CDTA already has a functioning GIS, full implementation is expected to be completed in January, 1996.

Table 27
CAPITAL REGION GIS CONSORTIUM

<table>
<thead>
<tr>
<th>Agency</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital District Transportation Authority</td>
<td>CDTA</td>
<td>Regional Transit Operator</td>
</tr>
<tr>
<td>New York State Department of Transportation</td>
<td>NYSDOT</td>
<td>State Transportation Agency</td>
</tr>
<tr>
<td>Capital District Transportation Committee</td>
<td>CDTC</td>
<td>Metropolitan Planning Organization</td>
</tr>
<tr>
<td>Capital District Regional Planning Commission</td>
<td>CDRPC</td>
<td>Regional Planning Agency</td>
</tr>
</tbody>
</table>


SPATIAL DATA RESOURCES

Multiple data sources and data sharing are significant advantages to GIS consortium development. The CDRPC is the regional repository for demographic and land use information. Other layers are provided by member agencies.

Table 28
DATA SOURCES AT CDTA

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Service Data</td>
<td>Transit Operator (CDTA)</td>
</tr>
<tr>
<td>Road Network</td>
<td>State Transportation Agency (NYSDOT)</td>
</tr>
<tr>
<td>Travel Data</td>
<td>Metropolitan Planning Organization (CDTC)</td>
</tr>
<tr>
<td>Census</td>
<td>Regional Planning Agency (CDRPC)</td>
</tr>
</tbody>
</table>

CDTA's basemap consists of State and local highway maps supplied by NYSDOT and Mapinfo StreetInfo files (ver.3.0). Bus routes were coded using NYSDOT State and local highway maps, while bus stops were geocoded using Mapinfo's StreetInfo files and enhanced address layer files. CDTA intends to use raster images primarily for map production. Traffic Analysis Zones will be used for travel related information and analysis (travel times, origin and destination by mode) and census data will be used to provide additional employment and income information at the blockgroup level.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Source</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Map</td>
<td>NYSDOT</td>
<td>Background layer, geocoding</td>
</tr>
<tr>
<td>Bus Routes</td>
<td>NYSDOT</td>
<td>Dynamic segmentation (buffer analysis)</td>
</tr>
<tr>
<td>Bus Stops</td>
<td>CDTA</td>
<td>Buffer analysis, data inventory, operations planning</td>
</tr>
<tr>
<td>Political Boundaries</td>
<td>NYSDOT</td>
<td>Background layer</td>
</tr>
<tr>
<td>Census Data</td>
<td>NYSDOT, CDTC, CDRPC</td>
<td>Marketing analysis, policy planning</td>
</tr>
<tr>
<td>Raster Images</td>
<td>NYSDOT</td>
<td>Map production</td>
</tr>
</tbody>
</table>


HARDWARE AND SOFTWARE PLATFORM

A decision was made for ArcView to be the standard GIS for DOT and MPO activities in the State. An agreement was negotiated between the State Department of Transportation and ESRI, Inc., developer of ArcInfo and ArcView software. This agreement charged ESRI with staff training and software modifications to permit better visual display of transportation data. ESRI will also be responsible for transferring T-Model (transportation network analysis software) data into ArcView for display. Mapinfo was also acquired to supplement data layers.
Table 30
HARDWARE DEVICES AND PERIPHERALS

<table>
<thead>
<tr>
<th>Device</th>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer</td>
<td>HP 5/90C 90 MHz Pentium, 16 Mb RAM, 1.2 Gb Hard disk, 4x CD-ROM</td>
<td>1</td>
</tr>
<tr>
<td>Monitor</td>
<td>HP Ultra VGA 1280 17&quot; monitor</td>
<td>1</td>
</tr>
<tr>
<td>Tape Backup</td>
<td>HP Jetstore 200</td>
<td>1</td>
</tr>
<tr>
<td>Printers</td>
<td>HP Laserjet 4 (currently reviewing color plotters)</td>
<td>1</td>
</tr>
</tbody>
</table>


Table 31
SOFTWARE PACKAGES

<table>
<thead>
<tr>
<th>Name</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mapinfo 3.05</td>
<td>Desktop GIS</td>
</tr>
<tr>
<td>ArvcView 2.0</td>
<td>Desktop GIS, T-model data display</td>
</tr>
<tr>
<td>Lantastic 6.0</td>
<td>Network software</td>
</tr>
<tr>
<td>T-Model</td>
<td>Travel model software</td>
</tr>
<tr>
<td>GFI</td>
<td>Farebox software</td>
</tr>
<tr>
<td>G/Sched</td>
<td>Scheduling software</td>
</tr>
</tbody>
</table>


Current GIS Applications

The CDTA is currently in the process of implementing its demonstration project. Full implementation will be based on the results of the demonstration project. Applications are proposed to use GIS for Operations Planning, Policy Planning, and Market Analysis.

Operations Planning

The CDTA will be using GIS to display operations analysis data such as link volumes on streets (taken from ridecheck data), boardings per vehicle hour by link, boardings by stop, performance measures by route and link transit speeds. The proposed project for operations planning includes the following objectives:
• Operations analysis - Specifically, this entails mapping operations analysis data such as passenger boardings and other business performance measures.
• Performance analysis - This includes ride check data—show passenger flow on all links and route analysis—show routes with productivity (> 25 boardings/hour).

Policy Planning

Another proposed GIS application is to develop a number of system-wide measures for the region. These measures include the following:

• Developing mobility performance measures, i.e., proportion of households without automobiles which can access a large grocery store within a 30 minute travel window.
• Understanding journey-to-work data to improve transit utilization. This includes mapping the proportion of the population that could feasibly use transit for journey-to-work trips (transit travel time < some multiple of highway travel time).
• Route-level demographics. Displaying population living within x-miles of a particular transit route.

Marketing Analysis

This task will involve two activities:

• Display and analysis of census journey-to-work data
• Modeling of transit demand to assess new services.

Maps will be prepared to illustrate transit market share for 12 individual major employment sites based on traffic analysis zones. For traffic zones with unusually low transit market shares, the GIS will be used to assess the quality of transit service in the neighborhood to determine if improvements are warranted.
Future Work

- Overlay transit routes on air photos. By using air photos, better visualization of residential/commercial densities relative to CDTA routes and stops can be achieved.
- Improve accessibility to the telephone information unit. This will provide telephone information agents with more information for answering customer questions related to schedules and routing.
- Develop a shelter and stop photo database. This will be useful for maintenance and management of bus stops and shelters.

BENEFITS AND OBSTACLES TO IMPLEMENTATION

Major obstacles to development of GIS at CDTA include staff training, data availability, and inter-agency coordination and cooperation. Because CDTA is in the early stages of GIS development, they have yet to experience some of the software application limitations that seem to be common in GIS implementation.

GIS IMPLEMENTATION STRATEGIES

The CDTA combined several elements that will facilitate implementation of a comprehensive GIS-T: the consortium strategy, a demonstration project, and PC-level implementation. The work plan developed by the CDTA helped ensure a successful GIS implementation by outlining the project in two major areas: data collection and data analysis.
Data Collection

- Bus stop database
  --Includes 4,000 stops, 50 routes, 600 timepoint segments, and 450 patterns
  --Data attributes include location, routes serving stop, position (nearside, farside, midblock),
  municipality/county, and shelter
- Plot routes (70)
- Census database
- Travel time database
- Route characteristics database

Data Analysis

- Thematic maps
- Route assessment maps
- Buffer analysis
- Traffic flow maps

Implementation was eased by following the same methodology for each application. A consistently
reliable data clearinghouse and the ability to choose from two software packages further eased
implementation.

Lessons Learned

The most important lesson at CDTA was the needs assessment. A formal evaluation of an
organizations needs should include:

- A general review of the organization’s spatial issues.
- A functional review of the type of analysis and output that a GIS can provide.
- An assessment of the data sources and database design.
- Analysis of personnel, hardware, and software costs.
- A formal implementation plan for short/long term GIS needs.
Bloomington Public Transportation Corporation

Overview of Transit System

Located in south central Indiana, the city of Bloomington is a fast growing service hub that operates two types of transit service, a fixed route bus service (Bloomington Transit) and a demand response service for people with disabilities (BT Access). Bloomington Transit operates 20 buses and carries just over 1 million passengers per year. BT Access operates four vans and provides approximately 18,000 trips per year to 500 users. The Bloomington Public Transportation Corporation (BPTC) is managed by McDonald Transit Associates, Inc., headquartered in Fort Worth, Texas.

<table>
<thead>
<tr>
<th>Table 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSIT SYSTEM CHARACTERISTICS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service Area (sq. mi)</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area Population</td>
<td>60,633</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>24</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>19</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>2,845,503</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>668,043</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>2,100,000</td>
</tr>
<tr>
<td>Total GIS Implementation Costs</td>
<td>12,000</td>
</tr>
</tbody>
</table>


The Bloomington area is serviced by two additional transit systems. Indiana University operates a bus system that serves campus locations, and Monroe and Owen counties operate a third network that provides city access to outlying areas. Passenger trips provided by these three systems outnumber all other Indiana cities, except Indianapolis.
OVERVIEW OF GIS AT BLOOMINGTON PUBLIC TRANSIT CORPORATION

History of GIS Implementation

This case study is an example of how inter-agency cooperation and interoperability can facilitate a small transit system in acquiring and implementing a GIS system. Beginning several years ago, the City of Bloomington, in cooperation with the City of Bloomington Utilities, began developing a GIS database. The City of Bloomington Utilities is a public corporation that manages water and sanitary sewer services for the City of Bloomington. Currently, the City is working with Monroe County through a sharing agreement to expand the database to include parcel information. The city also contracts with Indiana University to obtain GIS interns. Cooperation efforts led to the development of a detailed spatial database that could be expanded.

GenaMap was chosen for spatial database development. Layers produced by City and Utilities GIS staff included streets, parks, utilities, and zoning. Basemap development was completed by digitizing aerial photographs over a two year period. Access to these GIS databases were made available to the BPTC.

Beginning in 1994, an effort began to implement a GIS at the BPTC for data/map display purposes. The BPTC added a GIS development element to the pass through agreement with the local MPO for Section 8 planning funds. Approximately 80 percent of GIS implementation funding was supported by Section 8 funding. It was felt that customers could obtain more accurate schedule information if they could point at a bus stop on a computerized map rather than estimating elapsed time from a key time points in a timetable. Moreover, training time for new staff who give customers schedule information over the phone would be greatly reduced. This is critical in an organization where job sharing is common, because anyone could quickly and accurately answer scheduling questions.

Development and implementation of BPTC’s GIS was concurrent with the City of Bloomington’s GIS. Therefore, system software compatibility was critical to future development. A stand-alone system was purchased, and software modifications were developed to ease user interfacing.

HARDWARE AND SOFTWARE PLATFORM

Because data compatibility is a key issue in GIS development, the BPTC acquired GenaMap. Costs and local constraints dictated the purchase of a used UNIX stand-alone workstation. Future applications may necessitate the need for connection to the City of Bloomington’s GIS network.
Table 33
GIS Platform at BPTC

<table>
<thead>
<tr>
<th>Hardware</th>
<th>HP 715 UNIX Workstation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory and Drives</td>
<td>64MB RAM, 1GB hard drive, 2GB DAT tape drive</td>
</tr>
<tr>
<td>Operating System</td>
<td>HP-UX (release 9.0)</td>
</tr>
<tr>
<td>Software</td>
<td>GenaMap (release 6.1)</td>
</tr>
</tbody>
</table>


SPATIAL DATA RESOURCES

The City of Bloomington digitized a basemap from aerial photographs over a 2 year period. Updates to this basemap are transferred from the City's GIS system using DAT tape. The system’s fixed bus routes were digitized and color-coded by an Indiana University graduate student using existing road-centerline data from the City of Bloomington. Line segments were tagged with route numbers and approximately 500 bus stops points were digitized and tagged with a unique identifier for each.

Because the project required increased schedule information accuracy, it was necessary to assign an exact scheduled time for each intersection in all directions along each bus route. To this end, staff members sometimes rode buses and marked intersection times. Collected data, bus stops, and schedule data were then entered into a Microsoft Excel spreadsheet and coded for GenaMap recognition. Street corners were also named and coded for linking attribute tables to GenaMap vector route maps. Daily bus stop times were calculated to the minute. A sample portion of a spreadsheet follows.
Table 34
SAMPLE EXCEL SPREADSHEET HEADINGS USED FOR GENAMAP GUI

<table>
<thead>
<tr>
<th>Fields</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>GenaMap unique identifier</td>
</tr>
<tr>
<td>Route</td>
<td>Route number</td>
</tr>
<tr>
<td>Day</td>
<td>Weekday, Saturday, or Special route</td>
</tr>
<tr>
<td>Bus Direction</td>
<td>Inbound Only, Outbound Only or Both</td>
</tr>
<tr>
<td>Stop Location</td>
<td>Stop Attributes</td>
</tr>
<tr>
<td>Street1</td>
<td>East/West intersecting street</td>
</tr>
<tr>
<td>Street2</td>
<td>North/South intersecting street</td>
</tr>
<tr>
<td>Transfer Points</td>
<td>Intersecting bus routes</td>
</tr>
<tr>
<td>Sign/Shelter</td>
<td>Presence of sign of shelter</td>
</tr>
<tr>
<td>Bus/Trip Time</td>
<td>Data time points</td>
</tr>
</tbody>
</table>


CURRENT GIS APPLICATIONS

A GUI interface was developed to facilitate painless access of data for everyday users. GenaMap's internal GUI builder, Genius II, was employed for this task. Users can look up locations using a number of different query methods: intersection, address, subdivision, major building name, or by point and click. A box can be drawn with the mouse and users can zoom in and out. By clicking on an intersection node, bus route direction is indicated and a to-the-minute list of all scheduled times for that route is displayed. A bus schedule printout can also be generated for individual customers. Furthermore, the user can tell customers how far bus stops are from their homes.

The GUI developed by the BPTC (Genius II) was consistent in look and layout with the City of Bloomington's GUI interface. Various views of map layers and ancillary data are possible using a combination of mouse clicks and keyboard entry. Pull-down menus, a Text Entry line, Text Scroll window, and a Graphics Window were standardized with the City's GUI. The application was customized to access and view specific bus routes and schedule information. Other applications include the ability to query by address. This allows the user to instantly determine if that address is within the city limits and, therefore, within the BPTC's service area. The query-by-address function is critical to system operations, because BT Access trips must be limited to BPTC's service area.
BENEFITS AND OBSTACLES TO IMPLEMENTATION

Software/Hardware

Although cooperation between BPTC and the City ultimately resulted in a functioning and expandable GIS, considerable effort on the part of BPTC was necessary to overcome dependency pitfalls. After the BPTC committed significant resources to collecting and digitizing data as well as administrative approval, delays in the City's GIS implementation process mandated a different approach by BPTC.

The following discussion details changes in BPTC's implementation process dictated by changes in the City's implementation decisions. Originally, the BPTC planned to invest in software simply to map/display bus schedule information. Full-blown GIS implementation was not planned. The intent was to obtain a relatively low-cost means to display and query digital data on an existing PC network. Implementation depended on the City of Bloomington's plans to purchase a similar PC-based system. However, the City delayed its purchasing plans indefinitely. This left the BPTC with the need to find a new solution for GIS implementation. A decision was made to fund and acquire software and hardware compatible with the City of Bloomington (GenaMap on a Unix system).

By abandoning the original system design, some negative effects resulted. Significant system implementation delay and larger capital outlay resulted. Because the original design was based on simple query and display software, database and tag identifiers had to be reworked for integration with the new system. Furthermore, rather than purchasing a system with an integrated user interface and database viewer, customized GUI scripts had to be written. Because the learning curve was steep, labor costs resulted in BPTC successfully using a comprehensive and expandable "true" GIS.

GIS IMPLEMENTATION STRATEGIES

The success of the BPTCs GIS implementation was the result of both strategy and serendipity. By combining savings strategies (purchasing used hardware, utilizing student interns, free data and updates) with good timing and inter-governmental cooperation, the BPTC was able develop and implement a GIS with minimal funding. Furthermore, strategic planning facilitated low cost data updates, interoperability, and system expansion potential. Total implementation costs were approximately $12,000. This included hardware, software licensing ($6,500), software maintenance fee, and labor for system development. Significant savings were realized by using student resources.

Future applications include using the GIS for an inventory of bus stop signs, shelters, furniture, and passenger count data by bus stop. Also in development is an application using scheduling data for the three bus systems for a centralized telephone information service. Transit route planning applications are also planned for development using already encoded census and zoning data. The addition of an AVL system is also being considered for the future to further improve customer information accuracy.
LESSONS LEARNED

Development Process

More planning at the beginning stages of system implementation may have been beneficial. System development, planning, organizing, and documenting might have increased implementation efficiency and possibly enhanced the fit of the end product with BPTC operations.

Specifically, these initial efforts may have included conducting a more formalized procedure for assessing requirements, examining work flow, defining the scope and timetable of work, determining core functions and additional features of the product, and setting a method for evaluating performance. Although these issues were discussed throughout the course of project implementation, a detailed analysis was not conducted.

Because the BPTC is a transportation organization rather than a software development firm, it was difficult to translate its needs into usable software without losing something in the translation. At first, a detailed needs assessments did not seem necessary because the project was limited to producing, viewing, and querying digitized routes and spreadsheets of bus timetables. However, when the project scope was shifted to implementation of a GIS and GUI customization, increased time spent on these issues would have been beneficial. Smoother system transition could have been enhanced by reducing differences between conceptual models and reality.

Project Coordination

Because BPTC is not a large organization, expertise from a few full-time staff members is necessary. Work is supplemented with student interns. A significant amount of operational management of the project was left to the creativity and initiative of interns. This is because BPTC's staff members had either insufficient knowledge or other pressing duties. The use of student resources may be mutually beneficial to transit agencies, providing low-cost labor pools while enhancing practical application skills for students.

Other small organizations that wish to implement an information system may experience similar difficulties. Transit staff can contribute valuable knowledge to technical staff regarding organization and information needs. Formalizing procedures for updating progress, scheduling meetings, articulating concerns, and gathering feedback, may significantly enhance performance without the need to dedicate management staff for daily supervision.
OVERVIEW OF JOHNSON CITY TRANSIT SYSTEM

The Johnson City Transit system is the smallest system examined in this report. Two types of public transit exist in Johnson City: a fixed route bus system, and a small paratransit fleet. The fixed route bus system consists of six buses operating on a pulse schedule system, alternating every 30 minutes. The paratransit fleet consists of four vehicles operating at maximum service. A contingency van supplements the paratransit service when necessary.

Table 35
Johnson City Transit System Characteristics

<table>
<thead>
<tr>
<th>Service Area (sq. mi)</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area Population</td>
<td>52,810</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>16</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>11</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>1,963,186</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>471,187</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>1,026,576</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Transportation, Data Tables for the 1992 National Transit Database, Section 15 Report Year.

OVERVIEW OF GIS AT JOHNSON CITY

Johnson City was one of the earliest small cities to implement a comprehensive GIS. Implementation began in 1984, and expansion continued steadily. Currently, Johnson City’s GIS is particularly advanced when compared to other systems in cities of similar size. The purpose of the GIS Division at Johnson City is to respond to the mapping and spatial analysis needs of City departments and to offer low-cost GIS services to other public and private entities.
Three principal GIS activities occur at Johnson City's GIS Division:

- Managing and enhancing a spatial database of geographic features and their attributes
- Creating maps and statistical data from the database
- Performing geographic analysis through the development of special-purpose spatial models.

Although the Johnson City GIS is essentially centralized, some GIS equipment and users are found in other departments and divisions. All transit requests are funneled through the GIS Division.

History of Implementation

The inception of Johnson City's GIS began with a federal grant from the Urban Mass Transit Administration (UMTA). This grant provided funding for procurement of hardware and software training to help establish a city-wide GIS. The intent of UMTA as the sponsoring agency was that GIS applications ultimately be transit integrated for all Johnson City departments. Three primary departments were involved in the initial implementation: Transit, (including the local MPO), Planning, and the Water and Sewer Division.

Originally, the Johnson City GIS was decentralized in terms of hardware, software, locations, and users. Although this arrangement exhibited many benefits, it became evident that increased central coordination was needed. Subsequently, GIS Database Manager GIS Director positions were established. In addition, Johnson City established a symbiotic relationship between the City and East Tennessee State University (ETSU) that provided a source of low-cost GIS technicians and contractual revenue. Student labor pools were effectively utilized as a means for students to acquire skills while augmenting departments' limited personnel for individual project development.

The first major project was building a digital transportation or street network. Because of the lack of easily accessible and accurate digital data during the 1980s, Johnson City created its street network almost entirely in-house. This project entailed mapping school bus routes and fixed guideway routes. Section 15 ridership data was also digitally mapped and some data analysis was performed.

Table 36 details some important hallmarks in the development of Johnson City's GIS.
Table 36
JOHNSON CITY GIS HISTORY

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>Began using existing mini-computer with Lexidata 2400 terminals and AutoGIS (MOSS) software</td>
</tr>
<tr>
<td>1985</td>
<td>Purchased digitizing table &lt;br&gt; Digitizing of tax block layer complete &lt;br&gt; GIS user group established</td>
</tr>
<tr>
<td>1986</td>
<td>14-pen Houston Instruments plotter purchased by Transit Department &lt;br&gt; Digitizing tablet purchased by Transit Department &lt;br&gt; GIS coordinator appointed &lt;br&gt; Water lines completed &lt;br&gt; GIS Master Plan proposed &lt;br&gt; City/University Joint Research Center established</td>
</tr>
<tr>
<td>1987</td>
<td>354mb hard disk purchased by Transit Department &lt;br&gt; First GIS contract work approved &lt;br&gt; Formal GIS Division established</td>
</tr>
<tr>
<td>1989</td>
<td>Compilation of U.S. Census and Tennessee tax data &lt;br&gt; Digitization of property parcels &lt;br&gt; Transit route analysis and map preparation &lt;br&gt; Water and sewer line mapping</td>
</tr>
<tr>
<td>1991</td>
<td>New Data General mini computer acquired (dedicated to GIS) &lt;br&gt; Implemented ArcInfo software &lt;br&gt; Completed conversion of existing maps and databases &lt;br&gt; Completion of revised zoning maps &lt;br&gt; Completed conversion and updating of all state tax parcel database/maps &lt;br&gt; Procurement of color electrostatic plotter &lt;br&gt; Completion of 1990 land use layer</td>
</tr>
<tr>
<td>1992</td>
<td>Changed hardware to Data General stand-alone workstations &lt;br&gt; Completed installation LAN and revised software &lt;br&gt; Completed production of new zoning map atlas &lt;br&gt; Completed corridor study maps for Med-Tech/Northwest Bypass &lt;br&gt; Addition of 1990 Census data</td>
</tr>
<tr>
<td>1993-1994</td>
<td>New GIS Director and Database Manager hired &lt;br&gt; Developed and implemented a GIS model to determine prospective sites for a new Johnson City Library &lt;br&gt; Produced snow removal route maps &lt;br&gt; Developed methodology for construction of meaningful demographic maps and statistical computations from census data</td>
</tr>
<tr>
<td>1994-1995</td>
<td>Building spatial database of Johnson City Power Board electrical system; 1,500 maps digitized &lt;br&gt; Enhanced address ranges coded for automated mapping &lt;br&gt; Design of city and county map of transportation and places of interest &lt;br&gt; Full-time GIS Technician hired to maintain parcel, zoning, and annexing layers</td>
</tr>
</tbody>
</table>

Organizational Structure

The GIS Division at Johnson City is currently administered under the Planning Department and functions as a centralized spatial data facility. The GIS Division also serves as a service bureau for all City departments and divisions, including Johnson City Transit. These departments also have GIS equipment and users. The GIS Division creates, processes, and maintains an extensive collection of geographic map and data features including property parcels, transportation features, utilities, City limits, land use, zoning, topographic contours, soils, hydrography, and other regional layers.

HARDWARE AND SOFTWARE PLATFORM

Early Development

The first GIS software package used by Johnson City was called AUTOGIS (Autometric, Inc., Fort Collins, Colorado). Developed in the early 1980s and used by several large federal resource management agencies, AUTOGIS was an early, yet sophisticated modular package that ran on a Data General MV10000 mini computer. AUTOGIS used a Map Overlay and Statistical System (MOSS) configuration for map manipulation and database creation/updating. Johnson City was the first "small" Autometric client. Several departments within the City accessed and used AUTOGIS using peripheral hardware devices.

In 1990, the MV10000 was replaced by a new Data General mini computer. The system used Lexidata "dumb" terminals simultaneously accessing the mini for processing data. In 1991, it was realized that significant cost savings and speed improvement could be realized if the GIS was operating in a workstation/local area network environment. In 1992, five Data General Aviion workstations were purchased to replace the mini. Each of these stand-alone units is linked with Ethernet cable on a LAN. Two personal computers are also linked to the system and are used for interfacing with the engineering divisions.

Current Platforms

Three Data General 310 workstations and two 530 workstations run ArcInfo v.7.0.1 on a Unix platform. Additional software and hardware summaries are listed in the tables below.
Table 37
Hardware Devices and Peripherals

<table>
<thead>
<tr>
<th>Device</th>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer</td>
<td>Gateway 2000 (486)</td>
<td>2</td>
</tr>
<tr>
<td>Workstation</td>
<td>Data General Aviation</td>
<td>5</td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>HP650C</td>
<td>1</td>
</tr>
<tr>
<td>Plotter - electrostatic</td>
<td>Precision Image 636</td>
<td>1 (obsolete)</td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td>Calcomp 9500 (3) Numonics (2)</td>
<td>5</td>
</tr>
</tbody>
</table>


Table 38
Software Licenses at Johnson City GIS

<table>
<thead>
<tr>
<th>Software Licenses</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc/Info floating seat license</td>
<td>2</td>
</tr>
<tr>
<td>Arc/Info Node-locked license</td>
<td>2</td>
</tr>
<tr>
<td>ArcView license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Tin license</td>
<td>1</td>
</tr>
<tr>
<td>Arc/Info Grid license</td>
<td>0</td>
</tr>
<tr>
<td>Arc/Info Network license</td>
<td>1</td>
</tr>
<tr>
<td>X-emulation packages(PC Xware)</td>
<td>2</td>
</tr>
</tbody>
</table>


SPATIAL DATA RESOURCES

The GIS Division owns and maintains approximately 90 point, line, and polygon coverages from a variety of sources. Sources include State tax maps digitized from hard copies, USGS Digital Line Graph (DLG) files, TIGER line files, and 1990 U.S. Census data. Much of the data is digitized from aerial photos and existing infrastructure maps using in-house personnel and ETSU student interns.
A partial list of Johnson City GIS coverages includes:

<table>
<thead>
<tr>
<th>Alleys</th>
<th>Annexations</th>
<th>Arterials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
<td>Block Grants</td>
<td>Bus Routes</td>
</tr>
<tr>
<td>Cemeteries</td>
<td>Collectors</td>
<td>Contours (20’, 100’)</td>
</tr>
<tr>
<td>City Limits</td>
<td>De-annexations</td>
<td>Fire Stations</td>
</tr>
<tr>
<td>Flood Zones</td>
<td>Growth Plan</td>
<td>Industry</td>
</tr>
<tr>
<td>Hospitals</td>
<td>Hotels</td>
<td>Libraries</td>
</tr>
<tr>
<td>Neighborhoods</td>
<td>One-way Streets</td>
<td>Parks</td>
</tr>
<tr>
<td>Restaurants</td>
<td>School Zones</td>
<td>Shopping Centers</td>
</tr>
<tr>
<td>Signals</td>
<td>Sinkholes</td>
<td>Slope</td>
</tr>
<tr>
<td>Snow Routes</td>
<td>Subdivisions</td>
<td>Water (lines, points, and tanks)</td>
</tr>
<tr>
<td>Zoning</td>
<td>Detours</td>
<td>Free Roads</td>
</tr>
<tr>
<td>Historic Sites</td>
<td>Historic Districts</td>
<td>Blocks, Blockgroups, Tracts</td>
</tr>
<tr>
<td>Hydrography</td>
<td>Powerlines</td>
<td>Railroads</td>
</tr>
<tr>
<td>Soils</td>
<td>Tax Indexes</td>
<td>TAZs</td>
</tr>
<tr>
<td>Zip Codes</td>
<td>Roads</td>
<td>National Forests</td>
</tr>
</tbody>
</table>

While the GIS Division maintains all spatial layers, the Transit Department maintains relational databases (i.e., paratransit, special students). Principal transit layers include bus routes, paratransit routes, school bus routes, student street addresses, and TAZs.

**CURRENT GIS APPLICATIONS**

Although the Johnson City GIS was established in 1984, transit applications were limited to map production. Only during the past three years has the Transit department used the analytical capabilities of the GIS, primarily due to more readily available data. The increased use of GIS analysis has allowed for more accurate transit service evaluations.

Currently, the principle transit applications at Johnson City Transit are:

- Digital cartography (address-range mapping, pin mapping, bus route mapping)
- Demographic mapping and analysis (population and housing statistics, distance buffering, optimal routing of paratransit and school buses)
- Mapping and route modelling of paratransit citizens and school buses. Route modeling was also developed for city street sweeping and trash collection.

One unusual aspect of Johnson City's GIS is that the boundaries of the Johnson City School District and Johnson City are the same. Johnson City's GIS is therefore used for school bus route selection. Student address locations were geocoded and used for mapping student patterns and analysis.

Requests for GIS maps and analysis are made by the Transit department and submitted to the GIS Division. Requests typically consist of hard copy maps and digital tabular data based on spatial queries. Map requests may be as simple as route maps and student address locations, or may require more sophisticated spatial analysis. For example, a recent route evaluation request by Johnson City Transit required data by census tract (or smaller unit) that included the following information:
Typical map requests at Johnson City Transit include City maps with updated street names and school zones, routing maps of special education children, address range maps (1"=500'), thematic maps portraying selected census variables, and revised maps of mini-bus student locations. Recent emphasis at Johnson City Transit focuses on streamlining route structures based on census data analysis to reveal changes in demographic variables over time.

Future Applications

Future transit GIS applications may include additional optimal routing as well as transit planning. Although optimal routing models have been developed for trash collection and street sweeping, bus route models are still in development. Implementation of ArcView in the transit office is also being considered, which will allow for basic queries to be performed without the need for requests. Objectives 1995/96 of the Johnson City GIS division for 1995/96 includes:

- Acquire digital orthophotographs, and detailed topographic and planimetric data from Atlantic Technologies
- Add speed limits and intersection characteristics to the street layer (route modelling as a function of time rather than strictly distance)
- Adjust locations of census boundaries
- Promote GIS products and services to the public
- Reduce maintenance and operating costs of map production (less expensive technologies than electrostatic plotter)
- Continue formalization and data updating procedures

BENEFITS AND OBSTACLES TO IMPLEMENTATION

Generally, obstacles encountered at Johnson City can be classified as historical and current. Historical obstacles faced during the early stages of implementation include:

- Poor hardware and software connectivity and development - This was primarily due to the lack of software and hardware flexibility. Therefore, implementation was extremely difficult as well as time and labor intensive.
- Organizational obstacles - During the early days, expansion was difficult due to lack of personnel and lack of organization.

In terms of transit related obstacles, Johnson City reported no particular historical obstacles. Generally the GIS Division maintained a good working relationship with the Transit division. This may be partially because the GIS and transit divisions and located in the same building. When the GIS Division became headquartered in the Transit center, problems were encountered with wide area linkages to other departments such as City Hall and Engineering.
Current obstacles encountered by the Johnson City GIS Division are primarily related to database maintenance. These include:

- Creating a quality address ranging database
- Creating a place-name alias file for address connectivity
- Updating and address-matching the paratransit customer database

GIS IMPLEMENTATION STRATEGIES

Because the Johnson City GIS was established with financial assistance through a federal grant, local contributions were minimal in comparison. Implementation was easier because several financial barriers were removed during the beginning stages. Because the city was less financially burdened with hardware and software acquisition costs, City departments could better afford to allocate personnel resources to the project. Moreover, the initial cost savings promoted the recruitment of low-cost student technicians for data entry and digitizing.

In the beginning, cost allocation was relatively simple. Each department using a GIS workstation was billed according to their use of computer time. Because the system was new, less emphasis was placed on equipment replacement and more emphasis was placed on supplementing the original GIS hardware.

As the system developed, the need for additional personnel surfaced. This raised the question of which departments should pay for the additional staff. Fair cost allocation was a concern, particularly if the departments did not have GIS facilities. A system of billing individual departments and divisions was established based on hours devoted to GIS requests.

Although implementation of the Johnson City GIS began in 1984, it was not until February, 1988 that a five-year development plan was initiated. The early stages of development operated informally. Between 1984 and 1986, the GIS was being used without an officially sanctioned work program. In 1986, the GIS Coordination Team did adopt a work program as an unofficial guide, but it was still not management-endorsed. It was not until 1987 that a formal GIS division was established. The lack of a clearly defined plan was primarily due to the decentralized nature of GIS personnel, hardware, and work stations.

In 1988, the production of a five year development plan called for a formalized GIS work program that addressed the decentralization problem. Because some City departments had access to GIS equipment and had followed their own work program, and other City departments were without access to GIS equipment, a comprehensive method for incorporation of these issues was needed. The solution consisted of two elements:

- Individual departments with GIS capabilities carrying out their own work programs, subject to how that work related to overall GIS objectives.
- A method for potential GIS users with no GIS equipment to request, schedule, and have GIS work performed.

Paramount to this development plan was an agreed method of updating and maintaining GIS maps and databases. Finally, methods to allow GIS users to monitor costs and keep time and progress records for GIS work projects needed to be obtained. To ensure GIS data and maps are updated and accurate, the plan called for a GIS Database Manager and a method to fund a student co-
Further, an update schedule was defined for each GIS layer. The plan also called for a centralized GIS division to be created to streamline production, analysis, GIS development, and billing issues.

Johnson City also significantly increased its productivity through the continued use of student interns from East Tennessee State University (ETSU). Both parties benefit from this arrangement. Student intern tasks included:

- Address geocoding and matching
- Urban transportation network analysis using Network module of ArcInfo (paratransit routing)
- Data automation and database design
- Interface design of Arc Macro Language (AML) applications
- Cartographic map design and production using ArcInfo

LESSONS LEARNED

Johnson City GIS lessons were primarily related to early development. These include:

- Make organizational changes in the early stages of project implementation
- Address implementation design and formal development plans early
- Delegate enough responsibility for system operations in the formative stages of development
- Start with modest, achievable goals and build from these.
Other Cases

The following section contains brief summaries of preliminary phone interviews conducted with the GIS departments of several transit agencies throughout the nation. These agencies were not selected for a full case study, however, the inclusion of informal survey information in this document may be of interest to readers.

NEW YORK CITY METROPOLITAN TRANSIT AUTHORITY

Overview of GIS at NYC-MTA

Currently, NYC-MTA uses three systems TRANSCAD, INTERGRAPH, and OTIS. GIS needs were originally established by personnel with modeling backgrounds who realized the value of visualization. It began with a single crude subway network. Currently, NYC-MTA uses TRANSCAD as a sophisticated GIS based travel demand modeling system. The system combines bus routes, subway network, and a walk network, and connects these to census tracts. GIS Plus is also used.

The application of INTERGRAPH evolved somewhat separately from the TRANSCAD application and for different reasons. An initiative began ten years ago to draw stations, tracts, stairways, exits, etc. The intent was to provide simultaneous visualization for the fire department and transit applications. Mutual improvement was envisioned. The INTERGRAPH system essentially evolved as a CAD based system and is not considered a true GIS.

A third system currently in use is OTIS (Online Travel Information System). OTIS is a GIS which utilizes landmarks, addresses, etc. for routing algorithms. OTIS also evolved separately from the other systems, primarily because it targets a separate application best and alternate routing.

Benefits and Obstacles to Implementation

The biggest obstacle was the immense size and detail required for implementation of the system(s). With TRANSCAD, database manipulation was clumsy and time consuming. The Windows version of TRANSCAD has a much better DBMS than the non-Windows version. With the Windows version, dBASE format is used and is directly linked to the graphic attributes. NYC-MTA is beta testing the Windows version of TRANSCAD.

Lessons Learned

Implementation does not happen casually. The full support of the parent organization(s) is necessary. Separate applications typically move ahead, separate from an overall comprehensive vision. Furthermore, large scale organizational problems occur in large systems. The coordination of different applications requires significant effort.
Overview of Transit System at SMART

Table 39
TRANSIT SYSTEM CHARACTERISTICS

<table>
<thead>
<tr>
<th>Service Area (sq. mi)</th>
<th>891</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Area Population</td>
<td>4,246,712</td>
</tr>
<tr>
<td>Total Fleet</td>
<td>453</td>
</tr>
<tr>
<td>Maximum Number of Vehicles Operated</td>
<td>359</td>
</tr>
<tr>
<td>Annual Passenger Miles</td>
<td>78,208,262</td>
</tr>
<tr>
<td>Annual Vehicle Miles</td>
<td>12,628,278</td>
</tr>
<tr>
<td>Total Annual Operating Expenses</td>
<td>46,278,900</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Transportation, Data Tables for the 1993 National Transit Database, Section 15 Report Year.

Overview of GIS at SMART

Beginning in 1988, the SMART planning department established a need for visually displaying passenger boarding and de-boarding data. To this end, a consultant was hired to build a software package that would display bus routes, bus stops, and their associated attributes. These layers were then overlaid on a digitized street network of the tri-county service area (Wayne, Oakland, and Macomb).

Pinnacle Graphics Software (UMA Engineering) was commissioned to develop the SMART GIS system. The software package, called Transit Master, originally ran on DOS but now runs on the Microsoft Windows platform. Transit Master included three mapping programs and two utility programs.
Table 40
GIS HISTORY AT SMART

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>Needs established for GIS development</td>
</tr>
<tr>
<td>1989</td>
<td>Proprietary GIS software developed (Transit Master)</td>
</tr>
<tr>
<td>1991</td>
<td>Updated to TIGER base map</td>
</tr>
<tr>
<td>1992</td>
<td>TIGER updated for 1990 census display</td>
</tr>
<tr>
<td>1993</td>
<td>Updated to ETAK basemap</td>
</tr>
<tr>
<td>1995</td>
<td>Implemented Windows based system</td>
</tr>
<tr>
<td>1996</td>
<td>Quovadis AVL software integrated with Transit Master</td>
</tr>
</tbody>
</table>

Source: Suburban Mobility Authority for Regional Transportation, 1993. SMART G.I.S., p.23.

Spatial Data Resources

Current data sources are R.L. Polk Employment Data (business listing) and 1990 census data (STF1 tape).

Hardware and Software Platform

Currently, SMART’s GIS runs on Pentium P90 computers, each with 16 megs of RAM. The system upgraded to Windows in January, 1995.
Table 41
HARDWARE DEVICES AND PERIPHERALS

<table>
<thead>
<tr>
<th>Device</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Computer</td>
<td>10</td>
</tr>
<tr>
<td>X-terminal</td>
<td>0</td>
</tr>
<tr>
<td>Workstation</td>
<td>0</td>
</tr>
<tr>
<td>Plotter - inkjet</td>
<td>6</td>
</tr>
<tr>
<td>Plotter - electrostatic</td>
<td>0</td>
</tr>
<tr>
<td>Digitizing Tablet</td>
<td></td>
</tr>
</tbody>
</table>


Table 42
SOFTWARE COMPONENTS OF TRANSIT MASTER

<table>
<thead>
<tr>
<th>Type</th>
<th>Program Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mapping</td>
<td>Geographic Maintenance Program (GMP)</td>
<td>Defines and maintains geographic elements of fixed route transit (routes and stops)</td>
</tr>
<tr>
<td>Mapping</td>
<td>Geographic Data Display Program (GDDP)</td>
<td>Queries and displays ridership information</td>
</tr>
<tr>
<td>Mapping</td>
<td>Corridor Analysis Program (CAP)</td>
<td>Performs census tabulation and display. Developed for ADA requirement compliance. Also used for point location query and display</td>
</tr>
<tr>
<td>Utility</td>
<td>TMCONFIG (Transit Master Configuration Program)</td>
<td>Analyzes current directory and allows user to interactively configure Transit Master</td>
</tr>
<tr>
<td>Utility</td>
<td>MATCHER (Address Matching Program)</td>
<td>Assigns X/Y coordinates to addresses for display on base map</td>
</tr>
</tbody>
</table>

Source: Suburban Mobility Authority for Regional Transportation, 1995. SMALLR.R.L.C., p. 3.

"Quovadis" is also used. Quovadis is a PC-based paratransit bus scheduler that uses AVL technology (UMA Engineering Developed). Currently, the GIS and Quovadis do not interface. Some potential is seen by SMART for integration of the two systems.
Current GIS Applications

Currently, the SMART GIS system is used for ridership analysis and mapping. Specific applications include analysis or determination of the following:

- Ridership patterns
- Optimum passenger shelter locations
- Bus stop locations
- Bus route locations
- Modify routing alignments through heavily populated areas
- Ridership in various communities
- Corridor demographics (total population, racial distribution/population, male/female distribution/population, total families)
- Standees per trip
- Trip generation (number of households)
- Peak load locations

Buffer applications are used for determination of business types, number of businesses, population, and other variables. With the implementation of the Windows system, tri-county employment data was geocoded.

Obstacles to Implementation

*Proprietary Software*

- Benefits: Because the software was developed from a private vendor for user-specific application, greater flexibility was realized. Software updates are easier because the user can request the developer to write code based on user-specific needs.

- Obstacles: Developing and updating the software was time intensive. Also, because the end user was also the beta tester, the user had to go through an arduous process of evaluation and change. However, since the initial versions the software has improved. Other drawbacks include incompatibility with other systems like ArcInfo, and requests for graphic data may not be facilitated easily.

Lessons Learned

Because SMART purchased a proprietary software package, source code modification must be performed by the original consultant. Software revisions or updates are limited to funding availability. Furthermore, data exchange/sharing is not easily accomplished.

Collection of updated raw data is currently extremely time and labor intensive. It takes approximately one year to fully update passenger count information. Automation of the process would be beneficial. However, logistics may be difficult. Some possible methods include.

- Automated fare box and passenger counting.
- Survey forms completed by drivers (union approval for wage increases may slow implementation).
INDIANAPOLIS PUBLIC TRANSIT CORPORATION

Overview of GIS at Indianapolis Public Transit Corporation

The Indianapolis Public Transportation Corporation (IPTC) is considered a small transit system (<200 vehicles). One planner is currently working on GIS implementation. As of June 1994, ArcView 1 was in place. This program did not meet existing or foreseen demands. Therefore, a needs assessment was conducted for GIS software acquisition. A number of criteria drove the needs assessment. The software needed to be:

- PC-based
- Capable of transportation-specific data structures and calculations
- Able to read and write ArcInfo files
- Compatible with FTA TRANSCAD standard

It was determined that ArcView 2 also was an inadequate application tool. In January, 1995, TRANSCAD for DOS was purchased and is installed on a single PC. Plans exist for acquiring ArcView 2 as well. The IPTC sees TRANSCAD as a heavy duty creation and maintenance tool and ArcView 2 as a presentation application. ArcView 2 may also be used for less demanding applications such as correlation of databases and for public information but generally not as a generative tool.

Currently, implementation is three to six months away from completion. Future tasks will include:

- Data input (bus stops, routes, shelters), census tracts
- Generating maps for Title 6 compliance
- Ridership surveys and pattern analysis
- Correlate destinations with trip sources to evaluate performance efficiency.

Spatial Data Resources

The IPTC is currently part of a GIS consortium called the Indiana Mapping and GIS project (IMAGiS). This consortium includes city, county, and university members. IMAGiS uses ArcInfo, and is currently in the process of producing a uniform GIS system so that data can be easily shared. Approximately 30 GIS coverages are currently available. The IPTC bus route map is currently being digitized by the City of Indianapolis.

Benefits and Obstacles to Implementation

The primary obstacles encountered so far have been funding. Route data input is not proceeding quickly because personnel resources were not available. Furthermore, because only one person has been implementing the system, the process is slow. Additional funding cuts will further delay implementation. Funding reductions from $25 million/yr to $16 million/yr are expected. This will reduce bus route from 39 to 19.
Lessons Learned

The evolutionary imperative that drives software development does not work well. Proprietary software data formats are a problem. For example, the manufacturer of the fair box does not make its data compatible with any other database formats. Great potential exists for data coordination.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY (WMATA)

Overview of GIS at Washington Metro

Lamin Jeng, a planning analyst at Washington Metro, was solely responsible for initiation, acquisition, and implementation of Washington Metro’s GIS. Jeng introduced the idea of GIS through a series of in-house seminars. These seminars demonstrated the capabilities of a GIS system specific to applications in transit.

Next, Jeng wrote a needs assessment/analysis for implementation. Interviews were conducted to find out what geographic data tasks would end users want to perform. Thirty potential end users were identified and the results were presented to management. A proposal was approved for implementation, after which the MTA advertised for in-house work. Software was purchased (Caliper’s TRANSCAD 3.0 for Windows). The end result included thirty users on a Novell network.

Benefits and Obstacles to Implementation

Probably the biggest obstacle encountered by Jeng was resistance to change. People were generally happy with the status quo.

Some obstacles included:

• Hesitance to release data
• Lack of willingness to be trained
• Desire for individual applications, a challenge was to show people that their needs relate to the big picture.
• "Territoriality"—people did not like the concept of having a GIS imposed upon them.
• Unfamiliarity with concepts of spatial data queries and manipulation.

The biggest benefit noted by Washington Metro was that people are beginning to realize alternatives to traditional task completion approaches.

Lessons Learned

Jeng highlighted several important lessons that may be applied to agencies of various sizes:

• Implementation is time intensive, even with management support. Moreover, it is difficult for one person to tackle unless the implementation entails only a few applications.
• It is probably necessary to educate users on basic GIS and geographic concepts, i.e., spatial data representation, locational data manipulation, etc.
• Maximize cost savings. This can be done by utilizing existing hardware where applicable, and by using existing data sources rather than digitizing. Washington D.C. MTA used existing PCS, so hardware purchases were limited to upgrades.

Most GIS implementation costs are associated with developing data. Washington D.C. MTA did not digitize anything during the course of implementation. They used TIGER files and ARTS (Automated Routing and Transportation Systems) files for data sources. Existing geocoded routes in the non-graphic ARTS environment were generated into TRANSCAD. Bus stops were converted into TRANSCAD using a TRANSCAD macro.

CHICAGO METROPOLITAN RAIL

Overview of GIS at Chicago Metro Rail

Because routes are fixed, Metro Rail’s focus is on operations rather than planning. A justification for full GIS system implementation is hopefully forthcoming.

Currently, ATLAS GIS is being used on a single stand-alone PC workstation. Applications include the use of census data with TIGER files to examine demographics related to the network. Future plans include the acquisition of a SUN workstation equipped with ArcView. This acquisition will be a narrow scope demonstration project aimed at selling the merits of GIS to decision makers (estimated cost: $90,000). If it works, they may justify implementation of a full GIS (projected cost: $500,000).

SOUTHWEST OHIO REGIONAL TRANSIT AUTHORITY

Overview of GIS at Southwest Ohio RTA

Beginning in 1991, Southwest Ohio Regional Transit started its GIS with the purchase of a TRAPEZE system (UMA). Originally, the intent was to use the GIS as a scheduling and run-cutting package. The mapping component of the software was not being accessed. Currently, the only use of the mapping component of TRAPEZE is to track mileage. The system is being run on a LAN with a 486 file server.

Southwest Ohio RTA is preparing to conduct a needs assessment for determining future improvements to the system. Consideration is being given to AVL for use with paratransit and fixed route systems. Consideration is also being given to upgrading the existing base map. Currently, a TIGER street network is used. This is considered inadequate, and an alternative is being sought. One potential alternative source could come from a joint project between the City of Cincinnati and Hamilton County. A nearly-completed street network in ArcInfo format could be used by the Transit Agency. TRAPEZE can read Arcinfo files. However, all routes would need to be re-entered. Another possibility would be to use an outside vendor for a better street network.

Benefits and Obstacles to Implementation

Benefits of GIS implementation have yet to be realized. True GIS applications have not yet occurred. The biggest potential benefit, according to Southwest Ohio RTA, would be the acquisition
of a highly accurate base map. An improved street network would facilitate enhanced analysis. A decision is anticipated by the end of 1995.

Data sharing and cooperation between the city/county project would be mutually beneficial. Bus networks and stops could be used by other agencies and the Transit Authority would receive an accurate street network.

NEW JERSEY TRANSIT CORPORATION

Overview of GIS at New Jersey Transit

Coverages at New Jersey Transit are very extensive. Spatial data exist for large areas of New Jersey, New York City, Philadelphia, and some New York counties. These include over 1800 bus routes, major railways, subway systems, and street networks.

New Jersey Transit currently uses TRANSCAD and TIGER files on personal computers. Because the large datasets are exceeding the limits of the existing personal computer software, NJTC is in the process of purchasing INTERGRAPH MGE. They feel this environment would better handle the huge data files. Upgrading to Pentiums would also improve performance.

One of the most important anticipated improvements would be updating the TIGER street files. NJTC feels these files are currently inadequate. A strong street centerline will be obtained using an existing vectorized and orthorectified aerial photo street layer. In addition, the bus stop inventory will be merged.

Benefits and Obstacles to Implementation

The biggest obstacle encountered was trying to convince data owners of the benefits of GIS implementation. Because a very large initial up-front effort is needed for GIS implementation, funding obstacles are significant. Difficulty arises from trying to convince funding sources that a GIS would make stronger use of inherently spatial data. Further impedance comes from the large initial cost outlays.

Some benefits of GIS implementation are that anticipated application needs are better met a GIS makes stronger use of the data in terms of maps and analysis.

Lessons Learned

- Draw from the best sources and create a large master file.
- The shortcomings of TRANSCAD and Tiger data quickly exceeded the hardware and software capabilities.
- Consider anticipating end user applications of digital data.
- Ease people into the GIS mentality by creating public workstations within the agency
- Duplication of effort.
Summary and Conclusion

Predictably, comprehensive implementation of a GIS system was primarily limited to large transit agencies. Large transit agencies with a well-developed GIS typically favor interoperability and enterprise-wide implementation. Typically, cost-benefit justification is more difficult in small to mid-size agencies. A common theme in small-agency implementation is the use of student resources and inter-agency cooperation.

COMMON THREADS

One of the most common trends in large-agency GIS implementation found in these case studies is the shift toward a combination centralized/decentralized GIS. Because most large agencies have existing centralized GIS data distribution regimes, implementation was limited to decentralization of their systems.

SANDAG, LACMTA, and King County Metro have, or are implementing, the ArclInfo-ArcView software married to a network of personal computers. This approach allows end users (planners) to access core spatial data for a variety of common analysis queries using desktop GIS software that is compatible with the large system. Typically, the desktop GIS software (usually ArcView) is modified for specific applications using the software's macro language (ArcView-Avenue, Mapinfo-MapBasic, GenaMap-Geniusll). Additional benefits from the desktop approach include reduction of workload requests for core GIS personnel, related cost savings, and immediate access to GIS databases.

The decentralization theme is carried a step further through enterprise-wide implementation. This approach facilitates data accessibility across department and/or agency boundaries. For example, a transit agency could share route and schedule information with an MPO while using the MPO’s land use data for ridership forecasting. Typically, implementation of such enterprise-wide GISs currently requires significant effort in data conversion (LACMTA). At least one transit agency (Orange County Transportation Authority) has commissioned vendors to provide data import and export utilities between GIS and scheduling packages (UMA and ESRI). Development of common spatial data standards is critical to maximizing GIS potential in the transit industry.

Factors contributing to slow adoption of GIS by transit operators/agencies include:

- Lack of resources
- High costs of maintaining accurate spatial databases
- Software incompatibility between the GIS and existing agency software
- Convincing decision makers of the value of GIS.

Size-Specific Trends

Among mid-size transit agencies surveyed for this report, personal computer-based GIS implementation appears to be favored. Likely contributors to this trend include increased personal computer power, increased software sophistication and user-friendliness, and decreasing capital costs. Further incentives contributing to the use of PC-based systems include increasing compatibility with larger Unix-based systems. For example, the increasing proliferation of ArcInfo
as the dominant GIS software package has a direct influence on software considerations at the PC level, i.e., ArcView compatibility. In lieu of the development and implementation of data exchange standards, desktop GIS software vendors (Mapinfo, TRANSCAD, INTERGRAPH) usually include some provision for compatibility with ArcInfo.

Custom modification of desktop GIS programs to fit user needs was also found in mid-size agencies. ArcView’s Avenue, Genamap’s Genius II, and Mapinfo’s MapBasic, are some examples. Service planning continues to dominate GIS applications in this size category. Motivating factors may include increasing catchment area efficiency, Title VI compliance, ADA requirements, shrinking subsidy levels, and the lack of GIS-specific personnel.

Cost effective GIS implementation is more difficult in small agencies. However, small agencies may implement a cost-effective GIS by using student resources, sharing maintenance of spatial data with other city/county agencies, and using existing hardware and datasets (if available). Data sharing consortiums also appear to be significant factors bolstering cost-effective implementation. Small agencies are perhaps more likely to adopt implementation strategies specific to local constraints and opportunities. Johnson City, for example, established its GIS based on a federal grant making subsequent development easier. Agencies may also be opportunistic and selective with regard to implementation as with the Bloomington example (acquiring used equipment, utilizing student resources for software development).

A number of agencies chose to implement their GIS using a proprietary software package. Advantages and disadvantages were noted for this method of GIS implementation. Cost considerations were weighed against data compatibility and operations issues. Data exchange/sharing limitations were significant when weighed against the trend towards enterprise wide implementation, interoperability, and data exchange consortiums. This trend illustrates how GIS implementation strategies are shifting to conform to budget constrained environments, decreasing hardware/software costs, and rapidly increasing network infrastructures.
This annotated bibliography was prepared to serve as a reference for organizations and individuals interested in the use and application of GIS in transit planning, operations, marketing, and analysis. Nearly 100 bibliographic references are provided, most of which focus on the specific use of GIS in various aspects of public transportation. Many of these references do not relate specifically to transit but should be useful for any GIS application to transportation in general.

References that relate specifically to transit are listed in italics. The references included in this draft were identified through several mechanisms, including (1) a TRIS search, (2) a university library search, (3) a review of recent conference proceedings, and (4) word of mouth.

For additional information on this bibliography, contact the Center for Urban Transportation Research, (813) 974-3120.

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Abdel-Aty, Mohamed A., Ryuichi Kitamura, and Paul P. Jovanis, “Route Choice Models Using GIS-Based Alternative Routes and Hypothetical Travel Time Information Input,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950244 (January 1995). This paper utilizes statistical analysis to explain the route choice of commuters. The analysis is based on mail-out/mail-back survey questionnaires which were customized using routes generated by a GIS. The results indicate the significance of the following variables on route choice: travel time, travel time reliability, traffic safety, and roadway characteristics.

Abkowitz, Mark, Paul Der-Ming Cheng, and Mark Lepofsky, “Use of Geographic Information Systems in Managing Hazardous Materials Shipments,” Transportation Research Record 1261 (1990). This paper discusses the relevancy of GIS in providing for improved decision support in managing safe transport of hazardous materials shipments. GIS applications are defined for hazardous materials transport problems, and the benefits that can be achieved through the adaptation of GIS to this subject area are demonstrated. The following topical areas are examined: (1) the decision environment for managing hazardous materials shipments, (2) GIS data availability to support analysis needs, (3) application of a first-generation GIS model to identify preferred hazardous materials shipment routes, (4) comprehensive approaches using GIS for emergency preparedness and evacuation planning, and (5) problems encountered in using GIS technology for hazardous materials transport applications.

Allen, Jr., William G., and Srinivasan Mukundan, “Use of GIS in Transit Alternatives Analysis,” Presented at the Fourth National Conference on Transportation Planning Methods Applications (May 1993). This paper presents a process for using GIS in the Transit Alternatives Analysis. Studies of major transit capital investments often rely on regional travel forecasting models and large-scale computerized transit networks. GIS can be used to modify network coding, reflect various transit alternatives, and then analyze the impact of these alternatives. Examples of alternative investments include a new fixed guideway facility, significant improvements in local or express bus frequency, new park-and-ride lots, and improved feeder bus service. The authors build upon earlier work by others to develop a way to systematically display service level differences between any two transit alternatives or between an alternative and some base condition.

Anderson, L.D., “Applying Geographic Information Systems to Transportation Planning,” Transportation Research Record 1305, Finance, Planning, Programming, Economic Analysis, and Land Development, pp. 113-117 (1991). A technology crucial to better coupling of land use and transportation planning is Geographic Information Systems (GIS). Because few documented practical applications of this technology have been developed, the Planning Support Branch of FHWA’s Office of Environment and Planning, with the Transportation Planning Division of the Maryland-National Capital Park and Planning Commission (M-NCPPC) in Montgomery County, Maryland, conducted a three-month case study examining M-NCPPC’s application of the GIS Spatial Analysis System (SPANS) software to its transportation planning activities. This case study comprises one module within FHWA’s GIS/Video Imagery Demonstration Project 85. SPANS was used to disaggregate the county’s traffic analysis zones (TAZs) into smaller subzone components to produce finer-grained modeling data. The primary goal was to compare current and planned housing and employment with prescribed development ceilings. This activity permits creation of future scenarios based on the amount of remaining legally developable land, as well as the future demand for transportation by mode (automobile, bus, rail, walking, bicycle, etc.). The results indicate that using GIS-produced disaggregate socioeconomic data with travel demand modeling techniques improves the planner’s ability to model both trip generation and modal choice. Further work by planners and GIS software developers alike will expand the application of the GIS well into the future.
Antonisse, R.W.E., "GIS-T Applications in Transit: Recent Experience in Seattle and Boston," (American association of State Highway & Transportation Officials, 1991). GIS-T has many potential applications in the transit context, which may exhibit quite different characteristics from established uses in, for instance, state DOTs or municipal government. One possible area of transit operations where implementation of GIS-T may be of benefit is in the development of customer information systems. To date, little research has focused on GIS-T applications in transit, compared with other, more highway-oriented, contexts. This paper compares case studies of the Seattle and Boston transit authorities in order to discuss the possible benefits and difficulties of implementing GIS-T in transit agencies.

Azar, Kamal T., and Joseph Ferreira, Jr., “GIS for Transit Passenger Information Systems,” Proceedings of the 1991 Geographic Information Systems Symposium, Orlando, Florida (1991). A Passenger Information System (PIS) answers passenger inquiries about how to get from address A to address B. GIS software often includes address matching and routing capabilities but the raw tools are not enough to make a PIS viable. This paper (a) explores the feasibility of replicating the basic functions of a PIS in a GIS, (b) identifies the conceptual and practical differences between a custom-designed PIS and a GIS-based system, and (c) explains the advantages and disadvantages of each approach as the development and sharing of maintainable databases for road networks, routes, and demographic information become more and more common.

Azar, Kamal T., and Joseph Ferreira, Jr., “Using GIS Tools to Improve Transit Ridership on Routes Serving Large Employment Centers: The Boston South End Medical Area Case Study,” Comput., Environ., and Urban Systems, Vol. 18, No. 3, pp. 205-231 (1994). This paper discusses how planning transit routes can be transformed into a more proactive process, and how GIS technologies can be used to reach that goal. The authors' methodology uses the address-matching capabilities of GIS to pinpoint the residences of the employees of large employers and to map these locations with respect to existing transit lines and employment sources. A statistical analysis of current accessibility is then completed. The authors apply their methodology to practice, by utilizing data from three large medical institutions in the South End Medical Area of Boston.

Azar, Kamal T., and Joseph Ferreira, Jr., “Visualizing Transit Demand for Current and Proposed Transit Routes,” Proceedings of the 1992 Geographic Information Systems Symposium, Portland, Oregon (1992). This paper describes one of the models used by transit agencies for estimating ridership and discusses areas of integration of GIS into such models and the benefits derived from such integrations. It also explores the effects of visualization of routes, demographics, and employment data on the process of designing route alignments with better targeting of high transit ridership areas.

Baaj, M. Hadi, Suleiman A. Ashur, Miguel Chaparrofarina, and K. David Pijawka, “Design of Routing Networks Using GIS: Applications to Solid and Hazardous Waste Transportation Planning,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950843 (January 1995). This paper utilizes two different case studies to illustrate the practical importance of GIS to the field of transportation engineering, specifically, transportation routing. The first study examines the design and analysis of different Arizona statewide waste tire collection transport networks corresponding to different percentages of total annual waste tires collected. The second case crosses national boundaries by presenting EPA-sponsored research on the transportation routing and risk management of hazardous waste shipments across the U.S.-Mexico border region.

*Bailey, Marc, and Simon Lewis, “Creating a Municipal Geographic Information System for Transportation: Case Study of Newton, Massachusetts,” Transportation Research Record 1364 (1992). This paper utilizes a case study approach to illustrate the merits of using a GIS to provide an additional range of transportation functionality for smaller agencies with limited staff and resources. Examples of transportation functionality elements include, but are not limited to, traffic assignment, vehicle routing, reapportionment of traffic zones, and location of centers (such as fire stations). The preparation of a GIS-T toolbox approach to planning and analysis is reviewed.

Beck, S., and T. Andriole, "The Use of GIS in the Study of the Location and Feasibility of a Magnetic Levitation Transit System Within the Baltimore-Washington Corridor," Compendium of Papers, Volume II, 4th National Conference on Transportation Planning Methods Applications (1993). The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provides for the development of a domestic prototype Maglev system in six years. While Maglev technology is generally regarded as feasible in this time frame, site-specific route and alignment studies are needed to assess economic viability, rights-of-way compatibility, and environmental impacts. Selection of a suitable corridor for implementation of the ISTE A prototype is essential to the assessment and success of a domestic Maglev system. KCJ Technologies, in association with Martin Marietta Corporation and a number of other firms, is conducting a location and feasibility study to evaluate the 10-mile-wide Baltimore-Washington corridor with respect to the Prototype Development Program authorized under ISTE A. This location and feasibility study is being conducted in three phases. The initial and iterative phases characterize potential corridors in terms of: Maglev technologies, alignment geometries, environmental impacts, operations scenarios, ridership revenues, lifecycle costs, and cost-effectiveness measures. The evaluation phase consists of a disciplined analysis and assessment of viable corridors with respect to ISTE A factors. This paper discusses the use of a GIS as a tool for collecting, organizing, evaluating, and displaying environmental data for this project. Emphasis is placed upon the design and implementation of databases and digital maps and the development of project-specific applications. Also discussed is the interface between the GIS and Martin Marietta's Ground Transportation Analysis System, a modelling tool for collecting and evaluating route alignment information along transportation corridors at the planning scale.

Bennion, M. Wayne, and Wende A. O'Neill, "Building Transportation Analysis Zones Using GIS," Presented at the 73rd Annual Meeting of the Trans-
literature review and personal interviews, and to compile an inventory of transportation-related GIS systems, databases, and applications in Florida. A general overview of GIS in transportation is provided followed by an overview of the use of GIS in transit. Four major categories of GIS uses in transit are identified, including information dissemination, transit planning, facilities and real estate management, and transit operations and control.

Choi, Keechoo, Paul F. Hanley, and Tschangho John Kim, “GIS-Based Traffic Analysis Zone Design,” Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. This paper describes a GIS-based Traffic Analysis Zone (TAZ) design method. A spatial indexing method is developed to cluster homogeneous spatial units that can serve as traffic analysis zones. The paper explains a two-step procedure using GIS: (1) to provide the topological relationship among basic spatial units, and (2) to integrate databases. The authors illustrate how, once the delineation is complete, GIS generates a revised matrix of attribute data for further analysis, such as trip generations.

Cipolloni, M.J., “Using GIS to Manage Existing Transportation Facilities,” Compendium of Technical Papers, Institute of Transportation Engineers, 63rd Annual Meeting (1993). Many decades of underspending on maintenance has left the infrastructure of many countries in need of repair, especially in the U.S. However, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provides some relief for transportation needs. Section 1034 requires that all 50 states implement six management systems by fiscal year 1996 or face a possible loss of federal funds. These include Highway Pavement, Bridges, Highway Safety, Traffic Congestion, Public Transportation Facilities, and Intermodal Transportation Facilities. This paper discusses the many uses of GIS to better manage existing transportation facilities and covers in some detail an example of how New Jersey has employed this technology to manage their traffic control signs.

Cooke, Donald, “Updating TIGER-The Census Perspective,” GIS World, pp. 124-125 (February 1991). This article discusses the historical background of the U.S. Census Bureau's TIGER, a computerized map of the United States depicting virtually all streets, boundaries, railroads, and water features to serve as the master geographic base for the 1990 census. In addition, the article touches upon current issues, like what is being done to keep TIGER updated. Concerns such as lack of cooperation among agencies (public and private) and duplication of effort are addressed.

Corbin, Lisa, “Maps Go On-Line,” Government Executive, pp. 28-34 (March 1993). This article discusses the ever increasing role being played by GIS in federal government. It discusses briefly how GIS works and how it is used to help governmental agencies accomplish their missions (especially those agencies which manage natural resources or monitor environmental impacts). Finally, the article emphasizes the importance of the Spatial Data Transfer Standard (SDTS) which is necessary to eliminate expensive data-conversion and increase data-sharing activities.

Craig, William J., “The Rising Tide of GIS,” CURA Reporter, Center for Urban and Regional Affairs, University of Minnesota (May 1993). This article discusses the rapidly increasing use of GIS in the State of Minnesota. It emphasizes the need for the academic community to take an active role in assisting governmental agencies harness the technology. It summarizes briefly the various areas in which GIS can be used (i.e., urban issues, environmental issues, forest stand management) and discusses the financial aspects of utilizing this technology.

Culp, Linda, “Short Range Transit Planning and Marketing Using Desktop Geographic Information Systems,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950467 (January 1995). This paper summarizes a cooperative arrangement between the San Diego Association of Governments and the region's transit operators to design a desktop GIS application that staff from each individual operator can access directly to enhance regional transit planning and marketing. The primary objective was to develop a system at a relatively low cost and that required minimal training. The paper identifies several applications that can be accomplished by the system, including transit service potential, socio-economic profiles of areas surrounding transit, route analysis, Title VI evaluation, and future growth areas, among others.

Dowlng, Linda A., “Technology Transfer-High Tech Department of Energy to High Tech Transit,” Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. This paper summarizes a project being conducted by the City of Albuquerque Transit and Parking Department and the Sandia National Laboratories (SNL) that involves the use of SNL's hazardous material tracking GIS software as the basis for a full-
function, client-sensitive tool for the city's paratransit services. In addition to supporting the paratransit services, the project was also designed to meet the geographic and travel information needs of an emergency response center capable of supporting both the rural and urban aspects of New Mexico.

Dueker, Kenneth J., Ric Vrana, and Gary Bishop, "GIS Applications in Urban Public Transportation: Pilot Projects and Implementation Strategies for Tri-Met, Portland, Oregon” (Portland: Center for Urban Studies and Transportation Northwest, October 1991). This report summarizes the incremental experience of the Tri-County Metropolitan Transportation District of Oregon (Tri-Met), as it implements a strategy of database integration around a modified version of the TIGER line files. The functional GIS application areas in transit are identified and discussed, including facilities management, facilities engineering, service planning, operations and control, and customer service. The use of TIGER as a base network also is reviewed as a potential integrating framework. Four pilot projects demonstrate the usefulness of GIS for transit applications. Projects were selected to provide proof of concept and to illustrate GIS applications to issues of concern for Tri-Met. The four projects include: (1) incorporating transit routes into a GIS, with relation to an enhanced TIGER, (2) analysis of aged and disabled paratransit clients and trips to determine the proportion served by fixed route transit service, (3) use of GIS for analysis of land use adjacent and near bus shelters, (4) use of GIS to relate bus stop locations to traffic zones.

Dueker, Kenneth J., "Access to Data: National Spatial Data Infrastructure," Presented at the 74th Annual Meeting of the Transportation Research Board (January 1995). This paper details the significance of the National Spatial Data Infrastructure (NSDI). It briefly describes the program and explains its applicability to the transportation planning profession. It outlines the unique needs of transportation in the NSDI and specifically discusses which data are sharable in this program. Finally, the paper addresses the linear data transfer problem under the NSDI and identifies weaknesses of the current program that could be strengthened to make it more successful.

Eberlein, X.J., and J.N. Brown, "Combining Land Use and Transit Planning Using GIS," Proceedings of the 1991 Geographic Information Systems Symposium, Orlando, Florida (1991). GIS software can help policymakers analyze the relationship between land use and transportation, and thus serve as a useful tool in developing policies that alleviate traffic congestion. This paper presents a basic GIS methodology to integrate and analyze transit and land use data at the regional level. For this study, rail transit use patterns are related to the siting of federal facilities in the Washington, D.C. region. The GIS analysis recommends that some of the region's new federal site developments be concentrated or relocated, so to reduce the site developments' negative impact on traffic congestion and to improve their positive impact on transit use. This simple example provides the basic structure with which to develop similar GIS analyses of higher complexity or for other regions.

Federal Transit Administration, “National Transit Geographic Information System: A Component of the National Transportation System,” (Office of Technical Assistance and Safety, 1994). This brochure is intended to inform the transportation community and the general public that the FTA is developing a national transit GIS incorporating user-friendly, personal computer software technology. The GIS will have the capability to display inventory and other selected data of fixed public transit facilities in the United States, as well as to display information of other transportation facilities including highways, airports, marine ports, freight and passenger rail systems. The Transit GIS will facilitate the exchange of information among the modal administrations and the transit industry. It will also enable managers at all levels to analyze and retrieve existing transit inventory data, and project and program information. The Transit GIS will be a component of the National Transportation System and will enhance the National Spatial Data Infrastructure.

Gallimore, W. Paul, David T. Hartgen, and Yuanjun Li, "Applications of Geographic Information System-Transportation Analysis Packages in Superregional Transportation Modeling,” Transportation Research Record 1364 (1992). This paper illustrates the merits of using GIS (TransCAD) to conduct a transportation analysis for the Charlotte, North Carolina, area. This study was undertaken in an attempt to address some of the concerns associated with a proposal for a 150-mile (or more) road around this region, called the Carolina Parkway. The software develops a sketch network where traffic can be simulated using a doubly constrained gravity model technique. Problems and opportunities presented by super-regional modeling are also discussed.

ticle presents a GIS-Aided procedure designed to overcome the major problems that exist in the current practice of the census-to-TAZ data conversion process. The three problems that the author addresses are: (1) the manual method of developing equivalency tables by matching census and TAZ hard copy maps, (2) the problem which arises from the unnecessary non-contiguous census and TAZ area boundaries, and (3) the use of a single equivalency table, which can be extremely inefficient.

Goodwin, Cecil W. H., and Stephen R. Gordan, "Reinterpreting the Location Referencing Problem: A Protocol Solution," *Compendium, GIS-T 95* (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper critiques the assumptions behind the "common method" approach to location referencing, and reevaluates its necessity and practicality. A prototype protocol for Intelligent Transportation Systems (ITS) applications, the Location Reference Message Protocol (LRMP), is presented. The paper concludes that the protocol is flexible enough to accommodate different location referencing methods and thus to facilitate market and product development for ITS, and can be extended for use within distributed GIS-T networks.

Groff, Jonathan, "Dynamic Segmentation as an Implementation Path to an Evolved Transit Data Model" (Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper describes the necessity of constructing an implementation path to ease the transition to an integrated environment. Specifically, the paper details the experiences of the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) in which a linear referencing system was adopted utilizing the Arc/Info Dynamic Segmentation model for the purposes of integrating core operations at Tri-Met. The author explains that this evolved system was necessary due to the impending acquisition of spatial data intensive applications such as Automated Trip Planning, Paratransit, and Bus Dispatch.

Guo, Bo, and Allen Poling, "A GIS/GPS System Design for Network Travel Time Study," Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950332 (January 1995). This paper is based on a study conducted by the Maricopa Association of Governments (MAG) for the purposes of examining travel speed and delay in the Metropolitan Phoenix area. Specifically, the paper focuses on a GIS/Da..
The objective of the database was to determine: (1) which agencies may have a bus route GIS database completed, (2) which agencies may complete a bus route GIS database within the next two years, and (3) which agencies will not be developing a GIS database within the next two years. The memorandum summarizes the results of the research, provides some technical documentation of the database of GIS in Transit use, discusses the implementation of the database during the outreach phase of the Federal Transit Administration (FTA) GIS development, and discusses some problems and opportunities arising from the conduct of the research.

Hartgen, David T., and Yuanjun Li, “Geographic Information Systems Applications to Transportation Corridor Planning,” Transportation Research Record 1429, pp. 57-66. This paper describes two case studies in which GIS procedures have been applied to transportation corridor planning. The two studies are purposefully different from one another in an attempt to demonstrate the wide-range of capabilities and applicability of TransCAD, a transportation-oriented GIS. The first case study focuses on display capabilities of the GIS process to assist in analyzing a rural multicounty corridor recently upgraded to an Interstate system corridor. The second concentrates on travel demand modeling, using the study of a ring road around a large metropolitan area as an example.

Henderson, Thomas, “A Comprehensive Proposal for the Acquisition, Use, and Maintenance of Geographically Related Information in the New Mexico State Highway and Transportation Department” (January 1989). This paper was written in response to the 1988 statement made by the National Council on Public Works Improvement that America’s infrastructure, including its transportation systems, may be on the verge of crisis. The paper describes the need for state DOTs to adopt an integrated approach for planning, designing, building, and maintaining effective transportation systems. It emphasizes the importance of a common geographical environment as the foundation for this integrated approach. It details the process used to acquire, maintain, and use the locationally related information necessary and recommends specific strategies to achieve the desired outcome.

Henry, Victor, and Stuart Sirota, “Using GIS to Identify Locations With Greatest Potential for Increased Transit Ridership.” Compendium, GIS-T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper identifies how GIS was used in response to an intensive effort to identify ways in which ridership could be increased on the light rail system operated by the Maryland Mass Transit Administration (MTA). Selected management employees were teamed together and given three weeks to identify market segments with a potential for increased ridership, to develop recommendations for ridership increases, and to present the recommendations to MTA senior management. A GIS was used to display and analyze current transit ridership, origin-destination survey data, and the 1990 Census Transportation Planning Package (CTPP) Journey-to-Work data.

Hickman, Mark, and Theodore Day, “Organization of Spatial Data at California Transit Agencies,” Compendium, GIS-T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper provides a status report on a research project designed to identify and investigate the current technical and institutional framework for the use of spatial data of transit agencies in California. In particular, three primary areas are examined, including the use and sharing of spatial data for functions associated with real-time operations management, service planning, and traveler information. These topics are researched through a broad survey of transit agencies in California to examine their needs for spatial data and the flow of the data within each transit agency.

Hsiao, S., and J. Sterling, “Microcomputers in Transportation: Use of GIS for Transportation Data Analysis,” Fourth International Conference on Microcomputers in Transportation, Baltimore (1993). This is a description of how GIS techniques were applied to analyze commuter rail survey data from which a Los Angeles intercounty rail service design can be projected and tailored. It is noted that the use of the GIS enhances the accuracy and efficiency of O-D survey data analysis and provides detailed spatial analysis results for transportation service evaluation. The GIS provides a flexible approach for data analysis. It was found that both short term commuting service design and long range transportation planning activities can be developed based upon a common GIS database structure, from which specific information can be queried to address unique project purposes. This makes possible an integrated data analysis environment.

Innes, Judith E., and David M. Simpson, “Implementing GIS for Planning,” APA Journal, pp. 230-236 (Spring 1993). This article provides a literature review on the subject of technological innovation as it
relates to GIS. The authors attempt to provide a "big picture" perspective on the subject area and its effects on the planning profession. They conclude that planners must understand GIS not only as a dynamic, socially constructed technology, but also as a tool that brings with it a lot of responsibility and a plethora of issues that must be considered before its implementation (i.e., legal issues, organizational issues, etc.). The article recommends a strategic approach to the utilization of GIS involving a delicate balance between human and technical systems.

Iqbal, Muhammed Shahid, Carolyn S. Konheim, and Brian T. Ketcham, "The Development of a Regional GIS-Transportation ITS/IVHS Network," Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950499 (January 1995). This paper details the development of a GIS-T for an Intelligent Transportation Systems (ITS) network for the 23-county metropolitan region of New York, New Jersey, and Connecticut. The goal of the study was to design a regional ITS, which would serve as a framework for an integrated and multi-modal transportation network. The GIS network was used as a tool for identifying critical transportation corridors within the regional area that could benefit from ITS technologies. In addition, the GIS network could assist decision-makers in defining and prioritizing projects for implementation and expansion of ITS in these corridors.

Javid, Massoud, Prianka N. Seneviratne, and Prabhakar Arraluri, "Applications of GIS in Planning Transit Services for People With Disabilities," Presented at the 73rd Annual Meeting of the Transportation Research Board, Paper No. 940266 (January 1994). This paper describes the application of GIS to the estimation of demand for transit services by people with disabilities and the scheduling of demand responsive transit vehicles. The paper shows that information, such as block group population, the proportion of people with disabilities, and general travel characteristics of people with disabilities, can be used to estimate demand for transit services. The use of a GIS for scheduling demand responsive service where fixed-route services are unavailable also is demonstrated.

Johnson, Brad H., and Michael J. Demetsky, "A GIS Decision Support System for Pavement Management," Presented at the 73rd Annual Meeting of the Transportation Research Board, Paper No. 940674 (January 1994). This paper describes the development of an attribute database for pavement management purposes. The authors consider two primary types of roadway data in their study: (1) inventory data describing the physical characteristics of the traveled way, and (2) pavement management data describing the actual surface condition of the roadway. The difficulty inherent in tying two databases together is discussed. The resulting database was applied to demonstrate how the information can be used to support pavement maintenance decisions.

Johnson, Brad H., and Michael J. Demetsky, "A Geographic Information System Environment for Transportation Management Systems," (University of Virginia, Department of Civil Engineering, January 1993). This report, utilizing a case-study approach, examines the merits of applying GIS technology to the area of transportation management systems. These systems include bridge management, intermodal transportation, pavement management, public transportation, safety, and traffic congestion. The authors use Albemarle and Greens Counties in Central Virginia as the focus of their research. The report develops a pavement management decision support GIS environment. The authors demonstrate that GIS is an appropriate tool for the decision-making process and therefore it is likely to be applicable to other types of transportation management systems.

Kinsey, Ken, and Uri Avin, "GIS in Action," Urban Land, pp. 18-21 (March 1992). This article provides three different examples of cost-effective applications of GIS technology. Each example presents its own unique problems, but they all require the coordination and synthesis of diverse sources of information. The three examples discussed are: (1) producing and coordinating an intricate development plan for a golf course/resort community, (2) developing a county wide holding capacity/land condition analysis for long-term utility planning and routing, and (3) performing regional planning analysis for a metropolitan area.

Koncz, Nicholas, and Joshua Greenfeld, "GIS-Based Transit Information Bolsters Travel Opinions," GIS World, pp. 62-64 (July 1995). This article stresses the necessity of user-friendly, geographically-based information systems to encourage citizen use of public transportation. Specifically, the article discusses the use of GIS in tandem with a Transit Advanced Traveler Information System (TATIS) to achieve this goal. A GIS forms an excellent backbone for TATIS by combining the abilities to spatially locate the transportation routes, bus/other stops and origin/destination addresses with attribute information, such as schedules and fares. The authors discuss the key components of a TATIS, the data needed to design a
TATIS prototype, how it is analyzed, and the best way to present the information once it has been processed.

Kutz, Scott A., “GIS Inventory Data Preparation: Assigning Spatial Properties to Highway Feature Files Using Independent Data Sources,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950375 (January 1995). This paper addresses the methodological weaknesses of Advanced Traveler Information Systems (ATIS), a primary component of Intelligent Vehicle Highway Systems (IVHS). Specifically, the authors note the fact that travel is a derived demand and is generated by the decision of individuals to participate in various activities. This concept (known as activity-modeling) is ignored in the context of ATIS and, therefore, traveler’s choices in response to unexpected traffic delays are largely confined to alternative routes. The authors argue that a broader perspective built upon the activity-based approach and the activity scheduling framework would allow other alternatives to be considered. The paper attempts to address this issue based on the activity-based approach and the use of GIS.

Kwan, Mei-Po, and Reginald G. Golledge, “Integration of GIS with Activity-Based Model in ATIS,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950419 (January 1995). This paper addresses the methodological weaknesses of Advanced Traveler Information Systems (ATIS), a primary component of Intelligent Vehicle Highway Systems (IVHS). Specifically, the authors note the fact that travel is a derived demand and is generated by the decision of individuals to participate in various activities. This concept (known as activity-modeling) is ignored in the context of ATIS and, therefore, traveler’s choices in response to unexpected traffic delays are largely confined to alternative routes. The authors argue that a broader perspective built upon the activity-based approach and the activity scheduling framework would allow other alternatives to be considered. The paper attempts to address this issue based on the activity-based approach and the use of GIS.

Lebeaux, P., “Helping Area Planners With GIS” (Metropolitan Washington Council of Governments, 1993). This paper explains how a GIS will enable transportation planners to better analyze travel patterns and travel behavior in the Washington metropolitan area. Using the GIS, Council of Governments staff will be able to pull together the transportation, land-use, and air quality data files necessary for these analyses. The GIS will be used both for internal analytical projects and to create reports and maps that can be individually tailored to provide information to policy makers and the public. Eventually, local planners will be able to call up the system and obtain data on-line in formats determined by the user.

Lepofsky, Mark, Mark Abkowitz, and Paul Cheng, “Transportation Hazard Analysis in Integrated GIS Environment,” Journal of Transportation Engineering, pp. 239-254 (March/April 1993). This paper describes methods employing GIS-T that can provide the capability to perform transportation hazard analysis and incident management. The methods discussed are practically applied in several case studies involving highway operations in California to illustrate their usefulness. The paper concludes with a discussion of how the GIS-T approach to incident management may be extended to address dynamic management in an IVHS environment.

Li, Yuanjun, “GIS-Based Spatial Representation and Trip Pattern Analysis for The 1985 Charlotte Household Travel Survey” (The University of North Carolina at Charlotte, Center for Interdisciplinary Transportation Studies, 1983). This paper studies the urban household travel patterns of Charlotte, North Carolina, in an ArcInfo GIS environment in an attempt to illustrate how GIS can be used in the area of transportation planning in order to assist in activity-based urban transportation planning. The use of GIS and the concept of decision support systems (DSS) for transportation also are discussed.

Lycan, Richard, and James D. Orrell, “An Analysis of Bus Ridership Potential to Oregon Health Sciences University Using a Geographic Information Systems Approach” (Center for Urban Studies and Transportation Northwest, February 1990). This report shows that GIS address-matching and overlay techniques can be used in the analysis of specialized transportation problems. These techniques allow planners to evaluate accessibility issues for various market segments in the population. As a result, this information enables improved decisionmaking regarding the feasibility of adjusting routes or schedules, or providing new services to potential users. A case study is presented that focuses on the commuters of the Oregon Health Sciences University and the potential for altering existing bus routes to better serve these commuters or the possibility of establishing direct-service vans to serve the commuters.

May, James W., and Teri Kutch, “Automated Mapping and GIS for Smaller Communities,” Homer Hoyt Center for Land Economics and Real Estate, Florida State University (January 1993). This monograph was designed as a GIS information resource for local governments. It offers advice from differing perspectives on how GIS can be implemented in a local
Alternatives Analysis of the technology and its business purpose of GIS technology, planning and route location studies. Native corridors being considered for a proposed GIS for understanding and evaluation of the area. The use of corridors in the area encompassed a ten county, 3,000 square mile area. The use of GIS was critical in the alternatives evaluation and impacts assessment of the proposed corridors.

METRO, Municipality of Metropolitan Seattle, ‘GIS Project Phase I Feasibility Study’ (July 1992). The purpose of this paper was to: (1) provide a foundation for understanding Geographic Information Systems (GIS) technology, (2) provide justification for the adoption of GIS technology by identifying potential applications of the technology to current and future Metro business needs, and (3) identify the core data elements for GIS applications. In addition, this document provides perspective by examining current GIS usage at Metro and highlights key issues related to meeting user needs.

METRO, Municipality of Metropolitan Seattle, “GIS Project - Alternatives Analysis and Recommendation” (March 1993). This document is the final report of the Phase I - GIS Project Feasibility Study for the Municipality of Metropolitan Seattle. It describes the rationale used for alternatives analysis, presents a comparison of GIS alternatives outlining the pros and cons of each, and recommends an alternative for implementation in Phase II of the GIS project.

Meyer, Michael D., and Wayne Sarasua, “Geographic Information System-Based Transportation Program Management System for County Transportation Agency,” Transportation Research Record 1364 (1992). This paper describes a prototype GIS-T that was developed for a suburban county transportation agency in metropolitan Atlanta. The rationale for developing the prototype was to design a system which would assist the agency in better managing its transportation program. An organizational assessment was conducted and applications that would most benefit the agency were detailed. The paper concludes that GIS-T provides a strong decision support capability for agency officials. It also provides a more efficient way of conducting different types of analysis.

Moore, Alisoun K., and Martha Stauss, “Cooperative Approach Towards an Integrated Geographic Information System (GIS) at the Maryland State Highway Administration (MSHA),” Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. This paper outlines the approach Maryland is taking in developing its GIS for Transportation. MSHA has adopted a strategic user-based approach to development and implementation of GIS. This approach has two major tenets: (1) development of a coordinated and stable information architecture and technology, and (2) technical support for the development of useful and well-engineered applications desired by various user groups. The paper also discusses the linkage between organizational goals and GIS, specific organizational mechanisms used, information architecture description and development, database management approach, application development techniques and user involvement.

Neuerburg, Nancy, and Wayne Watanabe, “Implementing a Successful Transit GIS,” Presented at...
the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. In the last few years, King County Metro Transit (Metro) successfully completed the business analysis, requirements definition, alternatives analysis, and implementation of an agency-wide GIS. This paper discusses the implementation process. The GIS was required not only to provide new functionality, but to also meet existing needs for automated geographic information from systems such as the Automatic Passenger Counters, AVL/AVM, BUS-TIME (automated next bus time information), and others. The paper also describes the extensive educational process and teamwork throughout the agency that was required, and successfully provided, to ensure successful implementation.

Newcombe, Tod, “GIS: Beyond Pipes and Plats,” Governing, pp. 25-26 (December 1993). This article provides an overview and examples of what GIS technology can do. Specifically, it discusses factors like cost, user-friendliness, and accessibility which all contribute to a greater use of this technology. The article also discusses the beginnings of the Defense Department’s Global Positioning System (GPS) and its important contributions to the success of GIS.

Nichols, Woodrow W., Jr., “GIS-T in Transit Planning and Management,” (Raleigh, NC: Southeastern Transportation Center, The University of North Carolina Institute for Transportation Research and Education, May 1994). The purpose of this study was to contribute to the understanding of the potential uses of GIS-T for transit planning and management by: (1) reviewing the current GIS concepts affecting transit; (2) identifying transit planning and management applications that could benefit from the adoption of a GIS; and (3) demonstrating how the different flow-control rules can be simulated within a GIS environment for transit planning and management.

O’Neill, Wende A., R. Douglas Ramsey, and JaChing Chou, “Analysis of Transit Service Areas Using Geographic Information Systems” Transportation Research Record 1364 (1992). This paper discusses a procedure for performing service area analysis on transit routes using a GIS as opposed to the more common technique of buffering. It describes the implementation strategies for three GIS software packages: ARC/INFO, TransCAD, and SPANS. A case study is utilized to compare the method being discussed with that of two other approaches. The effects of the data source and the accuracy of all of these approaches is discussed.

O’Neill, Wende A., and Balakrishna Akundi, “Automated Conversion of Milepoint Data to Intersection/Link Network Structure: An Application of GIS in Transportation,” Transportation Research Record 1261 (1990). This paper addresses the need to implement effective data restructuring models in the GIS environment. Specifically, the authors emphasize the importance of milepoint referenced data in road inventory files for transportation research. However, to utilize road inventory data in any analysis model, network information has to be converted from milepoint to an intersection/link format. In addition, data conversion efforts are needed to produce intersection/link network representations from milepoint data. A microcomputer model for data conversion is developed and application issues and model sensitivities are addressed.

O’Packi, Paul, and Eric Sabina, “The Implementation and Use of GIS-T Technology in Metropolitan Planning Organizations,” Compendium, GIS-T 95 (Geographic Information Systems for Transportation Symposium). This paper examines organizational, technical, and political issues involved in implementing GIS-T in MPOs drawing on experience with MPOs of varying sizes. GIS-T tools and techniques important to implementation in MPOs also are reviewed; these include network conflation, dynamic segmentation, and the use of linear referencing systems (LRSs). The challenges associated with upgrading from an existing GIS to a more robust environment with full GIS-T capabilities also are reviewed.

Panchanathan, Sriram, and Ardeshir Faghri, “A Knowledge-Based Geographic Information System for Safety Analysis at Rail/Highway Grade Crossings,” Presented at the 74th Annual Meeting of the Transportation Research Board, Paper No. 950717 (January 1995). This paper discusses the development of an integrated, user-friendly, knowledge-based GIS for evaluation of safety at rail-highway crossings. The authors underscore the importance of this undertaking by emphasizing that the allocation of federal funding for safety improvements at public, at-grade rail-highway crossings is made based on the performance of states with respect to accident reductions. The authors walk the reader through the information management process by describing the conversion of existing rail-highway crossings attribute data into a GIS acceptable format, the location referencing of the crossings attribute data to their location in the graphic database, interfacing with USDOT model, and interfacing with a knowledge-based expert system for considering the qualitative and heuristic information.
Paredes, Miguel, Emmanuel Fernando, and T. Scullion, “Pavement Management Applications of GIS: A Case Study,” Transportation Research Record 1261 (1990). This paper illustrates how GIS technology can be implemented within a MICRO-PES (a suite of computer programs developed to assist state district engineers with their network level pavement management activities) environment to satisfy the need of the various districts for graphics output capability. The authors developed a a prototype GIS module that provides the capability for graphically displaying the output from the existing MICRO-PES analysis subsystems. Using a case study approach, the authors were able to effectively demonstrate the applicability of GIS as a tool for pavement management.

Peng, Zhongren, Jonathan N. Groff, and Kenneth J. Dawer, “Dynamic Segmentation in Database Design for Transit Planning,” Compendium, GIS- T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper discusses the use of and need for dynamic segmentation in the design of a transit routing database. Although the concept of dynamic segmentation has been discussed extensively for highway analysis, it has not been common in transit planning, routing, and analysis. The paper identifies several transit network characteristics and data integration requirements that can be handled through the use of dynamic segmentation. The database design serves the current transit planning and scheduling needs, as well as future real-time applications in transit scheduling and demand management.

Petzold, R., “Yielding the Benefits of GIS,” American City and County, Volume 109, Issue Number 3, pp. 56-63 (1994). This article describes how a GIS permits users to obtain information related directly to the transportation system in a familiar format - a map. The benefits of GIS are listed. The most important objectives for using GIS are map/display and data integration. Agencies must identify potential issues that can be addressed through a GIS application more efficiently and effectively, and more economically than with prevailing methods. Federal, state, and local agencies are using GIS information to develop transportation policy and planning. The Federal Highway Administration expanded its GIS capability by developing a 1/100,000 highway system of the National Highway System (NHS). The U.S. Department of Transportation is now expanding its GIS by developing the National Transportation System (NTS), which will incorporate in a single database all modes of transportation. This GIS will analyze America’s future transportation investment choices, be the basis for communications and obtain input from state and local governments and develop new legislation. The article also describes a GIS-based Intermodal Transportation Management System (ITMS) being developed by the California Department of Transportation. ITMS provides information for supporting decisions concerning the priorities of investments in the state’s intermodal transport system. The article also considers a wide range of software packages for use as tools for developing applications.

Petzold, Roger G., and Deborah M. Freund, “Potential for Geographic Information Systems in Transportation Planning and Highway Infrastructure Management,” Transportation Research Record 1261 (1990). The efficient use of information throughout an organization becomes not only a political, but an economic imperative. Geographic information systems (GISs) may play a central role in serving users in executive, administrative, technical, and support staff positions. This paper discusses the requirement of GISs to develop frameworks for their own application. The authors address five specific applications of GIS: (1) the FHWA Geographic Roadway Information Display System, (2) FHWA’s GIS for policy analysis, (3) Wisconsin DOT GIS for pavement management, (4) North Carolina GIS for the Division of Highways, and (5) FHWA/Columbia Metropolitan Planning Organization, application of the Bureau of the Census, the Topologically Integrated Geographic Encoding and Referencing system for a metropolitan planning organization.

Pittman, Robert H., and Grant I. Thrall, “Using Geographic Information Systems in Economic Development: An Introduction,” Economic Development Review, pp. 14-21 (Fall 1991). This article discusses the role that GIS can play in economic development. The purpose of the article is threefold. First, the article defines the different levels of GIS (i.e., depth, geographical coverage, and geographical resolution). Second, it discusses several examples of GISs which are currently being used or are being built by economic organizations. Finally, the authors provide an introduction to the different types of GIS software, including features, costs, and hardware requirements.

Poling, Allen, Jim Lee, Patrick Gregerson, and Paul Handly, “Comparison of Two Sign Inventory Data Collection Techniques for GIS,” Presented at the 73rd Annual Meeting of the Transportation Research Board, Paper No. 940404 (January 1994). This paper describes the data collection process of a
sign inventory conducted in the Washington, D.C. area. GPS was utilized where possible. However, in sections of the study that were located near downtown, taller buildings blocked satellite signals. Therefore, GPS collection was infeasible and a more manual method was chosen using a measuring wheel. These two distinctly different data collection methods are compared using time to collect and time to process the data as standards for comparison. Finally, the authors detail the development of a GIS program to display the collected data.

Raj, Phani K., David Chia, and Walter Kulyk, “Application of GIS to Emergency Response in Transit Systems,” Compendium, GIS-T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper presents the features and potential future modifications of an emergency response system software for bus transit operators. Designed by Technology & Management Systems, Inc. to run on GIS type applications, the system displays the location of the bus on a map and provides the dispatcher with sequential and prioritized action prompts which are situation and accident dependent. Additional features include automatic recording of actions initiated and accident/incident report filling functions.

Ries, Tom, “Integrating Governments for Transportation Purposes Using Geospatial Framework,” Compendium, GIS-T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper provides suggestions for addressing the issue of data sharing for transportation needs and corresponding geospatial frameworks. Suggestions include: (1) determining what and where our needs are in the big picture of a transportation facility's life cycle, (2) defining and composing what geospatial frameworks are in terms of this life cycle, (3) identifying and resolving the conflicting views of spatial data brought on by consumers versus producers, and (4) describing an approach for how sharing can occur based on appreciating various business requirements and how they are inter-related. Case study examples are used to support these suggestions.

Schweiger, Carol L., “Current Use of Geographic Information Systems in Transit Planning” (USDOT, Federal Transit Administration, Office of Grants Management, August 1991); “Current Use of Geographic Information Systems in Transit Planning” Transportation Research Record 1349. This report and paper summarize the use of GIS technology in public transit systems and metropolitan planning organizations (MPOs) for transportation planning analysis. The data were collected through a 1991 survey that resulted in 74 telephone interviews with 67 organizations across 30 states. This included 46 transit systems and 21 MPOs. The survey instrument was designed to identify the range of GIS applications in transit planning. GIS products used and why, spatial data resources, GIS implementation plans, and factors in and obstacles to GIS implementation, among others.

Simkowitz, Howard J., “GIS Applications Benefit from Census Transportation Planning Data,” GIS World, pp. 38-40 (April 1993). This article describes a special tabulation produced by the U.S. Census Bureau called the Census Transportation Planning Package (CTPP). It describes the direct relevancy of the data set to transportation planning, and how GIS will play a central role in its use. The data included in the CTPP are reported by TAzs. GIS technology allows for quick and efficient building of TAzs right on the user's computer screen. The article further explains the significance of the TAZ-GIS relationship, and then provides more examples of areas in which GIS is useful (i.e., accident analysis, network modeling and logistics, impact studies, etc.).

Simkowitz, Howard J., “GIS Supports Transportation System Planning,” 1993 International GIS Sourcebook, pp. 234-236, (1993). This article describes the relevancy of GIS to the transportation community. It explains the role of spatially integrated data in transportation and uses examples to illustrate how GIS is applicable to this field (i.e., accident analysis, transportation demand modeling, pavement management systems). It discusses the role of TAzs and TIGER/Line files in GIS, describes how traditional GIS applications can be enhanced, and explains how GIS can serve as a platform for integrating unrelated transportation models.

Simkowitz, Howard J., “Using Geographic Information System Technology to Enhance the Pavement Management Process,” Transportation Research Record 1261 (1990). A pavement management system (PMS) should provide for all of the important aspects of the pavement management process: planning, programming, project development, and implementation. GIS technology can be used to expand and enhance each of these PMS components. The PMS can be built and operated on a GIS-based platform. This design when put into practice is designated as a PMS/GIS. This paper discusses the importance of a variety of spatially integrated data to pavement...
management decisionmaking. In addition, each component of the PMS process is addressed. This process, in turn, results in the identification of a core set of functions required for an effective PMS/GIS. These include: thematic mapping, flexible data base editing, formula editing, statistics, charting, matrix manipulations, network generation, and integrated models and algorithms.

Strazewski, Len, “Try GIS Off the Rack: Inexpensive, Efficient,” City & State, p. 20 (February 15, 1993). This article discusses the recent affordability of GIS and how a new category of users have gained access to this technology. The author uses an example of a small municipality having to redistrict itself to ensure minority representation within its community. In this case, GIS allowed the community to redistrict itself on computer (with three alternative plans) and then show those plans at a public hearing before making a final decision.

Vonderohe, A.P., L. Travis, R.L. Smith, and V. Tsai, “Adaptation of Geographic Information Systems for Transportation,” National Cooperative Highway Research Program, Report 359 (1993). This report addresses the need for GIS in transportation. The primary factors considered are (1) current and future needs for information analysis to support transportation agency missions, (2) the need for information systems integration within transportation agencies and across governmental lines, (3) trends in technology, and (4) organizational constraints. The report provides a conceptual framework and implementation plan for GIS-T.

Von Essen, Ian, Carol Hanchette, and Gerald Dildine, “Evaluation of GIS Workstation Performance within a Distributed Network Environment,” Transportation Research Record 1261 (1990). This paper outlines the methods used to evaluate graphics workstation performance for a statewide transportation GIS, specifically, the North Carolina Department of Transportation. Workstation products from three vendors were evaluated. Results of the evaluation are presented in the context of workstation performance tests, network capabilities, operating systems, vendor support, and workstation prices. Recommendations for workstation procurement specific to the needs of the North Carolina DOT are made.

“Van Est, J. P. and J. H. Bekkers, “GIS as a Tool for Planning and Management,”” (Transport and Road Research Laboratory, 1989). There is a growing interest in geographical data processing. GIS can be considered as a tool for helping answer spatial questions and for physical planning. Discussing such systems implies such questions as “what is a GIS?,” “who are the users?,” and “what can be done with such a system?” The first part of the paper gives a short introduction to GIS. The second part of the paper discusses two examples of GIS applications in the transportation field: (a) a study of planning bus stops in He city of Oldenburg, using catchment areas; and (b) a discussion of the possibilities for analyzing traffic accidents, using the traffic accident files of the Dutch Ministry of Transport and public works.

Ward, Beverly G., William L. Ball, and Joseph D. Hagge, “GIS in Transit: Applications and Lessons Learned,” Compendium, 5th National Transportation Planning Methods Applications Conference. This paper begins with a summary of GIS application areas in transit planning and analysis and then focuses on a variety of issues related to the use of GIS in a series of transit-related projects that have been conducted at the Center for Urban Transportation Research. These issues are identified and discussed in order to share the lessons that have been learned in the use of GIS in transit planning and analysis applications. The paper concludes with recommendations for developing a GIS implementation plan.

Watje, John M., and Paula Okunieff, “APTS Map Database User Requirements Adapted to the Spatial Data Transfer Standard (SDTS),” Compendium, GIS-T ’95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). This paper describes the work completed by the ITS Committee on Map and Spatial Databases Working Group to develop map and spatial database specifications for transit applications, especially those geographic spatial data systems that were specifically related to APTS application areas, such as customer information, demand responsive transit, operations, and planning. A major recommendation of the Working Group was the selection of the USGS Spatial Data Transfer Standard (SDTS) as the transfer standard most suitable for transit applications. The paper discusses why SDTS was selected over other spatial data transfer standards and the possible approaches that can be taken in implementing SDTS as a transfer standard for use with APTS applications.

Weaver, David, and Richard Sutton, “Using GIS for Rail Corridor Analysis: Siting of Interstate High Speed Rail Lines and Environmental Impact Statement Mapping for Improvement of Existing Rail Corridors,” Presented at the 1995 Geographic In-
Yang, Xinnong, “The Implementation of Optimization of Dynamic Vehicle Routing With GIS,” Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. Dynamic Vehicle Routing Problems (DVRP) can often be found in the case of technician dispatch, truck delivery, dial-a-ride services, and emergency vehicle dispatch, among others. DVRP deals with real time events and requires special consideration of temporal constraints. This paper investigates DVRPs and reviews a number of technical approaches to addressing these problems through the use of GIS. By processing and storing geographical and tabular data, GIS provides a powerful tool for developing a computerized dynamic routing system. The paper also introduces a prototype of a GIS Dynamic Routing System.

Young, David, “Getting the Gist of GIS-T in Fleet Management and Routing,” Presented at the 1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada. This paper discusses the application and use of GIS to the routing and scheduling of vehicles in various fleet operations. In particular, the software needs for the routing and scheduling needs of paratransit services are identified and discussed. In order for software to adequately address routing and scheduling problems, it must “know” three key items of information — when are the trips to take place, where does it originate, and where does it terminate. With this information, the paper illustrates how GIS can improve the routing and scheduling by reducing vehicle miles traveled by as much as 20 to 30 percent.

Young, J. Jeffrey, Wei-Ning Xiang and Owen J. Furuseth, “Univer-City Partnership Brings People, Technology Together,” GIS World, pp. 52-54, (March 1993). This article addresses the need for cooperation across organizations to meet the needs of urban planning in the 1990's. Specifically, the article discusses the cooperative effort of the city of Concord, NC, and the University of North Carolina-Charlotte (UNCC) to assist Concord in integrating GIS into city operations. The article stresses the benefits that can be derived from sharing resources. In this case, graduate students gained valuable experience, while Concord gained a GIS and learned how to use it.

Zhang, Zhanmin, Terry Dossey, Jose Weissmann, and W. Ronald Hudson, “GIS Integrated Pavement and Infrastructure Management in Urban Areas,” Presented at the 73rd Annual Meeting of the Transportation Research Board, Paper No. 940781 (January 1994). This paper summarizes the efforts to apply GIS to urban roadway and infrastructure management. It emphasizes how the linkage between a GIS and the effective management of pavement and other infrastructure in the urban area can greatly increase the service life of these facilities and reduce user costs. The paper implements and describes GISURMS, which is a user-friendly application program.

Zheng, Jilong, Dr. Kyriacos C. Mouskos, and Dr. Joshua Greenfeld, “A GIS Based Ridesharing Information System,” Compendium, GIS-T 95 (1995 Geographic Information Systems for Transportation Symposium, Sparks, Nevada). A major goal of Intelligent Transportation Systems (ITS) is to increase the average vehicle occupancy as a means for reducing congestion on the nation's roadways. Ridesharing is one of the means to achieve this goal, where drivers are matched with passengers having similar trip characteristics. This paper describes a Ridesharing Information System (RIS) that can function independently or as a module of a Multimodal Advanced Traveler Information System (MATIS). Components of the RIS include the determination of user trip profiles and ridesharing preferences, passenger/driver matching, and confirmation/cancellation procedures. Example applications of the RIS are presented for Union County in New Jersey.
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