Technical Report Documentation Page

1. Report No. Final	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TRP 99-32 GIS Implementation Strategy for WVDOT		5. Report Date December 2002
		6. Performing Organization Code
7. Author(s) Dr. Michael Robinson		8. Performing Organization Report No. Final Draft
9. Performing Organization Name and Address Rahall Transportation Institute 1 John Marshall Drive, Huntington, WV 25755		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTRS-98G-0012
12. Sponsoring Agency Name and Address US Department of Transportation, Research and Special Programs Administration 400 7th Street, SW Washington, DC 20590-0001		13. Type of Report and Period Covered
		14. Sponsoring Agency Code USDOT-RSPA
15. Supplementary Notes		

16. Abstract

The Rahall Appalachian Transportation Institute (ATI) and the West Virginia Department of Transportation (WVDOT) funded Marshall University and West Virginia University under Project RTI-99-32 Analysis and Exploitation of Geographic Information Systems (AEGIS) to develop a strategic plan for the implementation of a geographic information system (GIS). This plan supports the efforts of WVDOT to develop an integrated GIS resource management system to meet its evolving operational and managerial business needs. WVDOT will benefit through the ability of GIS to integrate, either logically or physically, the diverse and voluminous data necessary to operate the Department of Transportation and to distribute that data to its multiple customers in a seamless and transparent environment.

17. Key Word GIS		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Analysis and Exploitation of Geographic Information Systems

prepared by

Marshall University

College of Information Technology and Engineering

Dr. Michael Robinson, P.E. (Co-Principal Investigator)

Mr. Jamie Wolfe (Co-Principal Investigator)

Mr. Sean Litteral (Co-Principal Investigator)

and

West Virginia University

West Virginia GIS Technical Center

Mr. Kurt Donaldson

Dr. Trevor Harris

for

West Virginia Department of Transportation

Appalachian Transportation Institute

August 2002

Revised November 2002

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the accuracy of the data presented herein. The contents of this report do not reflect the official views or policies of the West Virginia Department of Transportation. The use of trade names does not signify endorsement by the authors.

ACKNOWLEDGEMENTS

The West Virginia Department of Transportation and the Nick J Rahall Appalachian Transportation Institute funded this research. The authors thank the many employees of the West Virginia Department of Transportation who provided assistance in the completion of this report. The authors also recognize the input from numerous individuals from various state transportation agencies who provided information on their GIS programs.

EXECUTIVE SUMMARY

The West Virginia Department of Transportation (WVDOT) seeks to develop an integrated geographic information system (GIS) resource management system to meet its evolving operational and managerial business needs. State transportation agencies have unanimously adopted GIS as a required technology and most have established an officially recognized GIS capability. The growth of GIS in the transportation field lies in its ability to integrate the diverse and voluminous geospatial data found in today's transportation agencies and to distribute that data to multiple customers in a seamless and transparent environment.

WVDOT currently has no personnel devoted strictly to the development and propagation of GIS, and therefore approaches the implementation process with minimal GIS expertise and experience. However, many WVDOT personnel are aware of GIS and the potential benefits that the technology can bring to their Department. This study recommends that GIS implementation proceed in a two phase approach with a concurrent appropriately timed consideration for training.

The recommended implementation plan builds GIS support and expertise within WVDOT in a phased approach that emphasizes "learn by doing." While there is the need to move wisely in the implementation process, WVDOT must begin the process as soon as possible and have some GIS product to build momentum for GIS. The phased approach attempts to minimize the risks associated with the process yet still move WVDOT forward with GIS.

The **recommended phase one tasks** are as follows:

- Develop / Identify GIS expertise
- Develop administrative / organizational structure for GIS unit
- Select standard set of GIS software tools
- Begin development of transportation base map
- Develop low risk applications
- Develop data and metadata standards

Two administrative tasks begin the recommended phase one tasks because they are considered important to overcome institutional inertia and to build upper management support for the implementation process. With minimal GIS experience and expertise within WVDOT, a nucleus of GIS expertise must be developed. It is also suggested that a GIS coordinator be appointed to lead the implementation process and an advisory committee with a different role than the current GIS steering committee be developed to assist the GIS coordinator. The advisory committee should be composed of personnel knowledgeable in GIS, WVDOT upper management and perhaps should also include members from the existing WVDOT-GIS Steering Committee. In addition to technical support and specific fact finding endeavors proposed in

this report, this advisory committee could also assist in detailing the phase tasks and subtasks, identification of individual task team leaders and members, establish: priorities, timelines, mission and objectives that are complimentary to the Department and determine the most cost effective approach.

A significant cost of GIS implementation is commonly associated with geospatial data. It is recommended that WVDOT maximize the extent to which existing data can be utilized. The West Virginia GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. The report focuses on the best geographic data available to the statewide geo-spatial community. It provides the status for eight core themes (hydrography, *transportation*, orthoimagery, elevation, cadastral, geodetic control, governmental units, topographic maps) used by most GIS applications and six applications-specific data themes (soils, geology, land cover, critical structures, flood mapping and economic development). For each framework data theme there is a brief description, mapping status, ultimate mapping goal and data producer information, which includes originator(s) of data, resolution, currency and data availability.

The second phase of the implementation plan focuses on developing the technical foundation of the GIS and addresses long-term issues, some of these issues have not achieved a consensus resolution within the GIS-T field. These tasks are significantly more complex and require significant knowledge and expertise in GIS and database management systems.

The recommended phase two tasks are to:

- Develop a list of new GIS applications for development
- Identify and develop strategic applications
- Develop a GIS Data Sharing Architecture
- Develop a Linear Reference System

During the final stages of completion of this report, the Rahall Transportation Institute has started to develop the first statewide GIS-T project focused on the Appalachian Corridors with funding through the WVDOT from the Appalachian Regional Commission matched with funding at RTI. This project includes development of GIS software customizations with consideration for the current WVDOT linear reference system. This project has been recently expanded to the state of Tennessee and will compliment the Tennessee Roadway Information Management System. In addition, RTI was recently designated to build the GIS System and Data Sharing Warehouse for the WV Development Office. RTI has also already developed a prototype online GIS information system i.e. Transportation and Economic Development System (TEDIS). This system was developed using data from the WVU GIS Technical Center in addition to new data and information from specific RTI projects and transportation and economic developed "value added" endeavors.

<u>Training is important</u> to the long-term success of GIS and most state transportation agencies have not established a formal structured GIS training program for staff but instead rely on ad-hoc training. A formalized, structured training program should be considered to develop internal GIS expertise and many transportation agencies recognize the following different levels of GIS users.

1. Those that use GIS as an exploratory tool. NOTE: if a web-based application is chosen for dissemination purposes then minimal training may be required and could be provided on line.
2. The next level uses data analysis outside of specific applications using spatial analysis functions i.e. engineers developing GIS solutions for specific projects.
3. The highest level of user is the application and data developer which are typically assigned full time GIS duties within a centralized GIS administrative unit.

This training program should be addressed concurrently by the advisory committee as the implementation plan progresses with budgetary considerations for both internal and external training. Inadequate training is considered one of the most commonly encountered implementation problems according to the FHWA.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ANALYSIS AND EXPLOITATION OF GEOGRAPHIC INFORMATION SYSTEMS

1.0 INTRODUCTION

The Rahall Appalachian Transportation Institute (ATI) and the West Virginia Department of Transportation (WVDOT) funded Marshall University and West Virginia University under Project RTI-99-32 Analysis and Exploitation of Geographic Information Systems (AEGIS) to develop a strategic plan for the implementation of a geographic information system (GIS). This plan supports the efforts of WVDOT to develop an integrated GIS resource management system to meet its evolving operational and managerial business needs. WVDOT will benefit through the ability of GIS to integrate, either logically or physically, the diverse and voluminous data necessary to operate the Department of Transportation and to distribute that data to its multiple customers in a seamless and transparent environment.

The utilization of GIS in the transportation field is so pervasive it has achieved its own acronym, GIS-T for geographic information systems for transportation. Applications of GIS-T abound in all modes and aspects of transportation including management of waterways and railways, mass-transit systems, and freeways. Indeed, major GIS vendors now market products specifically developed for the transportation field. State transportation agencies have unanimously adopted GIS as a required technology and most have established an officially recognized GIS capability (AASHTO, 2001). In addition to state transportation agencies, GIS-T has also found widespread and successful use by cities, counties, and metropolitan planning organizations (MPO's).

Although there are many successful GIS applications, GIS is only one of several information / data management technologies available to the WVDOT. As with any tool GIS has a specific purpose, will perform best when used for that specific purpose, and must be properly used to perform best at its specific purpose. A well defined strategic plan will help to insure that GIS finds its specific purpose within the WVDOT not only at the application level but also within the overall information systems / management strategy of the WVDOT. Although maps are the most visible product of a successful GIS implementation, it is the ability to extract useful knowledge from tables of interrelated spatial data that defines a successfully implemented GIS. A well-developed strategic implementation plan is essential regardless of the scale of implementation / integration selected by WVDOT to insure that GIS is not simply a map-making tool.

Interviews were conducted with personnel from all seven agencies of the WVDOT. However, as the needs analysis focused on the DOH the majority of interviews were with DOH personnel. Personnel at the Central Office, the District 2 Office, and the District 5 Office were interviewed. The interviews were grouped along the operational structure of the DOH: planning and research, highway development, and highway operations. The interviewed groups explained their work processes, the data required by those work processes, and potential GIS applications they envisioned for their group. The interviews were also used to create awareness within the WVDOT of GIS and its potential usefulness and most importantly to meet the personnel ultimately responsible for a successful GIS implementation.

1.1 Project Objectives

To aid in development of the implementation plan, the following objectives / tasks were identified in the AEGIS project proposal:

1. Conduct a GIS needs analysis to include
    a. Determining the architecture of WVDOT's technology and work processes
    b. Determining the current use of GIS within WVDOT and the extent and nature of outsourced GIS efforts
    c. Identifying organizational units with a high potential to benefit from GIS integration
    d. Analyze state and federal GIS applications
2. Develop a GIS data flow and integration analysis
    a. Identifying major data flows and processes
    b. Create a top-level process mapping of major data flows and processes
    c. Perform GIS integration into current workflow analysis
    d. Conduct a study of vendor capabilities with respect to GIS integration
3. Conduct a data availability and adequacy analysis
4. Evaluate the accessible, accurate geo-spatial information available to the WVDOT

1.2 Report Structure

This report while containing all the elements of the project objectives listed in Section 1.1 does not follow the outline presented in that section. During the project, it was determined that the GIS data flow and integration analysis effort in task 2 was not the best approach for the implementation plan. Instead of focusing on implementing GIS into specific workflow processes as listed in objective 2 c, the implementation plan is centered on specific tasks that will provide a solid foundation for the implementation and long-term success of GIS. The approach focuses on the strength of GIS, data integration and access, rather than on how GIS can improve specific work processes within WVDOT. In addition, the report emphasizes the value of geo-spatial data and the need for WVDOT to evaluate existing geospatial data and to make maximum use of existing data.

The report is divided into 7 sections. Section 1 is an introduction to the project, while section 2 through section 6 briefly describe the project tasks that supported the development of the implementation plan described in section 7. The implementation plan is series of tasks to be completed in phases. Each task includes a justification for the task and guidance on completion of the task. In addition, a report prepared by the West Virginia GIS Technical Center as part of this project discussing the accessibility of accurate geo-spatial information is included in its entirety. Relevant sections from this report have been included in the implementation plan. However, because of the critical role of geospatial data in the success of any GIS implementation effort the report is included in its entirety.

2.0 GIS RESOURCES IN WVDOT

2.1 GIS Activities Within WVDOT

None of the seven agencies of WVDOT use GIS in their work processes. There is, fortunately, awareness of GIS and its potential throughout WVDOT and especially in DOH. Many personnel interviewed expressed great interest in GIS and immediately envisioned potential applications in their respective areas. Many of these applications addressed current problems they were having in accessing and analyzing data.

Parkways, Economic Development, and Tourism use asset management software for sign management and is considering a similar application for lighting management. Although the asset management software is not a GIS based system the software provides many of the data analysis functions that would be available in a GIS based application. The specific software developer, CartéGraph, offers additional transportation related asset management software for bridges, pavement, signals, and markings in addition to an application that adds GIS functionality through use of a 2nd party GIS software (ESRI's ArcView).

2.2 GIS Usage Within Associated Organizations

The Urban Studies section of Planning and Research coordinates transportation planning between the Division of Highways and six local Metropolitan Planning Organizations (MPO's). The Brooke, Hancock, Jefferson Metropolitan Planning Commission was contacted regarding their current GIS usage. This MPO uses GIS for transportation related analysis and relies on data from the WVDOT and the DOT's from bordering states. Integration of WVDOT data into their GIS is severely handicapped because of the unavailability of data in a GIS format. Data exchange between the WVDOT and associated organizations (MPO's, consulting firms, other state DOT's, etc.) is hindered as many of these associated organizations now utilize GIS.

2.3 Inter-agency Data Exchange

Formal data exchange between the Division of Highways (DOH) and the other six agencies of WVDOT is minimal. The one case identified is the transfer and sharing of accident data between the DOH and the Division of Motor Vehicles (DMV). DMV initiates the raw accident data in paper format but transfers the data to the DOH in paper format where DOH personnel enter the data into the Statewide Accidents Record Database. The Traffic Planning section of the Traffic Engineering Division maintains the Accidents Record database, the state repository for accident data.

2.4 Existing Organizational Resources

GIS implementation will require human, hardware, software, and data resources. WVDOT currently has minimal human resources to support GIS implementation. A GIS Steering Committee has been established to lead the initial implementation phase of GIS. A series of GIS-related job classifications have been created within WVDOT to support and maintain the GIS. The capabilities and benefits of GIS are generally recognized throughout WVDOT with certain administrative units and personnel having greater interest in and knowledge about GIS. WVDOT has made a minimal investment in GIS software and no specific investment in hardware resources dedicated to GIS.

3.0 GIS UTILIZATION IN STATE TRANSPORTATION AGENCIES

Review of the current "state of the art" in GIS-T applications provides both an encouraging look into the possible future of the WVDOT as well as a healthy dose of reality to temper unrealistic expectations regarding the near future of GIS in the WVDOT. Although this section does not provide an exhaustive list of all GIS-T applications, there is a sufficiently broad listing of applications to serve as a starting point for "brainstorming" sessions by various WVDOT sections to consider how GIS might be utilized in their particular sections.

A GIS is "a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modularly and display of spatially referenced data for solving complex planning and management problems" (Federal Interagency Coordination Committee, 1988). In comparison, a GIS application is a custom interface built on the base GIS software to simplify data access and analysis for a specific purpose. GIS software has the capability to integrate, analyze, query, and display spatial data. A GIS application uses these capabilities to perform predefined operations on specific data sets. Frequently, much of the GIS work done within an application is invisible to the application user. Applications allow complex spatial analysis to be performed at all levels within the WVDOT regardless of the GIS knowledge of the user. The development of applications can depend on the needs the DOT, the availability of the data required by the application, or simply the need to develop an initial application to promote the integration of GIS into the DOT.

Most applications can be considered either a mapping application or an analysis application. A mapping application takes spatial data and displays the data on a base map. An analysis application, on the other hand, performs a higher level of spatial analysis/computation on one or more related data sets and then displays the results on a base map. However, a mapping application will often perform some level of data analysis, i.e. filtering of data. Generally, mapping applications are the initial applications developed because of their comparative ease of development and their usefulness. GIS applications often evolve from data retrieval and display applications to applications performing data integration and then finally to applications performing complex spatial analysis.

3.1 Common GIS Applications

Transportation agencies share many common functions and responsibilities as well as collect common core transportation data. Therefore, it is not surprising that DOT's implementing GIS have developed similar GIS applications. A survey of 40 state transportation agencies conducted in 2002 (AASHTO, 2002) found the following set of common applications:

- **Road feature inventory** (10 states)
- **Highway asset management** (7 states)
- **Safety management / crash analysis** (6 states)
- **Highway project locations** (6 states)
- **Traffic incident monitoring** (5 states)
- **Road conditions / weather** (5 states)
- **State highway map / atlas** (4 states)
- **Road construction / detours** (4 states)
- **Truck permitting / routing** (4 states)
- **Environmental impact analysis** (3 states)

Insufficient information was available to classify the applications as either a mapping application or an analysis application. However, the same survey conducted in 1999 as well as the 2002 survey found little use of GIS spatial analysis functions in the applications developed by DOT's. Most applications developed by transportation agencies provide a spatially referenced graphical view of existing tabular data. This does not minimize the development effort associated with these applications but instead shows GIS remains not yet a fully mature technology at the state DOT level.

The Pennsylvania Department of Transportation developed a list of high priority applications and other potential GIS applications during development of its strategic plan.

- **High Priority Applications**
  - Safety management
  - Congestion management
  - Project management
  - Roadway management
  - Bridge management
- **Environmental Impacts/Design Management**
  - Environmentally sensitive locations
  - Archeological locations
  - Historical locations
  - Wetlands
  - Wildlife habitat
  - Farmlands
  - Parks
  - Hazardous waste
  - Land use
- **Vehicle Routing**
  - Hazardous materials
  - Oversize / overweight vehicles
  - School buses
  - Evacuation planning

- Detour planning
- **Administrative Management**
    - Facilities
    - Tort liability
    - Revenues
    - Expenditures
    - Personnel
    - Driver licensing
    - Commercial driver licensing
    - Vehicle registration
- **Maintenance Management**
    - Snow removal
    - Surface treatment
    - Pipe replacement
    - Resurfacing
    - Concrete rehabilitation
    - Mowing
    - Spraying
    - Line painting
- **Equipment inventory**
- **Aerial photography inventory**
- **Geological management**
    - Decision support on geological information
    - Hazard inventory
    - Rock and soil boring logs

From discussions with personnel from several transportation agencies and a review of current GIS literature and websites an additional list of common applications was developed.

- **Update of state maps through creation new statewide databases**
    - Allows users to update map attributes within a database and for the new attributes to be shown on updated state maps.
- **Digital state transportation base map production**
    - States have different base map roads for this application. Some states use Digital Line Graphs (DLGs) or Topologically Integrated Geographic Encoding and Referencing system (TIGER) files while other states create their own base map.
- **Highway state maps preparation**
    - Allows users to assist in the preparation of state highway maps. The greatest advantage being the updating of road information in a digital form for quicker export to a hard copy map. Reduces or eliminates need for hand editing of maps.
- **Environmental Assessments**

- Maybe the most widely used application. Allows for overlaying of various environmental layers (i.e. wetlands, historical sites, endangered species habitat, etc.). Often used to determine best routes for future roadwork to minimize environmental impacts.

- **Statewide & Regional Traffic Studies**
  - Integration of traffic planning tools and travel forecasting models with GIS is the future of traffic studies.
- **Geotechnical Analysis**
  - As widely used as environmental assessment. This application allows for the analysis of various geotechnical themes graphically. Such themes as soil analysis, faults, ground water, contours, etc can be viewed as a complete picture.
- **Streets and bus transit routes, draft bus stop, transit route level of service**
  - Allows for the routing of public or private vehicles within a road network system. Commonly used to route public transit vehicles along most efficient route. Similar systems (E911) can be used for emergency vehicle routing.
- **Highways planning, design and construction**
  - Usually a combination of other applications. Most often used for planning. The application will take results from environmental analysis, geotechnical analysis, etc. to determine the best corridor for a new highway.
- **Accident location and analysis**
  - Allows for graphical display and spatial analysis of accident data.
- **Pavement condition mapping and analysis**
  - In most cases that is a management tool to help schedule pavement work. Using data such as date last paved, type of pavement, traffic loads, historical trends, and (in some cases) inspection data, management can better prioritize work schedules.
- **Internet roadway condition map**
  - This application is a public service tool. Instead of listing roads and their condition, the public can use the application to view road conditions graphically. This is helpful to those that are not familiar with road names but know the route they will be taking. It also can help show alternate routes available.
- **Congestion management**
  - This application is best used within a complete Intelligent Transportation System (ITS). Using road networks, routing software, real-time traffic counts, changeable signs, etc., congested areas can be rerouted to free congestion. This application is often used in highly populated urban areas.

- **Bridge Management**
    - This application is used as a management tool. Integrating databases, which already exist, within a GIS application allows for visual display of bridges. The development and implementation of the application provided the ability to manage bridge maintenance data and to analysis that data within the larger transportation plans of the state. The system can determine the best allocation of funds for bridge maintenance and/or upgrade based on future highway construction, safety concerns, and economic development plans within regions of the state.

3.2 Specific GIS Applications

Several specific applications of possible interest to the WVDOT are discussed in detail.

Sign Inventory Management and Ordering System

The Pennsylvania Department of Transportation (PennDOT) has implemented a GIS based asset management application, sign inventory management and ordering system (SIMOS), utilizing Intergraph GeoMedia (Marsteres and Wagner, 2001). PennDOT annually installs or replaces 100,000 signs that were managed through 11 nonconforming systems at its district level. Before SIMOS, sign inventory management systems ranged from districts that had no existing system to districts using paper records to districts that developed their own standalone databases. Without a centralized application, development of these district level systems depended on the incentive and skills of individual personnel at the district level. SIMOS provides a centralized application for all eleven districts. Users can pan and zoom inside a base map and then access data, including installation, inspection, and repair records as well as a graphical view, of any sign within the state highway system The central office maintains the master database while each of the eleven districts maintains its own data. Through a local area network connection, county employees regularly update their respective district's database, and the districts upload any changes to the master database.

Iowa Geographic Image Map Server

The Iowa Department of Transportation (IADOT) has implemented an web-based image delivery application (http://ortho.gis.iastate.edu/) based on Intergraph Geomedia Web Map to provide IADOT employees access to more that 3,000 georeferenced USGS and state survey maps and aerial photos. (http://www.intergraph.com/govt/profiles/idot.asp). The application allows users to zoom in from a state map to user-defined areas to identify available survey maps and aerial photos. Relevant photos and maps can then be directly accessed in multi-resolution seamless image database (MrSID) format.

Roadway Information Management System

The Tennessee Department of Transportation (TDOT) has implemented the GIS based Tennessee Roadway Information Management System (TRIMS) as the core of TDOT's roadway inventory and asset management system (Wagner, 2001). TRIMS performs inventory maintenance for the entire state, included dynamic segmentation of roads for pavement conditions, bridges, accidents, traffic segments and other roadway attributes as well as photologging for 27,000 miles of state routes and interstates.

The original TRIMS was developed in the early 1970's as a mainframe-based information system. The system was converted to an enterprise-wide, client/server environment serving over 700 users throughout the state over a large-area network. TRIMS is based on an Oracle Windows NT database management system utilizing Intergraph Modular GIS Environment (MGE) and GEOMedia software.

Users have access to a broad range of data including road ownership, right-of-way widths, speed limits, average daily traffic statistics, accident data, road curve, grade, and elevation information in addition to on-line access to the high-resolution digital photolog system. The almost three million 1,300 x 1,000 resolution images from the photolog system are indexed to all TRIMS data. Users can view a section of road and then access any relevant data about that road segment from within TRIMS. In addition, TRIMS provides a management tool for maintenance personnel. As a wide range of inventory data is collected and entered into the system personnel have the ability to spatially query and analyze data of guardrails, signs, sign posts, roadside ditches, mowing acreage, and wildflower plots as examples.

Work Program GIS Application

The Florida Department of Transportation (FDOT) has developed the Work Program GIS Application (WPAGIS) to aid in production of its five-year work program (ESRI, 1997). WPAGIS provides access to and integration of the Work Program Administration (WPA) database, CAD and GIS graphic reference layers, the bridge database, the physical roadway characteristics database, and numerous lookup tables. Users can specify multiple values for any combination of up to thirteen critical work program project variables. For instance, staff can query for all projects that occur in a certain fiscal year, have a construction phase during that year, are in certain counties, are funded by a federal highway fund, occur on the Interstate system, and involve addition of new lanes. WPAGIS is based on ESRI's Arcview and utilizes Oracle to store data replicated daily from the WPA and other databases.

3.3 WVDOT Identified Applications

The WVDOT has developed a list of GIS applications important to the mission of WVDOT. These applications include:

- **Oversize, Overweight Vehicle Routing**
    - Automate truck routing and permitting procedures for oversized shipments
- **Production / Updating of State Travel Map**
    - Allow for updates of State Travel Map and for posting of State Travel Map on internet
- **Highway Bridge Inventory**
    - Locate and display highway bridge data as well as scanned images of the bridges
- **GPS Accident Location**
    - Accident locations captured with GPS would be assigned to a mile point location. Using inventory, traffic, and accident data be able to identify locations with above average number of traffic accidents.
- **Customer Event Tracking**
    - Track calls from customers with information (complaints, accidents, potholes, signage problems, etc.) about the transformation system.
- **Internet Delivery of Road Construction Data**
    - Deliver road construction data on the Internet.
- **Internet Delivery of Winter Road Condition Data**
    - Deliver near real-time road condition data on the Internet based on reports from WVDOT road crews and State Police.
- **Multi-year and Annual Programming System**
    - Assist in multi-year and annual program formulation by providing access to integrated data and map production.
- **Right of Way Project Tracking System**
    - Provide public access to right-of-way information for projects,
- **Geodetic Control Point Query System**
    - Provide location and description of geodetic control points.
- **Highway-Railroad Grade Crossing Inventory**
    - Locate and display highway – railroad crossing data. Include ability to view schematic of crossing linked to photographs to allow user to view grade crossing from several different perspectives as selected from the schematic.
- **State Transportation Improvement Program Maps**
    - Generate maps showing improvement projects by jurisdiction along with the ability to generate reports.
- **Pavement Management System Maps**
    - Display pavement condition by county.

- **Temperature Map**
    - Model average high and low temperature ranges throughout the state to define temperature zones for determining asphalt grade mixtures for roadway construction.
- **Bike Map**
    - Develop possible bike paths based on average daily traffic, shoulder width, and shoulder type data.
- **Corridor Studies**
    - Conduct environmental impact analysis in corridor studies and other miscellaneous studies. Applications will provide integration of assorted environmental and historical/cultural data from both internal and external sources.
- **Traffic Sign inventory**
    - Manage the approximately 250,000 traffic signs on the state highway system
- **Aerial Photography Inventory**
    - Provide an automated inventory and retrieval of aerial photography.
- **Road inventory log**
    - Physical characteristics of State Highway System.
- **Straight-line diagrams**
    - Graphical representation of State Highway System showing fixed points and culture.
- **Road history records**
    - Tracks Commissioner's orders.
- **Traffic counts**
    - Based on date, location and times recorded.
- **Geotechnical data**
    - Such themes as soil analysis, faults, ground water, contours, etc can be viewed as a complete picture.
- **Historical – Environmental data**
    - Data such as: Environmentally sensitive locations, Archeological locations, Historical locations, Wetlands, Wildlife habitat, Farmlands, Parks, Hazardous waste, Land use.
- **Utilities**
    - Such themes as natural gas lines, wells, electric lines, sewer systems, etc.

3.4 State DOT Activities / Issues of Interest

In addition to examining the applications being developed by DOT's it is valuable to examine their recent activities and issues of interest. A summary of a recent survey by American Association of State Highway Transportation Offices (AASHTO) of state DOT's is shown in Table 1 (AASHTO, 2001).

3.5 GIS and CADD Integration

Although computer aided design and drafting (CADD) features are being introduced into GIS software, GIS will not replace (CADD) software as the dominant engineering design tool at DOT's. Instead, the goal is to make data more interchangeable between the two environments. GIS software has the ability to use CADD files as data sources while CADD vendors are adding simple GIS functionality to their software. Third party vendors are also developing software that improves the ability of GIS software to directly work with CADD files. In addition, agencies such as the US Army Corps of Engineers are developing methodologies for insuring their CADD data can be easily integrated with their GIS software (Cedfeldt and Scott, 2000).

Table 1 GIS Activities of Various State Transportation Agencies.

State	Recent Projects/Activities	Issues of Interest
Alabama	An automated oversize/overweight truck routing / permitting system using GEOMEDIA and Superload	
Alaska	Statewide DGPS centerline coordinates Web-based DGPS data access	Data warehousing GIS desktop applications
Arizona	Street centerline update project, business area analysis, ArcIMS, and routing	Asset management Data warehousing
California	System deficiency and project management application Current and future statewide system	Improving topology & its attributes Integrating non-GIS technologies into GIS
Colorado	Transportation corridor studies Engineering level GIS datasets Internet applications - Dial-a-Map	Transportation Internet applications
Delaware	ITMS Implementation Orbital CAD/AVL, Exor Network Manager Conflated Address Ranges on Center Line	Enterprise application integration WEB GIS accessibility
Georgia	1:12,000 statewide basemap layers Developed road division data model Corrected statewide CIR DOQQ's.	State-wide deployments involving multiple state agencies with data sharing strategies.
Idaho	Improved county roads Informal co-op with Boise County Pushing GIS to DOT District offices	Personnel classifications
Illinois	Crash analysis, data verification, project management, winter road conditions and road construction (both internet), and ADT application	Transitioning to ArcView 8 ArcIMS internet/intranet success stories
Indiana	Roll out of new CADD and GIS software Started the realignment of System 1 roads using DOQQ's	Problems with the integration of our CADD and GIS technology
Iowa	LRS development project using NCHRP 20-27 Aerial photo/image cataloging on intranet web page	Long range RTK GPS Applications Development of spatial objects in databases
Kansas	Truck routing information system Construction and Detour Information System. Highway Railroad Grade crossing Inventory Project	DOT use of remotely sensed data
Kentucky	Replace digitized centerline w/GPS Upgrading from "Oracle Highways" to "Highways by Exor"	Transportation internet applications

Louisiana	GeoMedia workspaces on intranet, survey benchmarks, on-line DOQQ Images, and Water Well Locations	Personnel classifications Current basemaps
Maine	Linear referencing synchronization, maintenance management, capitol project management and MDOT Atlas	Eliminating GIS as a separate function
Maryland	Excess state lands, highway needs inventory, surveyed wetlands, signal plans via ARC/IMS/SDE	NSDI core layers: possibilities for 1:2400 scale mapping
Minnesota	Location data server Archeological predictive model	DOT partnerships in regional corridors with GIS data and applications
Mississippi	Pavement management via GIS application P^2- Project "Project" - Web project information MDOT @ Work - Web GIS traffic information	Maintenance management
Missouri	Moved GPS into GIS . Created traffic map using MapPlex	Make use of STATUS codes in order to have history and planned locations on roadway coverage.
Montana	Installation of ArcIMS Photologging state maintained roads	FGDC standards for route naming
Nebraska	Replaced digitized state maintained centerline w/GPS Completed a strategic plan	Asset management Remote sensing applications
New Mexico	Working on a multi-agency internet mapping project	
New York	Capital program viewer State-wide accident location coding	Shared spatial relational data bases
North Carolina	Develop an LRS with attributes for routing Combining county and urban maps Incorporating 2 foot contours into DB	
North Dakota	Dealing with compatibility between CAD & GIS Conversion to Arc 8 products	
Ohio	GIS access to enterprise database, Ramp inventory, statewide DOQQ's statewide GPS Base station cover	GIS/DBase produced straight line diagrams GPS collected center-line issues Over sized/weight routing issues
Oklahoma	Developed the Oklahoma Collision Analysis Tools Developed a new, very accurate, statewide basemap from GPS data	What others are doing with respect to collision analysis and mapping. Intelligent Transportation Systems
Oregon	New GIS project development team Develop applications for environmental issues Pilot of a transportation network of "all" roads	LRS options Transportation impacts and ESA FDGC Framework Layers

Pennsylvania	Intranet activities Line work accuracy LRS Ownership	Printed Maps vs. GIS needs Training
South Carolina	Convert and update digital road center line files provided by county tax mapping, DGPS and DLGs	Standardization in updating route redesignations and LRS information
South Dakota	80,0000+ miles of GPS/GIS roads 137,000+ GPS/GIS point features 3,000,000+ attributes each for above	Intra/Internet mapping applications Asset management Automated routing systems
Tennessee	Expanded statewide LRS data Web enabled DigiLog TNDOT TRIMS thematic mapper	Serving GIS & map data via web. Partnerships for sharing data Oracle Spatial
Texas	IMS applications Imagery warehouse Centerline to roadbed base	Network applications/data deployment RPLS supervision/GIS certification Finding & retaining qualified staff.
Vermont	Weather related road conditions on the Internet using ArcIMS. RFP for a GIS straight line application	Moving GIS to a relational database Versioning of centerline network and corresponding event data.
Virginia	Rollout of enterprise web GIS	Local/state/federal partnerships for data sharing and maintenance
Washington	Transportation framework Real-time road and weather information Environmental applications	UNETRANS Arc 8.x and ArcIMS
Wisconsin	Created a statewide local roads database and Web maintenance system for local governments.	Migration of all GIS data to SDE Web based map creation
Wyoming	Utility/RR DB internet map server Overweight-Load GIS application Bridge inventory internet map server	Standardized road naming conventions - both codes & names

3.6 Findings

- There is a common set of GIS-T applications required by DOT’s and the majority of applications currently being developed are mapping applications providing a graphical view existing tabular data and digital imagery.
- Very few GIS-T applications make use of the spatial analysis tools available in GIS indicating that GIS is still not a mature technology in DOT’s.
- Most of the applications desired by the WVDOT are mapping applications and are similar to applications developed by other states.
- Application development may require extensive data related activities such as development data accuracy requirements, data standards, and metadata.

- GIS will not replace CADD as the dominant engineering design tool although there is increasing interoperability among the software and data.
- WVDOT should develop a presence within the GIS-T community to take advantage of the similarity of the GIS-T needs of state transportation agencies.

4.0 WVDOT SPATIAL DATA

An extensive description of DOH workflow processes is available in the Solutions Requirement Document for the Engineering File and Data Management System prepared by Impact Innovations Government Group. That report combined with numerous interviews provided the necessary information to develop an understanding of the work processes and data flow within the DOH. This section provides a broad overview of the spatial data used by the DOH and describes the flow of data through the DOH.

The DOH manages an extensive amount of data in numerous formats including mainframe databases, digital CADD drawings, local PC based databases, and paper drawings, files, maps, and imagery. This data exists in both documented systems such as the Road Characteristic Database and in undocumented systems developed by DOH personnel. An undocumented system simply implies a lack of corporate knowledge and documentation of the system. For example, spreadsheets and/or databases are often developed to track data for which there is no documented system available. While these databases are useful to their developers, there is a lack of uniformity and availability of these databases across the division.

Data within the DOH is represented as either repository data or linear data. Repository data generally represents data not related to a specific project while linear data represents data associated with a specific project. As a project moves from initiation in Preliminary Engineering to Project Control and then to In-House Roadway, data (and or information) is added to the project along the entire process until to a complete set of Plans, Specifications, and Estimates (PS&E) is produced. Data is frequently extracted from a data repository and associated with a project to become linear data. For example, during project initiation Preliminary Engineering may require data from the Road Characteristics Database. As such, repository data becomes part of the linear data process. Linear data is associated with projects and as such may not be available without reference to a project. For example, core borings data from the Materials Section, Contract Administration Division are referenced by project and are currently only retrievable by such reference. In addition, core borings data are now archived in the Engineering File and Data Management System via document imaging. This repository / linear characterization of the data is not a perfect representation but it does provide a satisfactory framework for discussion about GIS integration.

4.1 Repository Data

Repository data exists in many formats ranging from mainframe and PC databases to paper reports and maps to scanned document imagery. Examples include the mainframe Road Characteristic Database (Road Inventory Log), Straight Line Diagrams, and the County Map series. Repository data comes from both the DOH and associated external agencies. DOH personnel frequently cited limited access and the inability to integrate the data repositories as an important issue that needs to be addressed by any GIS implementation. DOH recognizes that access to the repository data is neither seamless nor transparent to its many users. Examples of repository data are given in **Table 2 -** mainframe databases, Table 3 - desktop applications, and, Table 4 paper documents. Repository data is the predominate data in the DOH and tends to be associated with planning and research and highway operations.

Ownership of repository data is frequently given to a particular unit within DOH. For example, the Roadway Records and Statistics unit is the owner of the Road Characteristic Database. Access to this database is widely available throughout the DOH. Other repository data, however, has limited or restricted availability. The Statewide Accidents Record Database is owned by the Traffic Planning unit and users of that data go through the Traffic Planning unit to gain access to the data. In addition, certain data within the database is restricted and not available to all DOH personnel.

The source of the repository data, the custodian, may not be the same unit as the owner and may even be outside the DOH. The Environmental Section requires National Wetlands Inventory maps to locate wetland sites within possible transportation corridors. Within DOH, the Environmental Section would be the owner of the data although the custodian (source) of the data would be the U.S. Fish and Wildlife Service. Issues of data ownership and data custodianship are in the data stewardship program, see Section 6.2.4.

Table 2 Examples of repository data - mainframe databases.

Data	Description / Comments
Road Characteristic Database (Road Inventory Log)	Physical characteristics of State Highway System. Mainframe flat file database owned by Roadway Records and Statistics, spatial location is by county, route, milepost
Highway Bridge Structure Inventory and Appraisal	Physical description and condition of bridges. Mainframe database, spatial coordinate is by county, route, milepost and/or by latitude / longitude
Maintenance Management System	Mainframe Database
Statewide Accidents Record Database	Information from DMV Accident Report Forms. Mainframe database owned by Traffic Planning, spatial location is by county, route, milepost
Project Tracking System	Provides project programming, scheduling, and status reporting. Mainframe application owned by Project Control Division, spatial location is by latitude / longitude although spatial location currently not populated)
Highway Performance Monitoring System	Owned by Roadway Records and Statistics
Local Name Database	Associates local road name to a route. Mainframe database with data downloaded to Microsoft Excel spreadsheet, owned by Roadway Records and Statistics
Bid Analysis Management System	

Table 3 Examples of repository data – desktop.

Data	Description / Comments
Traffic Volume (Counts)	Manual update of HPMS and Road Inventory Log (most recent year only), owned by Traffic Analysis
Intersection Turning Movements	Excel spreadsheet for each turning movement study (intersection), owned by Traffic Analysis
Vehicle Weights	Owned by Traffic Analysis
Vehicle Types	Owned by Traffic Analysis
Average Daily Traffic	Owned by Traffic Analysis
Traffic Direction	Owned by Traffic Analysis
Pavement Management System	Surface conditions of select segments of State Highway System Excel spreadsheet supplied by contractor in addition to video imaging. Roadway Records and Statistics
Abandoned Roads Database	Owned by Roadway Records and Statistics
Transaction Database	All additions and abandonment of roads, County, route, milepost, change in length (mileage added or abandoned). Excel spreadsheet owned by Roadway Records and Statistics
Orphaned Road Database	Contains same data as Road Inventory Log but for abandoned roads. Access database owned by Roadway Records and Statistics
Road History Database	Tracks Commissioner's orders. Legacy DOS database program - First Choice, owned by Roadway Records and Statistics
CADD drawings	Microstation

Table 4 Examples of repository data – paper.

Data	Description / Comments
Straight Line Diagrams	Graphical representation of State Highway System showing fixed points and culture Bound paper maps owned by Roadway Records and Statistics
Rock Fall Inventory	
County Map Series	Maps of all 55 counties
Flight Line Tracking	Shows flight lines to indicate various regions of state photographs. Paper. Information Management Unit, Administration Section, Engineering Division
USGS Topographical Maps	1:24,000 topographic maps. Paper maps
Aerial Photography	

Table 5 Examples of external data used by DOH.

Data	Description / Comments
USGS topographic maps 1 – 24,000 scale	Paper
FEMA flood plain maps	Paper
National wetlands inventory	Wetland Sites Paper
Historic and archaeological sites	Paper
Threatened and endangered species habitat	Paper
Land ownership	Paper
Cultural Resources	Paper
Intermodal / multi-modal transportation data	Railroads, rivers, and rail infrastructure Paper
U.S. Census data	

4.2 Linear Data

Linear data is considered any data not classified as repository data. Linear data tends to be associated with a specific project and exists mainly at the project level. Linear data tends to be the predominate data in the DOH units associated with highway development. For example, the Traffic Design section of the Traffic (Engineering) Division adds the design and details for signs, guardrails, and pavement marking to the design plans. This data is considered linear data, as it is not stored elsewhere. Although once entered onto a CADD file the data is in a sense now in a repository and may be considered repository data. However, due to the nature of CADD it is relatively inaccessible data in that it is difficult to aggregate the data from multiple projects for analysis.

4.3 External DOH Data

Various units within DOH require data not produced or maintained by the DOH. The Environmental Section of the Engineering Division relies heavily on external data supplied by the WV Department of Environmental Protection (DEP) and the West Virginia Department of Natural Resources (DNR). The Environmental Section personnel interviewed cited rapid access to this external data and the ability to integrate external data with DOH data as a high priority.

4.4 External Data Available to WVDOT

Geographic information is a valuable national resource. It is estimated that approximately 80% of all government information has a geographic or spatial component, so the availability of suitable spatial data lies at the core of any transportation project. The 2002 GIS-Transportation survey reveals that 83% of state transportation agencies participate in geo-spatial data sharing activities with other state agencies or organizations. The ability to share spatial databases utilizing geographic information systems not only reduces data redundancy and inconsistency, thus saving an organization time and money, but also provides users with valuable analytical and visual tools for enhancing transportation studies.

GIS transportation data incorporates multimodal transportation networks and facilities to include roads, trails, railroads, waterways, airports, bridges and tunnels. Ideally, it is collected to a known level of spatial accuracy and currency, properly attributed, documented in accordance with established metadata standards, and accessed through data clearinghouses at little or no cost and free of restrictions on use. Spatial transportation data can then be incorporated into robust, enterprise-wide GIS system that provide road and rail network topology for routing applications and other functions such as indirect location referencing systems for locating features like bridges, signs, pavement conditions, and traffic incidents. To implement a successful geographic information system, WVDOT must *appraise* the current West Virginia Spatial Data Infrastructure, *identify* cost-sharing partnerships to build a suitable digital mapping base, and then *design* a system that *integrates* and *shares* geo-spatial data originating from multiple sources.

The West Virginia GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. The report focuses on the best geographic data available to the statewide geo-spatial community. It provides the status for eight core themes (hydrography, *transportation*, orthoimagery, elevation, cadastral, geodetic control, governmental units, topographic maps) used by most GIS applications and six applications-specific data themes (soils, geology, land cover, critical structures, flood mapping, and economic development). For each framework data theme there is a brief description, mapping status, ultimate mapping goal, and data producer information, including originator(s) of data, resolution, currency, and data availability. **Table 6** depicts the transportation section of the report. **Table 7** lists some of the most common GIS transportation datasets available to WV DOT and the principal advantages and disadvantages of each transportation dataset. Table 8 groups the GIS transportation datasets by common functionality and shows the percentage of each digital product completed for the State. Tax assessor transportation databases may not always have an addressing component.

4.5 Data Flow

The DOH is characterized by two major data flows – a repository data flow and a linear data flow. The repository data flow is associated with the collection, compilation, and dissemination of repository data while the linear data flow is most often associated with the assembly of PS&E packages.

Table 6 West Virginia Transportation Framework Data – June 2002 Status.

TRANSPORTATION
DESCRIPTION
Transportation networks and facilities to include roads, trails, railroads, waterways, airports, bridges and tunnels. Road centerlines should incorporate street address ranges for geocoding applications and a linear referenced system for routing applications.
COORDINATION
Coordination between WV DOT and other transportation data producers in the state are necessary to establish core content standards and business relationships. Through such coordination will foster formal/informal agreements for sharing, creating, and maintaining statewide transportation data.
MAPPING STATUS
Environmental Systems Research Institute (ESRI): ESRI, a geographic information software company, is sponsoring a transportation data model consortium that will enable geographic information system (GIS) users to take greater advantage of ArcGIS 8 and the new geodatabases. http://www.esri.com/news/releases/00_4qtr/unetrans.html
Federal Geographic Data Committee (FGDC): The Ground Transportation Subcommittee (GTS) promotes the coordination of geo-spatial data for ground transportation related activities. The Subcommittee is sponsoring the development of a conceptual data model standard (NSDI Framework Transportation Identification Standard) for identifying road segments as unique geo-spatial features independent of cartographic or analytic representation. http://199.79.179.77/gis/fgdc/
National Park Service (NPS): The Rivers & Trails Program of the National Park Service is in the process of compiling state trails at a nominal scale of 1:100,000. http://wvgis.wvu.edu/data/data.php (search on trails)
U.S. Census Bureau (Census): Harris Corporation has been awarded an eight-year contract, valued in excess of $200 million, by the U.S. Census Bureau for the Master Address File/Topologically Integrated Geographic Encoding and Referencing Accuracy Improvement Project (MAF/TIGERâ AIP). The objectives of this program are to align existing 1:100,000-scale roads, hydrography, railroads, structures, landmarks, pipelines, power lines and other TIGER database features to a much greater locational accuracy (3-meter horizontal accuracy) for all of the nation's 3,232 counties by FY 2008. http://www.census.gov/geo/mod/maftiger.html
U.S. Department of Transportation (US DOT): The Federal Highway Administration (FHWA) is in the process of enhancing the National Highway Planning Network (NHPN), a comprehensive network database of the nation's major highway system. The current 1:100,000-scale geographic database consists of over 400,000 miles of the nation's highways comprised of Rural Arterials, Urban Principal Arterials and all National Highway System routes (http://wwwcf.fhwa.dot.gov/hep10/gis/gis.html). The National Transportation Atlas Data (NTAD) is a set of transportation-related geospatial data for the United States compiled by the Bureau of Transportation Statistics (BTS). The data consist of transportation networks such as the NHPN, transportation facilities, and other spatial data used as geographic reference. http://www.bts.gov/gis/ntatlas/index.html

U.S. Geological Survey (USGS): The USGS partnerships with the WV GIS Technical Center to collect digital vector representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from USGS 1:24,000-scale topographic maps. A USGS unit compiles information from state and local agencies for map revisions. USGS Digital Line Graph (DLG) road attribute data is limited to road classification and federal/state highway route numbers. http://wvgis.wvu.edu/data/data.php (search on roads)

U.S. Forest Service (USFS): The Monongahela National Forest maintains a trail and road geographic database for 3,300 miles of roads (http://wvgis.wvu.edu/data/data.php, search on roads). The spatial databases originated from 1:24,000-scale USFS Cartographic Feature Files and are linked to Oracle INFRA attribute tables which include linear referencing measures for event themes. http://www.fs.fed.us/eng/road_mgt/documents.shtml

WV Department of Transportation (WV DOT): The Division of Highways plans, designs, builds and maintains more than 34,000 miles of state roads. Only paper maps of transportation data are accessible to the public from WVDOT. Refer to http://www.wvdot.com/7_tourists/7d1_availablemaps.htm. The Appalachian Transportation Institute (ATI) at Marshall University and the WV GIS Technical Center at WVU are developing a GIS-Transportation strategic plan for WV DOH. Project Number TRP 99-32 (http://www.marshall.edu/ati/research/projects.htmlx).

Statewide Addressing and Mapping Program: Governor Wise has appointed a Street Addressing and Mapping Board to implement a statewide E-911 mapping project funded by Verizon. The goal is to provide a city-style address for every identifiable structure in the rural areas of West Virginia to improve delivery of emergency services.

DATA PRODUCERS:

DATASET NAME	*ORIGINATOR(S)*	*SCALE*	*MAP UNIT*	*% WV*	*CURRENCY*
TIGER	U.S. Census	1:100,000	County	100	2000
National Transportation Atlas	U.S. DOT	1:100,000	State	100	2001
County Highway Maps (Not Vector)	WV DOT	1:63,500	County	100	Variable
Digital Line Graphs (DLG)	USGS	1:24,000	7.5 Min. Quad	70	1950-1997
Cartographic Feature Files (CFF)	USFS	1:24,000	7.5 Min. Quad	15	1995
E-911 Road Centerlines & Addresses	WV E-911 Council	1:1200 to 1:100,000	County	5(?)	1999-present
Local Road Databases	County/City Govts.	1:1200 to 1:4800	Jurisdiction	?	Variable
New Roads	WV DOT / Contractors	Survey-scale	Planned Route	N/A	Variable
Major Trails	NPS, WV DNR, USFS	GPS to 1:100,000	Jurisdiction	90	Variable

ULTIMATE GOAL: Statewide 1:24,000 or larger scale mapping database of core transportation features.

Table 7 GIS transportation datasets available to WV DOT (sorted by scale).

DATASET	SOURCE	SCALE	PROS	CONS
TIGER/Line	U.S. Census	1:100,000	Attributes Standards Statewide Coverage	Spatial Accuracy
NHPN NTAD	FHWA BTS	1:100,000 1:100,000	Linear Reference System Standards Statewide Coverage	Spatial Accuracy
DLG	USGS	1:24,000	Standards Spatial Accuracy	Attributes Currency Partial Statewide coverage
CFF	USFS	1:24,000	Standards Spatial Accuracy	Attributes National Forest areas only
E-911/ local government	County	1:4800 or larger	Currency Geocoding Spatial Accuracy	No public access to data No uniform standards Partial statewide coverage Road centerlines only

Table 8 GIS transportation datasets by common functionality and percentage completed.

Common Functionality	Originator / Digital Product Name or Project	% WV
Addressing and Mapping (Geocoding)	Census MAF/TIGER Accuracy Improvement Project	0
	WV State Addressing and Mapping Project	0
	County E-911 / Tax Assessor Mapping Projects	8
1:24,000-Scale Topographic Maps	USGS Digital Line Graph (DLG)	70
	USFS Cartographic Feature Files (CFF)	15
Highway Planning Databases	FHWA National Highway Planning Network (NHPN)	100
	WV DOT transportation databases	?

Linear data flow tends to be at the project level, based heavily on computer-aided drafting and design (CADD) technology, and centered within highway development. Repository data flow, on the other hand, tends to be above the project level, based on mainframe databases, and centered within Planning and Research but also associated with various other units within WVDOT.

The repository data flow tends to be associated with data storage and retrieval operations and while data collection is centered in Planning and Research the data is accessed by personnel throughout the DOH. The Road Characteristic Inventory and the Straight Line Diagrams were the two most frequently referenced repository data sources during the interviews. A significant amount of repository data is also available from external sources.

Most GIS applications discussed in Section 3.0 are applications within the repository data flow. Few applications, with the exception of applications in the environmental area, are within the linear data flow. This is due to the dominance of CADD technology within the linear flow process and the generally yet underdeveloped integration of GIS and CADD technologies. The Engineering File and Data Management System Solution Requirements Document describes the linear data flow process through much of the highway development section. The Engineering File and Data Management System (EFDMS) is an attempt by the WVDOT to improve performance / efficiency within the linear data flow by creating an easily accessible and searchable data repository for engineering files and related documents. The relationship between GIS and EFDMS will need to be established once the EFDMS has been fully integrated into the WVDOT.

4.6 Findings

- There is a great need for improved data management and analysis capabilities within the WVDOT. Most administrative units expressed some level of frustration with current information management systems utilized in their daily work processes.
- WVDOT currently operates without GIS and does so reasonably well despite some frustration with the current information management systems.
- DOH data can be classified as either repository data or linear data. Linear data tends to be at the project level, based heavily on CADD software, and centered in Highway Development. Repository data tends to be above the project level, based heavily on database software, and centered in Planning and Research and Highway Operations.
- The roles of the engineering file and data management system (EFDMS) and GIS need to be addressed and their relationship, if any, defined.
- WVDOT should optimize the use of existing geospatial data.

- The West Virginia GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. The report focuses on the best geographic data available to the statewide geo-spatial community.

5.0 ADMINISTRATIVE / ORGANIZATIONAL STRUCTURE OF GIS UNITS

The administrative / organizational structure established to manage the GIS is important to a successful implementation. A study of the GIS implementation efforts of numerous organizations, including several state transportation agencies, found that developing overall and simultaneous efficiency and flexibility within the GIS administrative structure important to a long-term successful implementation (Azad, 1997). It is helpful to examine the two ends that define the continuum of possible administrative structures – the centralized GIS administrative structure and the decentralized GIS administrative structure.

The decentralized approach decentralizes GIS technology and its management by pushing the technology, including the data, applications, programming, and supporting resources, down into the organizational structure. GIS is the responsibility of every operating unit within WVDOT. The operating units are not bound through a centralized GIS administrative unit but through standardized data definitions and data format standards. The central GIS administrative unit, if any, would only ensure the integrity of the data definitions and data format standards. A decentralized approach offers the following advantages (Azad, 1997):

- Rapid implementation – A decentralized GIS structure allows GIS to be implemented quickly in those units having needs that can be easily identified and with GIS applications that are easily implemented.
- Innovative and effective solutions – Individual units within the WVDOT can create innovative and effective GIS applications to address their individual problems without having to wait for the development of a department wide application by the centralized GIS administrative unit. In the decentralized approach, GIS based solutions will be as easily developed as spreadsheet based solutions are currently.
- Short-term economic efficiency – A decentralized GIS can be more easily implemented in phases, therefore controlling the short-term costs associated with implementation.
- Low-level strategic resource – Managers tend to use the resources i.e., people, time, money, or GIS technologies, under their direct control to solve problems. Low-level managers will consider GIS as a resource available to them to solve problems and improve their work processes. There is no centralized administrative unit and its associated bureaucracy to deal with.

Unfortunately, a decentralized administrative structure has several disadvantages:

- Long-term economic inefficiency – A decentralized GIS structure will have greater long-term costs associated with the greater accumulation of technology at lower utilization rates and the duplication of effort to develop GIS-based solutions.
- Poor integration and integrity – Volunteer adherence to formalized standards at the lowest administrative level results in poor data integration and integrity. Data integration is having data

available throughout the organization. Data integrity is simply everyone knowing the exact meaning of a piece of data. For example, an accident location has certain spatial accuracy that must be understood by everyone using that data for analysis.

- Undistributed deployment and development effort – The deployment of GIS throughout the WVDOT, especially at the district level, can be uneven. Districts with personnel with an existing interest in or knowledge of GIS will develop GIS based solutions quicker than those divisions with little interest or no prior knowledge. Ideally, solutions are distributed to other districts. Unfortunately, district managers may see the utilization of their resources for development of GIS based solutions that will benefit other districts to be unfair and begin to hoard GIS resources.
- Short-term focus – The development of GIS applications to support a project may require a length of time that represents a significant fraction of the project timeline. Therefore, project management will see GIS application development as a threat to the short-term bottom line.

The centralized approach accumulates GIS technology and its management, including the data, applications, programming, and supporting resources, within a central GIS administrative unit. This unit may even reside outside the DOH as another division within the WVDOT. Central GIS applications are developed and distributed vertically throughout the organization. This approach places more of the responsibility of the GIS implementation on the leader of the GIS administrative unit.

A centralized approach offers the following advantages:

- Enhanced data integration – Centralized management allows for the development of well-planned databases that offer accessibility and scalability.
- Long-term economic efficiency – Redundant development costs are eliminated by using a core set of GIS applications.
- System flexibility – Applications developed independent of any organizational unit are generally flexible to handle unanticipated demands and new data.
- High-level strategic resource – Allows senior management to focus its time and attention efficiently of the GIS structure of the organization.

Unfortunately, a centralized approach also has several disadvantages:

- High developmental risk – The failure of a centralized GIS implementation can delay GIS usage throughout an organization for many years. A failed GIS application implementation at one level of a decentralized system does not necessarily effect GIS implementation at other units of WVDOT.
- Expense – Centralized implementation requires the commitment of management to supply both significant financial and technical resources to the implementation process.

- Heavy dependence on senior management – Senior management within the centralized GIS administrative unit must be able to anticipate the organizations needs and the data and systems required to meet those needs.
- Politics – A strong relationship between the GIS administrative unit and the rest of the WVDOT must be established. WVDOT personnel must view the centralized GIS unit as a solution source not a problem source. Many personnel interviewed had negative views of the Information Systems section. Similar attitudes towards the GIS unit can be avoided by involving end users in the implementation process.

The centralized and decentralized approaches are at two ends of possible administrative structures. It should be noted that most organizations are not completely centralized or completely decentralized. They may be classified as one or the other based on where they fall on the scale between the two. WVDOT falls closer to a centralized organization. As such, the initial GIS effort would be more of a centralized approach with the appropriate training, firewalls, procedures, etc. As the system grows and gains support, the district offices can take the groundwork and build upon it. This would move the administrative structure closer to a decentralized approach. In the end, it might look more like a hybrid approach.

6.0 GIS TRAINING

Development of both in-depth GIS knowledge (experts) and an operating knowledge (day to day users) is important to the success of GIS implementation. The development of long-term expertise within WVDOT is also necessary to advance the use of GIS within the department. Training will play a key role in the development of this knowledge. Inadequate training is considered one of the most commonly encountered implementation problems (FHWA, 2000).

Currently, WVDOT has no administratively recognized expertise in GIS. Two options are available for acquiring the needed internal GIS expertise: 1) hire trained GIS specialists; and 2) build internal capacity by upgrading the skills of current staff. Both strategies have inherent flaws and provide only limited security to WVDOT in meeting the need for GIS support staff. Many GIS users are self-taught which usually has a very steep learning curve. Investing in the new employee or in education of existing employees is risky too, given the high rates of employee turnover and transfer.

The GIS skills required by WVDOT personnel will vary on how they use the GIS. Many transportation agencies divide their GIS users into three levels of expertise. At the lowest level are people inside and outside WVDOT who will use GIS as an exploratory tool. They require the lowest level of training and for well-designed applications and systems (especially web-based applications) minimal training may be required. The next level of users conducts data analysis outside of specific applications using the spatial analysis function of GIS. These may be engineers at the district level developing GIS solutions to address specific problems within their district. The highest level of users is the application and data developer. These users are typically within the centralized GIS administrative unit and are assigned full-time to GIS duties.

6.1 State Approaches to Training

Most state transportation agencies have not established a formal structured GIS training program for staff but instead rely on ad-hoc training. An informal survey conducted through a GIS-T list serve (gis-t@egroups.com) provided some specific insight into GIS training at several state DOT's.

Massachusetts Highway Department

GIS training is generally through discretionary funding although training can be funded through external GIS projects related to the implementation, development, or enhancement of GIS within the DOT. In 2001, the Massachusetts Highway Department spent $15,000 on external ArcView training for non-GIS staff in addition to internal training of the non-GIS staff by the GIS staff. The seven GIS staff received approximately $15,000 of training from ESRI staffed training courses. Supplementing training is obtained through ESRI Virtual Campus website. (Personal communication, Douglas Carnahan, Data Resources Manager, Massachusetts Highway Department, Planning)

Arizona Department of Transportation

An on-staff authorized ESRI ArcView instructor teaches a minimum of four ArcView courses a year to DOT staff. In addition, one-day ArcView “quick start” courses are offered in combination with one-day application specific training. The DOT expects to expand training for ArcView 8 as GIS staff recently expanded to four full-time and one half-time positions. In addition, a contract was recently awarded for GIS training services to provide for a collection of GIS training consultants including ESRI. Jami Garrison Manager, GIS-T Section (Personal communication, Jami Garrison, Manager, GIS-T Section, Arizona Department of Transportation, Transportation Planning Division)

Iowa Department of Transportation

Normally provide GeoMedia training in-house. A GIS technical expert teaches application specific classes (bridge, pavement, safety analysis, map collection, etc.) to personnel in the respective areas. First half of the class is usually basics on GIS (scales, projections, datums, database, mapping, basic GeoMedia, etc) and the second half teaches them how to use the tools in their workflows. Classes vary from 2-5 days depending on the project and skill sets. For the more complex GIS products, GeoMedia WebMap for example, trainers are brought into the DOT or personnel are sent to vendor courses. (Personal communication, William G. Schuman, GIS Coordinator, Iowa Department of Transportation)

Florida Department of Transportation

Florida Department of Transportation has taken an "enterprise" approach -- the application is fully web enabled (intranet) and has the look and feel of typical windows (intuitive and user-friendly). The user selects the view of interest (enterprise, transit, safety, work program, etc) and loads the data and data themes of interest (point & click). Full metadata and help screens are available. FDOT is a decentralized agency (8 districts and central office). The Geo-Referenced Information Portal supports 7,000 internal users and no "formal" training is required. GIS staff tour all districts once a year to obtain feedback on improvements, comments, additional data to be included, etc. While in the districts a demonstration to the executive staff and to district staff is provided (attendance ranges up to about 25 at executive staff and up to about 200 at district staff). Before adopting the "enterprise" approach in late 1999, training was a nightmare and expensive -- at that time a training consultant was hired to provide training at various locations around the state. (Personal Communication, Mavis R. Georgalis, Manager, Specialized Technology , Florida Department of Transportation)

6.2 Findings

- Training is important to the long-term success of GIS.
- Most state transportation agencies have not established a formal structured GIS training program for staff but instead rely on ad-hoc training.
- A formalized, structured training program should be established and maintained to develop internal GIS expertise at all three levels of required expertise.

7.0 GIS IMPLEMENTATION PLAN

This plan focuses on developing an infrastructure within the WVDOT that will support the implementation and the long-term success of GIS and related technologies. Transportation agencies often focus on identifying strategic GIS applications within their implementation plans. However, because the WVDOT is new to GIS this plan adopts a "learn by doing" process that emphasizes a phased approach to implementation. By adopting a phased approach it is hopeful that a critical mass of GIS expertise will be developed within the department that can guide the implementation process during its more critical later stages of implementation. Because of this phased approach it is important that this plan be under constant review as the implementation process is undertaken and as GIS and related technologies evolve.

7.1 Goals and Success Factors

The implementation of GIS into the WVDOT can be considered successful if the following goals are achieved:

- GIS improves the ability of WVDOT employees to perform their duties
- Data is available seamlessly to all WVDOT employees allowing them to perform data analysis independent of the data's owners / custodians
- Data is continuously maintained to meet the temporal and spatial accuracy standards required by its users
- Data collection procedures allow data to meet the temporal and spatial accuracy standards required by its users

The National Cooperative Highway Research Program and the Federal Highway Administration (FHWA, 2000) have compiled lists of critical success factors for implementation of GIS-T. Among the items listed by these agencies include:

- A GIS "champion" must be identified. The champion will be the technical leader with vision, devotion, and enthusiasm for GIS.
- A GIS "sponsor" must be identified. The sponsor will be a member of upper management who can confront negative institutional inertia and provide managerial support to the champion.
- GIS must be fully integrated with the overall information system strategy and not a stand-alone information system.
- Staff must be developed / recruited with a fundamental understanding of GIS and an understanding of its potential use within the transportation field. This should not be assumed to be staff from the traditional information systems area.
- Staff must be trained to various levels of GIS skills. A core staff well trained at database design, application design, and GIS programming must be developed. A second level of users comfortable at

high-level programming of the GIS is also essential. All other users must be comfortable with using specific GIS applications.

- GIS should be implemented using a phased approach.
- There must be end user participation in the implementation plan.

7.2 First Phase Tasks

Because of the lack of GIS experience within WVDOT and because WVDOT currently operates reasonably well without a GIS, the first phase of the implementation focuses on establishing a GIS administrative infrastructure and developing support and momentum for GIS within WVDOT rather than the development of strategic GIS applications. The implementation plan is based on a "learning by doing" approach therefore the first phase of the implementation process does not address the development of strategic GIS applications. The first phase includes six tasks: two administrative and four technical. They are to:

- Develop / Identify GIS expertise – Section 7.2.1
- Develop administrative / organizational structure for GIS unit – Section 7.2.2
- Select standard set of GIS software tools – Section 7.2.3
- Begin development of transportation base map – Section 7.2.4
- Develop low risk applications – Section 7.2.5
- Develop data and metadata standards – Section 7.2.6
- Develop transportation data warehouse – Section 7.2.7

Two administrative tasks begin the list of initial tasks because they are considered important to overcome institutional inertia and to build upper management support for the implementation process. The completion of these administrative tasks will lead to the development of department policies and procedures that will aid the implementation process.

7.2.1 Develop / Identify GIS Expertise

Justification: The first step of the implementation process is to identify the GIS expertise necessary for the implementation process including the appointment of a GIS coordinator. Technical knowledge in the areas of GIS, database management, networking, and transportation will be required. Currently, WVDOT has no formally recognized GIS expertise within the administrative structure of the organization. This does not imply there are no personnel within the Department that have GIS skills but that those skills are not formally recognized in the administrative structure. The GIS Steering Committee provides management support to the GIS implementation effort but lack in-depth technical knowledge.

Guidance: WVDOT should appoint a GIS coordinator with sufficient GIS expertise to guide the implementation process. The GIS coordinator will have the "GIS champion" role the FHWA considers a critical success factor for successful GIS implementation. WVDOT should establish a GIS advisory committee to support the GIS implementation process and an interagency transportation task force to coordinate data sharing and to implement a transportation framework for the state. WVDOT should be the lead agency in the task force. To staff the advisory committee and the task force WVDOT should request participation from selective members such as county government, Metropolitan Planning Organizations, Planning and Development Councils, Rahall Transportation Institute, State GIS Technical Center, Statewide Addressing and Mapping Board, Monongalia National Forest, Federal Highways Administration, the U.S. Census Bureau, and transportation mapping experts from the private sector.

The GIS advisory committee is a working committee that will support the GIS coordinator in the implementation process. Its role is to provide a replacement for undeveloped internal expertise and its prominence in the implementation process can be reduced as WVDOT develops its internal expertise.

The proposed interagency task force should review technical and business relationships of independently maintained transportation databases at the federal, state, and local levels to determine if these databases are fully capable of transferring attribute and geometric data between corresponding segments in each of the datasets. If an "interoperability scheme" can be incorporated for multiple datasets while retaining the value of existing data investments, then mapping guidelines that support a common transportation framework for the state should be established. This will be a challenging task since no transportation model exists that is compatible with all standards. At a minimum, the task force should:

1. review the Federal Geographic Data Committee's NSDI Framework Transportation Identification Standard as a guide to provide a conceptual data model for identifying unique road segments which are independent of cartographic or analytical network representation;
2. review core content standards and business relationships implemented by other states for sharing data among multiple transportation datasets;
3. identify successful, economical methods for conflating or exchanging geometric and/or attributes between transportation databases;
4. evaluate indirect referencing systems to include linear referencing and geocoding (address matching);
5. identify other data themes that are compatible with transportation datasets; and
6. review mandates and other legislation from states like Minnesota that require local governments to provide road information.

A goal of the GIS implementation should be that WVDOT will eventually take the lead as the central coordinating agency at the state level to act as an "area integrator" and "data steward" to coordinate the integration of multiple, often incompatible transportation databases for West Virginia. The coordinating agency also will conduct the quality control necessary to insure data accuracy and completeness as well as to make the data accessible to government and private agencies.

In addition to the advisory committee and task force, WVDOT should develop a source of expertise to develop several initial GIS applications. Three sources of GIS application development expertise are available to WVDOT: internal expertise, consulting firms, and university research centers. The advantages and disadvantages of each source of expertise are compared in **Table 9**. To support the internal expertise, job classifications have been established for GIS related positions.

Table 9 Advantages and Disadvantages to Various Sources of GIS Expertise

	Advantages	Disadvantages
Internal Expertise	• Maximum control of GIS implementation process • Long-term stability to GIS effort • Could use personnel from other state agencies	• Lengthy period to train existing personnel or to hire new personnel. • Difficult to retain highly qualified individuals
Consultants	• Expedite application development • Access to specialized skills • Leverage consultant's previous experience • Can reduce role as internal expertise develops	• Slows development of internal expertise • Less control over implementation process • Bias toward own GIS system
University Research Center	• Expedite application development • Access to specialized skills • Synergy with center's transportation related research programs • Possible cost-sharing for research activities • Unbiased	• Slows development of internal expertise • Less control over implementation process

7.2.2 Develop an administrative / organizational structure for a GIS unit

Justification: A distinct centralized administrative unit for GIS should be established within WVDOT. Although this task is not considered an essential task for the initial implementation it will distinguish GIS as a separate entity from Information Systems (IS) and give an administrative identity to GIS. Many administrative units expressed dissatisfaction towards Information Systems. Therefore, distinguishing GIS as a separate administrative function from IS may be prudent.

Guidance: The trend is to locate the centralized administrative unit in Information Systems, see **Table 10** (AASHTO, 2002). The increasing importance of database design, the use of more complex database software, and the need to fully integrate GIS into the overall information system strategy may explain this trend. As stated above, GIS should be distinguished from IS even if it is administratively located within Information Systems. The GIS unit should be staffed with personnel having GIS expertise not simply IS expertise. The centralized administrative unit will be responsible for setting department-wide standards and for the development /maintenance of the department-wide strategic GIS applications. GIS activities outside this area should be decentralized to the appropriate units. However, the centralized administrative unit must insure horizontal distribution of GIS technology across the department.

Table 10 Location of GIS Administrative Unit in State DOT's

Location of GIS Unit	Percentage of States Responding
Information Services	34 %
Planning	26 %
Multiple Locations	24 %
No Official GIS Unit	8 %
Engineering	6 %
Mapping / Survey	2 %

7.2.3 Select a standard set of GIS software tools

Justification: A standard set of GIS software tools including any relational database management software must be selected by WVDOT before application development.

Guidance: ESRI and Intergraph are the dominant GIS software vendors used by transportation agencies, Figure 1. Oracle and Access are the dominant relational database management system (RDBMS) software used by transportation agencies, Figure 2. The selection of GIS software should be based on the technical capabilities of software, the compatibility of the software with GIS products from associated organizations, the comfort level with vendor's representatives and technical support, and the cost of software procurement and maintenance. WVDOT should invite both ESRI and Intergraph representatives to discuss their GIS-T products with the GIS advisory committee.

Technical capabilities: Core GIS functions (data capture, data storage, data management, data retrieval, data analysis and data display) differ little among the Intergraph and ESRI product lines. Specialized functions such as dynamic segmentation and web application development may differ

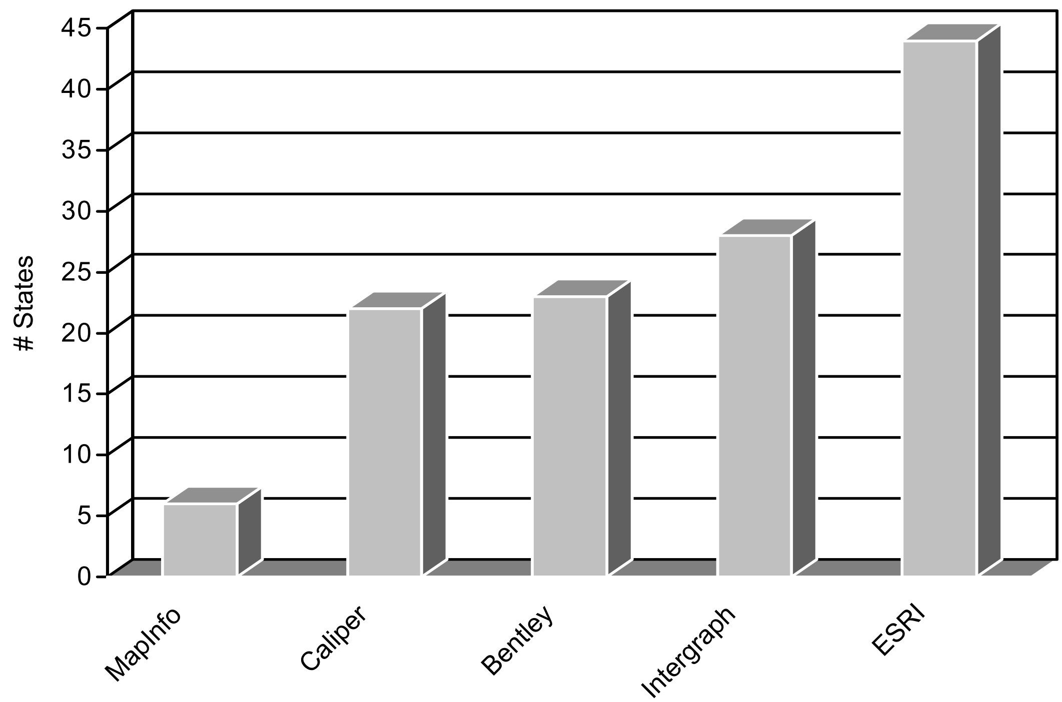

Figure 1 GIS software used by state transportation agencies (AASHTO, 2002)

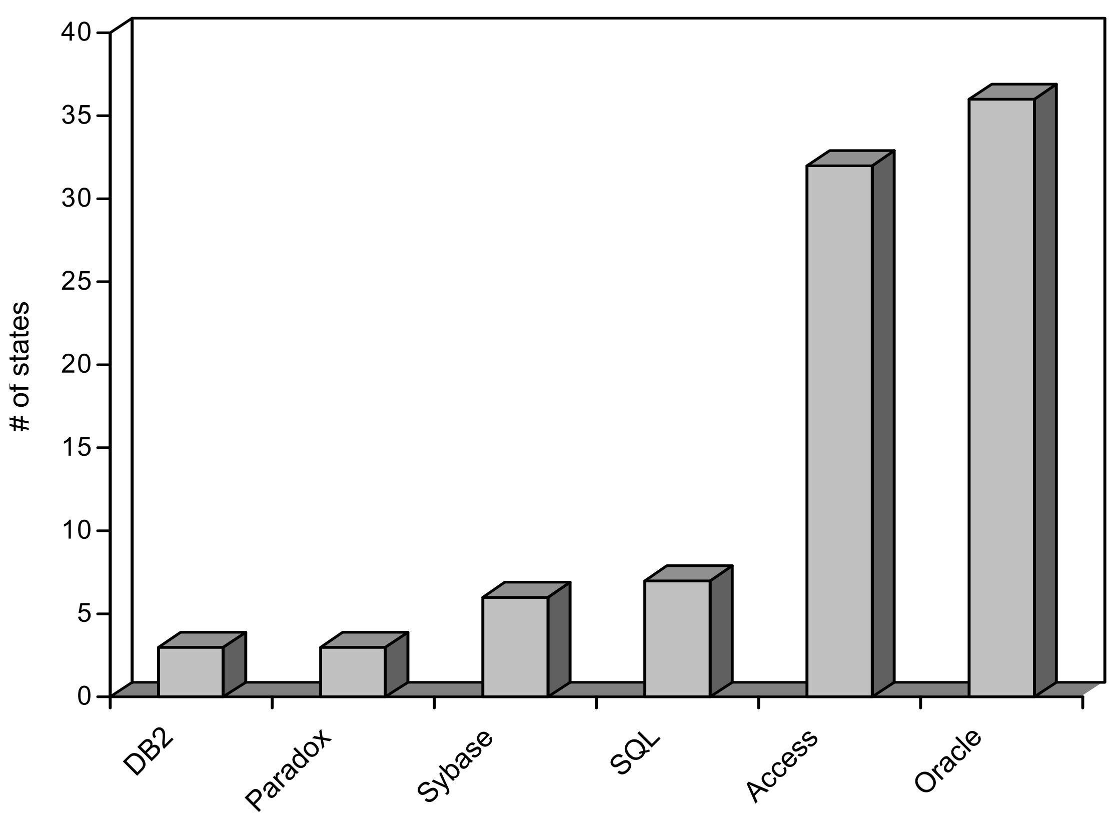

Figure 2 RDBMS software used by state transportation agencies (AASHTO, 2002)

significantly between product lines. However, new versions of software often introduce enhanced capabilities that may temporarily propel one vendor slightly ahead of the other vendor. The technical capabilities of either the Intergraph or the ESRI GIS product line will adequately meet the technical requirements of WVDOT. The technical capabilities of the GIS software are rarely the cause for an unsuccessful implementation.

Compatibility: The West Virginia state government has not established a formal GIS software for state agencies although the ESRI GIS product line is more prevalent in state agencies than the Intergraph.GIS product line. It is important that WVDOT not select the ESRI product line only because of its use by other state agencies. The issue of compatibility should be addressed by the Intergraph and ESRI representatives when they meet with the GIS advisory committee.

7.2.4 Begin Development of Transportation Base Map

Justification: A base map contains fundamental transportation features, geographic features, and location reference information from which thematic maps are produced. WVDOT must identify existing and future digital transportation data to form the "framework" for WV DOT's GIS transportation network and facilities mapping base.

Guidance: The Wyoming DOT base map consists of more than 20 layers of transportation, administrative, reference, and environmental data. The National Spatial Data Infrastructure (NSDI) framework specifies seven geographic data themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information (http://www.fgdc.gov/framework/frameworkintroguide/). Framework data provide a base on which users' data can be overlaid, or a frame to which they can be attached. Framework data are intended to provide basic geographic data in a common form that is readily accessible, so that organizations can devote their efforts to their own applications data and activities. The framework's transportation data include the following major common features of transportation networks and facilities:

- roads - centerlines, feature identification code (using linear referencing systems where available), functional class, name (including route numbers), and street address ranges;
- trails - centerlines, feature identification code (using linear referencing systems where available), name, and type;
- railroads - centerlines, feature identification code (using linear referencing systems where available), and type;
- waterways - centerlines, feature identification code (using linear referencing systems where available), and name;
- airports and ports - feature identification code and name; and

- bridges and tunnels - feature identification code and name.

Transportation base maps are generally produced at 1:24,000 scale making them sufficient for most planning applications, see Table 11. Other applications, such as congestion management, construction management, may require base map accuracy of 1:1200 (1" = 100') or better. Base maps between 1:24,000 to 1:1200 are more accurate than necessary for planning but generally are not accurate enough for detailed project design.

Table 11. Base Map Resolution Reported by State Transportation Agencies (AASHTO, 2001)

Base Map Resolution	Number of States
Unknown	3
Multiple	2
1 – 100,000	4
1 – 24,000	28
1 – 12,000 or better	13

The following briefly describes the process used by the Wyoming DOT to develop a base map (WYDOT, 1996):

1. Determine the data required for the base map to meet present and future needs. The NSDI transportation framework provides a good starting point.
2. Determine the availability of the required data
    1. Compile data dictionary of all available GIS base map data organized by:
        1. Type of data – major or minor
        2. Scale, accuracy, or resolution
        3. Area of coverage
        4. Format – will data require processing prior to use
3. Develop prioritized list for assembling data into a data clearinghouse.
    1. Highest to lowest priority (by major category)
    2. Consider availability of needed formats, scales, accuracy and resolution
    3. Prepare GIS base map clearinghouse by setting up a multi-level library structure and inserting the various GIS base map layers
4. Establish provisions for the obtaining unavailable map data by determining:
    1. Methods of preparing data.
    2. Required accuracy of data and required metadata.
    3. Timeframe to obtain unavailable data.
    4. Costs to obtain data. Factors that may influence production costs are map scale, the type and complexity of the terrain or urban area being mapped, and the level of accuracy required. Cost estimates should be adjusted accordingly. For example, a 1" = 100' map will normally cost about 120 % more than a 1" = 200' map due to the increased amount of information.

WVDOT should consider the following when identifying existing and future digital transportation data to form the "framework" for WV DOT's GIS transportation network and facilities mapping base:

- Establish Data Sharing Partnerships: It would be costly for a single agency to create and maintain a digital, spatially accurate road network base for the entire state. Consequently, the WV DOT should form statewide road data partnerships with other agencies that maintain highly accurate transportation data.
- Avoid Digitizing WV DOT County Highway Paper Maps for use in GIS: Do NOT create a digital mapping base from existing WV DOT general highway reference maps (1:63,500; 1" = 1 mile) because these maps are spatially inaccurate, incompatible with more accurate geographic datasets, and not seamless across sheet and county boundaries.
- Create a New, Highly Accurate Digital Transportation Base: Besides high-resolution digital data (i.e., GPS, engineer surveys) already collected by the WV DOT highway survey crews and its subcontractors, the WV DOT should consider spatially accurate (1) topographic-based and (2) address-based transportation databases as a framework for their digital map base. The WV DOT digital road network base should include ALL public roads for analytical applications and linear referencing systems.

7.2.5 Develop low risk applications

Justification: The development of the low risk applications will build end-user participation in the implementation plan, develop buy-in to the GIS implementation plan, demonstrate GIS web applications, and produce a GIS based applications for the general public to demonstrate WVDOT's GIS technology. The applications recommended are:

- highway bridge inventory system,
- road inventory log system,
- Internet delivery of road construction data,
- Internet delivery of weather-related road conditions
- environmental impact route planner.

The "learn by doing" approach adopted for the implementation plan favors the initial development of low risk applications as opposed to the development of strategic applications. The failure of one of these low risk applications will not be fatal to the implementation process. These applications also have manageable data requirements.

Guidance: Each application was selected for a specific purpose. The Internet delivery of road construction data and weather-related road conditions applications will familiarize WVDOT with the development of GIS internet applications and provide a product WVDOT can market to the public. The data requirements for these projects are minimal since WVDOT currently supplies of road construction data and weather related road conditions on its website in tabular format.

The highway bridge inventory system application will build end user support for the GIS implementation process at the district level. Initial discussions on the scope of this application have been conducted with District 2 personnel.

The road inventory log system will build end user support for the GIS implementation process at the state level.

The environmental impact route planner application was selected as an engineering GIS application. For highway development, GIS is commonly used early in the design process to examine the impact of highway construction on environmental, cultural, and historical sites. This application will provide the engineer with access to the most pertinent transportation, environmental, cultural, and historical data required for the environmental analysis. The North Carolina Department of transportation (NCDOT) developed a GIS system for use in its phased environmental approach in the planning process. GIS was used to address major environmental issues early in the planning process to identify and gain consensus on the most environmentally-acceptable corridor for each improvement in the transportation system.

The scope and functionality of these applications have not been yet fully developed for this report. Frequent interaction between the application developer and the application users will be critical to creating the best application possible. Application developers need to understand what the users do in their daily tasks and the application users need to learn about GIS and how it can help them do their job better.

7.2.6 Develop Data and Metadata Standards

Justification: A data stewardship program is needed to protect the investment WVDOT will make in spatial data and to make optimum use of existing geospatial data.

Guidance: Much of the information for this section is taken from Florida Department of Transportation guidelines for creating a data stewardship program (FDOT, 1999). Florida is developing a statewide data stewardship program encompassing many state agencies including the FDOT. The goals of the Florida data stewardship program are to:

- Eliminate duplicate data acquisition efforts
- Encourage data sharing across functional and organizational boundaries;

- Foster coordination including joint ventures between departments; and
- Increase confidence in the state's digital geospatial data by maintaining high data integrity.

The FDOT Data Stewardship program is not directly applicable to WVDOT because of the statewide administrative structure Florida established to "develop solutions, policies, and standards to increase the value, usefulness and reliability of geographic information for Florida (FDOT, 1999)." However, the general approach and concepts are still applicable. Data stewardship addresses many issues including:

- Adherence to metadata standards and documentation
  - Metadata is literally data about the data. It should describe all aspects of the data (what is it, how it was captured, who is the source, limitations). Metadata provides confidence in the data and allows outside organizations to make proper judgments on its usage. Guidance on metadata can be found in the Content Standard for Digital Geospatial Metadata produced by the Federal Geographic Data Committee. Metadata collection will maintain an organization's internal investment in geospatial data, provide information about an organization's data holdings to external agencies and provide information needed to process and interpret data to be received through a transfer from an external agency.
- Data quality analysis
  - Describe the procedures followed by the data provider to guarantee its data is of the highest quality.
- Data security specifications
  - Determine limitations placed on the distribution of data. Some data may be limited to only certain organizational units within WVDOT or only for WVDOT and not for public distribution.
- Data retention criteria
  - How long should data be retained before archiving? How should the data be archived? What data should be archived? Should the data be stored on-line or off-line in a secure location
- Updating procedures
  - Procedures should be developed defining roles and responsibilities, policies and practices and how often the data is updated.
- Liability issues
  - External organizations may make business decisions based on WVDOT data made available to the public as a result of the GIS implementation. WVDOT should

establish clear responses to any potential liability concerns before releasing any GIS data to the public. Providing a disclaimer with the data and the associated metadata may be an option.

7.3 Second Phase Tasks

While the first phase of the implementation plan focused on the administrative infrastructure and building support and momentum for GIS the second phase focuses on developing the foundation of the GIS. The second phase tasks tend to address long-term issues. Many of these issues, such as the GIS data model, have not achieved a consensus resolution within the GIS-T field. The second phase tasks are to:

- Develop list of new GIS applications for development – Section 7.3.1
- Identify and develop strategic applications – Section 7.3.2
- Develop a GIS Data Sharing Architecture – Section 7.3.3
- Develop a Linear Reference System – Section 7.3.4

These tasks are significantly more complex and require significant knowledge and expertise in GIS and database management systems.

7.3.1 Develop a list of new GIS applications for development

Justification: As GIS becomes incorporated into WVDOT and its benefits to the work process realized new GIS applications should be sought from the various administrative units.

Guidance: The first phase ”low risk” applications should encourage many personnel to consider how GIS may be incorporated into their work processes. WVDOT should consider holding demonstration sessions to educate personnel on the capabilities of GIS. These GIS applications will tend to be less complex than the strategic applications discussed in Section 7.3.2. These applications should address data access issues in workflow processes by providing access to previously unavailable data or by reducing the difficulty in accessing data. These applications will ingrain GIS technology into the everyday work process of the WVDOT employee.

7.3.2 Identify and Develop Strategic Applications

Justification: Strategic applications address access to department wide data needs and will provide the greatest benefit to the WVDOT.

Guidance: Strategic, or high priority, applications tend to be in the areas of safety management, congestion management, project management, roadway management, and bridge management. Asset management, in general, is becoming a strategic GIS application due to Government Accounting Standard

Board (GASB) Statement No. 34, which mandates transportation, and transit agencies increase accountability in financial reporting and decision-making.

WVDOT should focus on the development of two strategic applications - roadway management including improving access to the Road Characteristic Inventory Database, and maintenance management. The maintenance management application can also provide valuable asset management information. The development of the maintenance management system may require research into methods to best collect the spatial and attribute data required for the application.

7.3.3 Develop a GIS Data Sharing Architecture

Justification: The development of the data sharing architecture is necessary to integrate the various data management systems within WVDOT. Many transportation agencies are using Oracle as their database management system, Figure 2.

Guidance: The advantages of using a database management system as a central repository for spatial data include (ESRI, 2000):

- Easier integration of spatial data with other core organizational data
- Expanded database size limits
- Support for the larger number of users required for enterprise implementations
- Ability to take advantage of enhanced DBMS features such as administration and maintenance utilities, replication, and faster backup and recovery
- Ability to publish and distribute spatial data over intranets and the internet

Two approaches to data sharing available to the WVDOT are the enterprise approach and the data warehouse approach. The enterprise approach combines all corporate databases into a single, central relational database management system. Some transportation agencies have decided against translating the large volume of existing data into a common data format under a single database management system. The replacement of extensive legacy systems to maintain and query the data often is a cost and/or effort prohibitive process. The data warehouse approach permits data to reside in its existing data management system for maintenance but provides a new central database management system for GIS applications. A conceptual view of the Iowa DOT data warehouse (Schuman *et al.*, 1998) is shown in Figure 3.

The data warehouse is a repository built from distributed and often departmentally isolated data. The data is maintained in the legacy systems but is shared with the data warehouse. The data warehouse can provide near real-time data to the GIS depending on the user needs and update cycles from the legacy systems. Data initially selected to reside in the data warehouse may be based on usage rates or the ease by which the data can be made available to the GIS users.

.

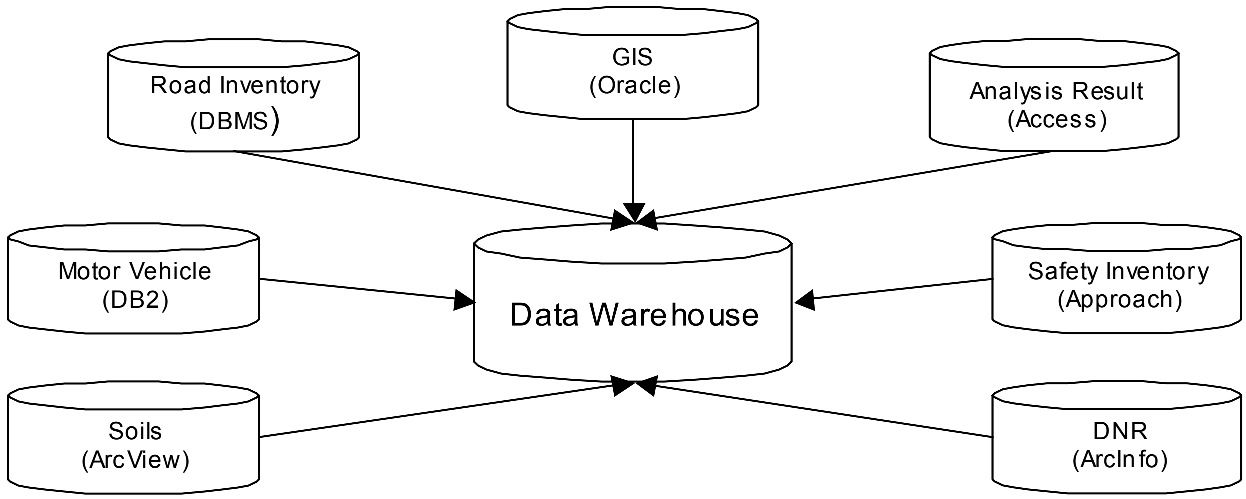

Figure 3 Conceptual representation of data warehouse approach to data sharing.

7.3.4 Develop Linear Referencing System

Justification: WVDOT's current linear referencing system supports a single linear referencing method – county, route, and milepost. Future needs will require a linear referencing system that can support multiple linear referencing methods, such as street name and address and global positioning system (GPS) measurements, in addition to temporal (historical) changes in the road network.

Guidance: A linear reference system (LRS) locates transportation features within a two-dimensional planar surface, a map, using a single coordinate. A LRS is necessary since even when both a highly accurate base map and planar coordinates (i.e. a GPS measurement) are used there is no guarantee the point, perhaps a bridge location, will fall on the transportation network. There is discussion within the GIS-T community that with the trend towards inexpensive, simple, and more accurate global positioning system (GPS) data collection and navigation tools that LRS may no longer be required. However, for the foreseeable future a LRS will be required.

The highway performance monitoring system (HPMS) requires states to maintain a LRS meeting requirements given in the HPMS Field Manual (FHWA, 1993). The Federal Geographic Data Committee under the National Spatial Data Infrastructure (NSDI) initiative has encouraged states to adopt a more standardized LRS that may ease the eventual transition to a national LRS (FGDC, 1994). Adams *et al.*

(2000) have developed functional requirements for a comprehensive spatial / temporal location referencing system that has been used by the Iowa DOT for the development of its LRS. The Pennsylvania Department of Transportation (PennDOT) has developed plans for a enterprise location referencing system (PennDOT, 2001).

Location referencing systems, of which a linear reference system is a subset, will be required to handle several different linear reference methods. Linear reference methods that may be used within a transportation agency include:

- Reference posts (milepost)
- Milepoint
- Base Record Segmental
- Stationing
- Literal Description
- GPS-Route
- Cartesian-Route
- Link-Node
- Street Addresses (discrete locations)
- Street Address Ranges (block address ranges that interpolate locations)

7.4 Timeline for Implementation Plan

There is no established timeline for the implementation process. In many ways the GIS implementation process is continuous with new applications and enhancements being added to the system. Many state transportation agencies are well beyond ten years of effort in the implementation process. One benefit of WVDOT not investing in GIS until now is that WVDOT can make significantly greater progress in their GIS program in similar time period compared to the progress made by states investing in GIS just ten years ago.

7.5 Cost of Implementation Plan

Development of costs associated with the GIS implementation process was not included within the scope of this project. Accurate data on implementation costs are difficult to obtain due to the evolutionary nature of GIS implementation at many transportation agencies. Determining the financial benefits of GIS implementation is even more difficult. It is frequently been stated that the costs of GIS implementation are front loaded while the benefits are back loaded. That is WVDOT will spend lots of money before realizing the savings. Although implementation costs were difficult to find Table 12 shows the annual budget for GIS activities at several state transportation agencies.

Table 12 Annual Budget for GIS (AASHTO, 2002)

	< $100K	$100K to $500K	$500K to $1 million	> $1 million
1996	2	13	4	1
1998	2	7	3	3
2000	4	16	7	5
2002	2	10	9	15

8.0 REFERENCE

Adams, Teresa M., Nicholas Koncz, and Alan P. Vonderohe. 2000. Functional Requirements for a Comprehensive Transportation Location Referencing System. Proceedings of the North American Travel Monitoring Exhibition and Conference

Azad, Bijan. 1997. High and Low Roads to GIS Development. 1997 CGIS Conference. (need rest of reference)

Butler, J.Allison and Kenneth J. Dueker. 2000. A Primer on GIS-T Databases. Center for Urban Studies, Portland State University. Portland. Oregon.

Cedfeldt, Paul T. and Mark A. Scott. 2000. Integrating CAD Data with Geographic Information Systems Using AutoCAD and ARC/INFO Software. US Army Corps of Engineers. ERDC/CRREL TR-00-1.

ESRI, 1998. Spatial Data Warehousing, An ESRI White Paper.

ESRI, 2000. ESRI and Oracle-Solutions for GIS and Spatial Data Management, An ESRI White Paper.

Federal Interagency Coordinating Committee Technology Working Group. 1988. A Process for evaluating Geographic Information Systems. *Technical Report 1* U.S. Geological Survey Open-File Report 88-105 (1200).

Federal Geographic Data Committee (Ground Transportation Subcommittee): NSDI Positions and Recommendations on Linear Referencing Systems. Washington, D.C., 1994.

Federal Highway Administration. 1993. Highway Performance Monitoring System (HPMS) Field Manual. U.S. Department of Transportation. Available on-line at: http://www.fhwa.dot.gov/legsregs/directives/orders/m56001b.htm

Federal Highway Administration. 2000. Geographic Information Systems - FHWA Eastern Resource Center Resource Packet.

Florida Department of Transportation (FDOT). 1999. Enterprise Information System Data Coordination and Integration: Guidelines for Creating a GIS Data Stewardship Program at the Florida Department of Transportation. Draft – November 16, 1999.

Ledet, Timothy and Alicia Cignatta. 2002. GIS in the Trenches: DELDOT's Corridor Capacity Preservation Program. Downloaded on February 4, 2002 from: http://www.esri.com/library/userconf/proc00/professional/papers/PAP482/p482.htm

Pennsylvania Department of Transportation (PennDOT). 2001. Enterprise LRS Executive Summary White Paper. Prepared by GeoDecisions and Bureau of Planning and Research, Geographic Information Division, Penn DOT.

Schumann, William G. Tim Strauss, Dan Gieseman, and Reginad Souleyrette. 1998. Iowa Department of Transportation Statewide Coordinated GIS. 1998 Transportation Conference Proceedings.

Trip (The Road Information Program). 2001., West Virginia's Road And Bridge System: Pavement Conditions, Travel Trends And Funding Needs.

Wagner, Mary Jo. 2001. Tennessee DOT: Streamlines Roadway Management. GEOWorld, August 2001.

WYDOT. 1996. Recommendations of the Wyoming Geographic Information Advisory Council's Base Map Planning Committee (Final Report), October 25, 1996, Prepared by: The Wyoming Geographic Information Advisory Council Base Map Planning Committee. Available on-line at: http://wgiac.state.wy.us/wgiac/reports/breport/