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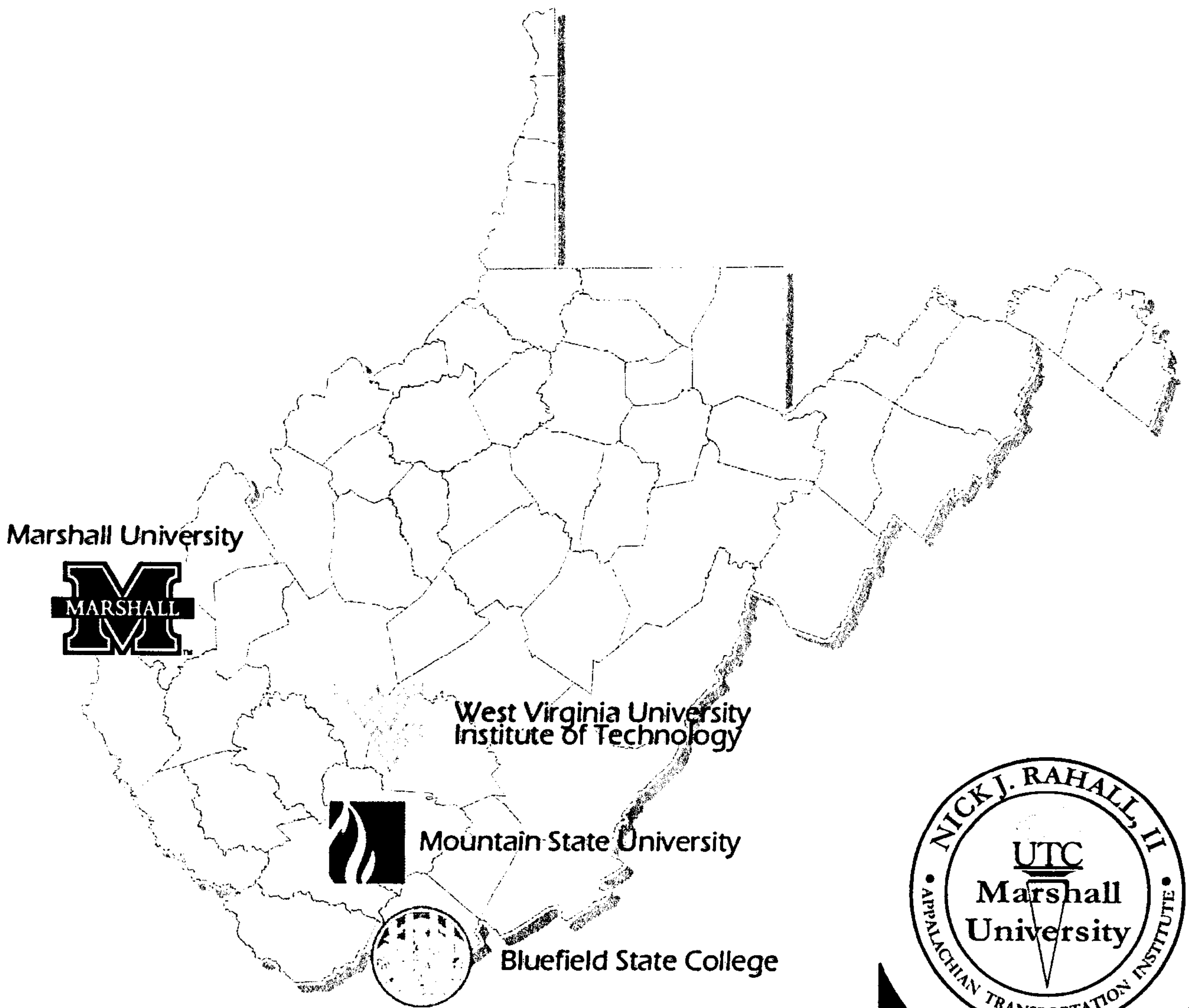
GIS Implementation Strategy for WVDOT
TRP 99-32



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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.

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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.

Training is important 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.

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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

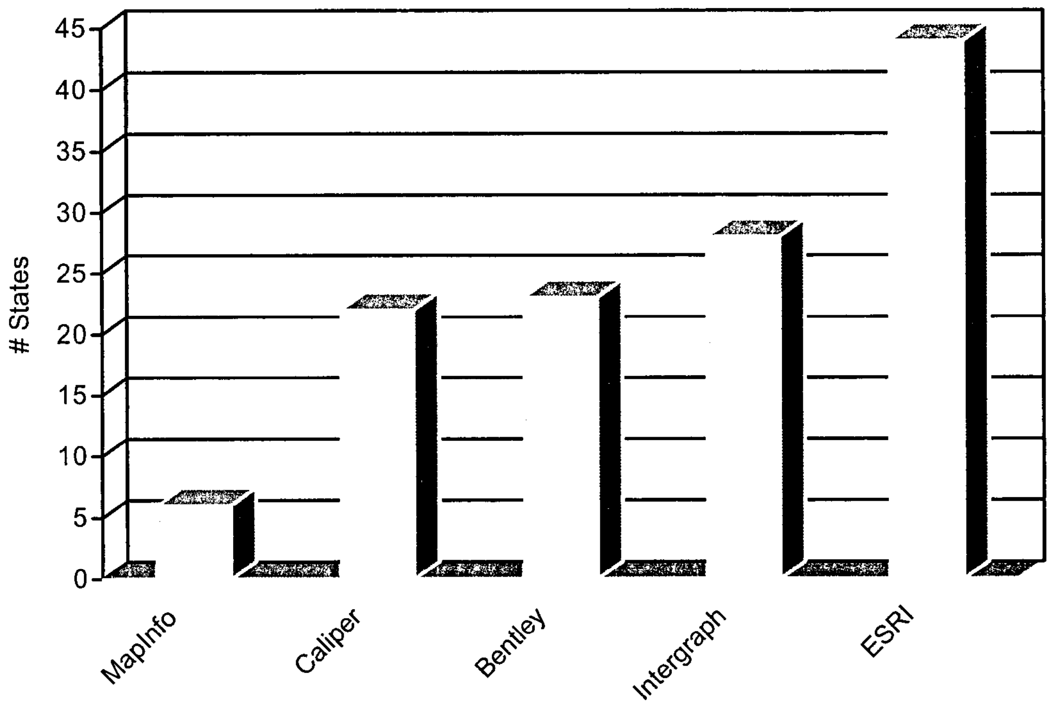

Figure 1 GIS software used by state transportation agencies (AASHTO, 2002)

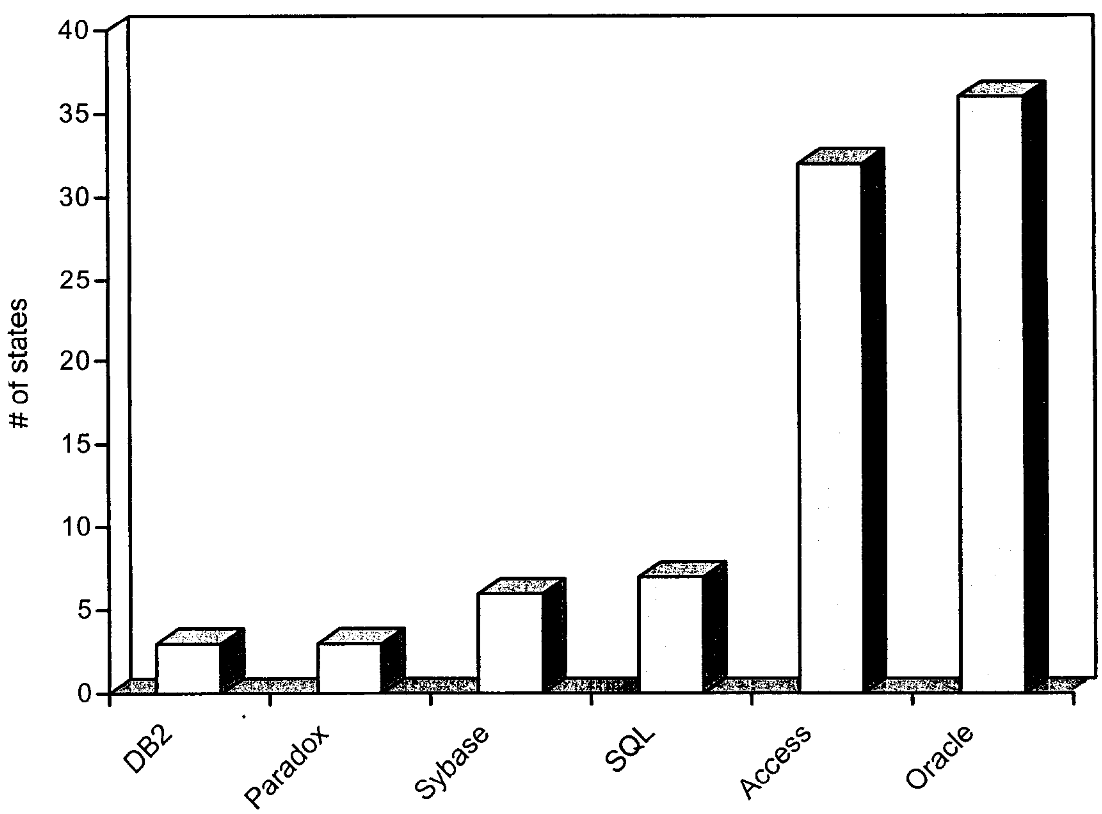

Figure 2 RDBMS software used by state transportation agencies (AASHTO, 2002)

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.

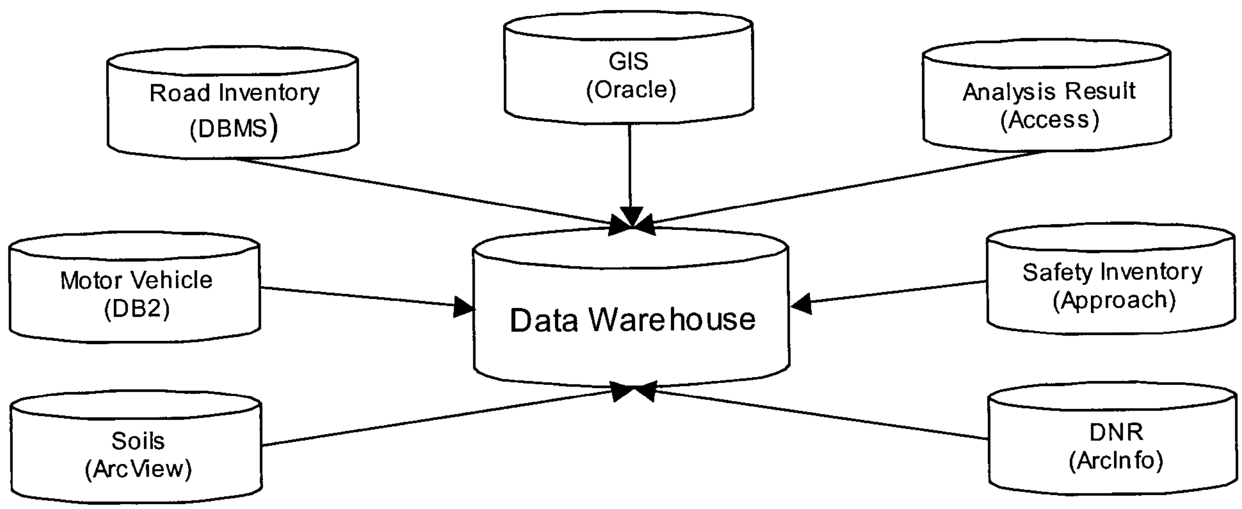

Figure 3 Conceptual representation of data warehouse approach to data sharing.

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

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Appendix A

West Virginia GIS Technical Center

West Virginia University

Department of Geology and Geography · Eberly College of Arts and Sciences

WV DOT GIS Implementation Study – August 2002 Report

In cooperation with Rahall Transportation Institute, Marshall University, this preliminary study identifies steps that should be undertaken by the West Virginia Department of Transportation (WV DOT) to implement geographic information system (GIS) technologies. As part of this strategic implementation plan, the WV GIS Technical Center focused on accessible, accurate geo-spatial information available to transportation decision-makers. A demonstration project created a GIS county highway map using the best available digital data and extended the value of the cartographic map with spatial analysis of a proposed expressway. It is hoped that the data development and coordination issues discussed in this report will encourage WV DOT to utilize existing spatial data to create a digital mapping base rather than digitize cartographic features from their paper county highway map series.

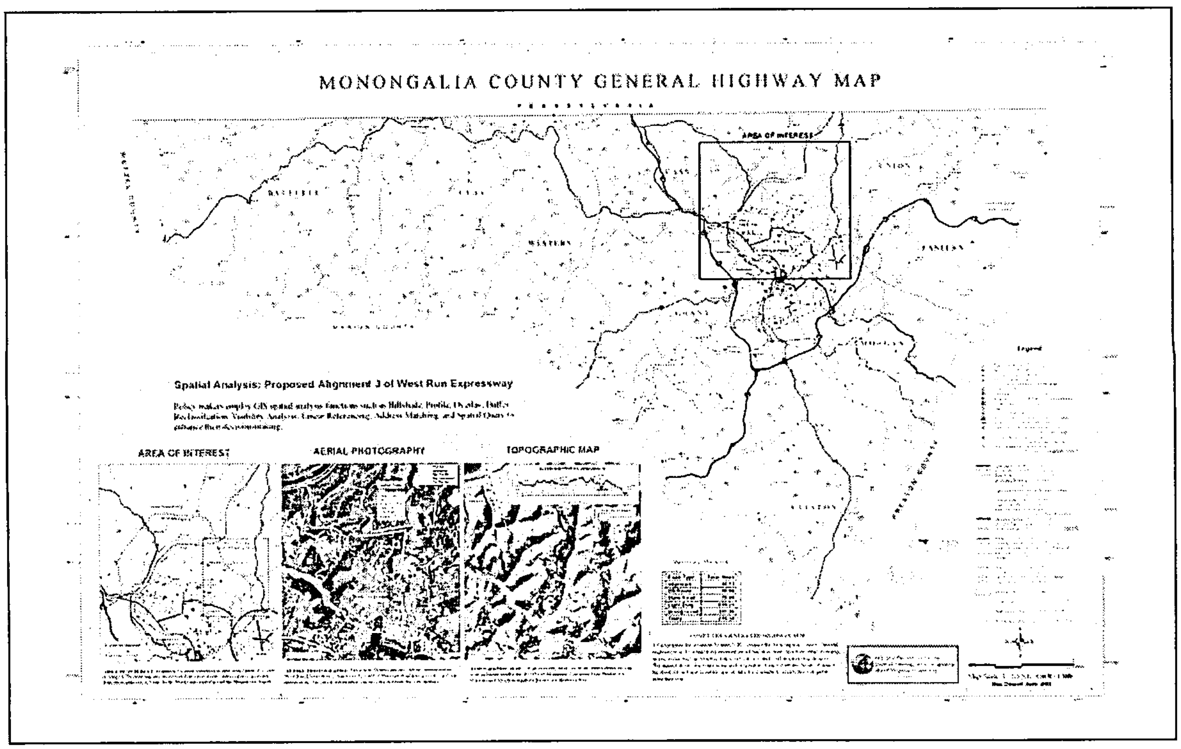

Figure 1: Main Map: GIS computer-generated general highway map for Monongalia County, West Virginia. Inset maps: Spatial analysis of proposed West Run Expressway (Alignment 3).

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I. INTRODUCTION

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 DOTs participate in geo-spatial data sharing activities with other state agencies or organizations (Appendix E). The ability to share spatial databases utilizing geographic information systems (GIS) 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. To demonstrate this concept, georeferenced highway data and other thematic layers were integrated to create a computer-generated highway map (Figure 1) similar to the current WV Department of Transportation's Monongalia County General Highway paper map. In addition to generating an electronic highway county map, spatial analysis was done for Alignment 3 of the West Run Expressway, a new road proposed north of Morgantown in Monongalia County, WV.

II. GIS TRANSPORTATION FRAMEWORK DATA

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, WV DOT 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.

SPATIAL DATA INFRASTRUCTURE

The National Spatial Data Infrastructure (NSDI) encompasses policies, standards, and procedures for organizations to cooperatively produce and share the "best" available geographic data throughout all levels of government, the private and non-profit sectors, and the academic community. One of the core "framework" layers identified by the Federal Geographic Data Committee is transportation, since a map or GIS application almost always incorporates some type of road information. Transportation and other commonly used framework data form the backbone of both the West Virginia and National Spatial Data Infrastructures.

The State GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. This 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 1 depicts the transportation section of the report.

DIGITAL TRANSPORTATION BASE

A digital transportation base serves as the critical foundation for which linear referencing systems and GIS applications are built upon. Therefore, the positional accuracy, currency, completeness, and availability of data are important factors in determining the best transportation base. Both national and state level base mapping viewpoints are discussed below.

National Perspective: Most federal transportation databases adhere to national standards and are accessible to the public (Table 2). In the past, transportation data was produced at the national level and disseminated to state and local government. Now federal agencies such as the U.S. Geological Survey, U.S. Census Bureau, and Federal Highway Administration are implementing programs to incorporate state and local transportation databases of suitable spatial and temporal scale into their national databases. Recently the Geography Division, U.S. Census Bureau, entered into several long-term contracts and partnerships in order to improve the accuracy of the information in its Master Address File (MAF) and associated Topologically Integrated Geographic Encoding and Referencing (TIGER) database. In June 2002 the Census Bureau awarded Harris Corporation an eight-year contract, valued in excess of $200 million, for the Master Address File/Topologically Integrated Geographic Encoding and Referencing Accuracy Improvement Project (MAF/TIGER AIP). The Master Address File (MAF)/TIGER Accuracy Improvement Project will create a complete and current list of all addresses and locations where people live and work. The Census modernization program also will update the TIGER digital database transportation features previously collected at 80-meter accuracy to a much greater spatial accuracy of 3 meters for the entire nation by FY 2008. Likewise, the Federal Highway Administration (FHWA) is incorporating higher resolution data with its existing 1:100,000-scale National Highway Planning Network (NHPN). In addition, national mapping initiatives (Appendix G) like the The National Map and Geospatial One-Stop propose to establish a seamless, continuously maintained, high-resolution transportation mapping database for the nation.

Other State DOT Perspective: Over 95% of the state DOTs have some operational GIS capability (Figure 3), and recent trends show that 89% of state highway departments now use a base mapping scale of 1:24,000-scale or better (Figure 4; Appendix E). State DOTs and their business partners have identified the need for higher spatial resolution transportation data for their mapping and analytical applications and thus are in the process of upgrading their mapping databases to a scale of 1:24,000 (1 inch = 2000 feet) or larger (Appendix F). Until a few years ago, most state DOTs built their digital transportation databases from 1:24,000-scale USGS topographic maps, but now the 1:24,000-scale standard (+/- 40 feet accuracy) is being superceded with geographic data collected from detailed photography or from Global Positioning System (GPS) centerlines (< 2 meter accuracy). State DOTs such as Pennsylvania, New Jersey, and North Carolina are using aerial photography, collected at mapping scales of 1:12,000 or larger, to revise their topographic-based linear transportation features, while Kentucky is implementing an accuracy improvement program utilizing GPS (Appendix F).

WV DOT Perspective: WV DOT should follow the national trend of building comprehensive, statewide transportation databases with more accurate spatial data. In addition to high-resolution digital data (i.e., GPS, engineer surveys) collected by the WV DOT highway survey crews and its subcontractors, the WV DOT should consider both (1) topographic-based and (2) address-based transportation databases as a framework for its digital map base (Table 3). Two *topographic-based* transportation databases, U.S. Geological Survey Digital Line Graphs (DLG) and U.S. Forest Service Cartographic Feature Files (CFF), are very similar geometrically in that they are digital representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from 1:24,000-scale topographic maps. At present, digital transportation features from 1:24,000-scale topographic maps are available for 85% of the state from the WV GIS Technical Center. The WV GIS Technical Center may complete the remaining 15% topographic-based, digital transportation files by summer 2003.

To access highly accurate road centerline data, consideration should be given to incorporating *address-based* transportation databases currently being developed in West Virginia. E-911/local government transportation datasets usually are more current and spatially accurate than other transportation databases, although each county has unique mapping standards and data sharing agreements. Often the local assessor and E-911 director do not collaborate or cost-share but produce independent transportation databases. Another barrier is that county governments may not release their transportation databases without cost-sharing agreements to recover data development and maintenance costs. With the advent of new mapping programs, the address-based transportation databases in West Virginia could become more uniform and accessible. To improve the delivery of emergency services in the state, the Legislature in 2001 established a Statewide Addressing and Mapping Board to provide city-style addresses for every identifiable structure in the rural areas of West Virginia. The board has formed a $15 million partnership with Verizon to map the state and create E-911 addresses. Another program already mentioned, the Census Bureaus' Master Address File (MAF)/TIGER Accuracy Improvement Project, will also make current transportation addressing and mapping databases more spatially accurate. Although specific details regarding the data collection and coverage extent have not been released, these two important programs could lead to a single, uniform addressing and mapping transportation database for the state.

DATA INTEGRATION AND SHARABILITY

Presently there is no single agency that *integrates* all transportation information nationwide, nor likely will there ever be one. In most states, including West Virginia, transportation data is developed and maintained at different spatial and temporal accuracies by federal, state and local entities to support their existing business requirements for information, reporting, and management of their road network system. As more accurate transportation data becomes available, it is very challenging to integrate transportation data of different positional accuracies (Figure 2), detail, coverage, and currency, while retaining the value of existing data investments.

Geographic data must not only be available and in a seamless, consistent format, but it must be adequately attributed and *sharable* with other computer systems. Because over 84% of state DOTs use more than one software product for their GIS applications, with ESRI GIS the most popular, followed by Intergraph/Microstation and TransCad, transportation databases must be properly designed to exchange attribute information. At the North Carolina DOT, for example, the Mapping Section uses Microstation software to develop and maintain digital county, urban, and state travel maps; while the GIS Programming & Analysis Section uses ESRI ArcGIS software to create specialized analytical map products. So information could be easily shared accross different software platforms, the North Carolina DOT GIS Unit implemented an appropriate database design along with a set of conversion programs.

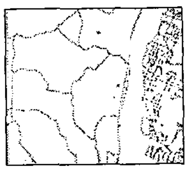
Unfortunately, some state highway computer mapping systems are like "islands" of technology because these systems cannot share information, either "horizontally" across DOT databases or "vertically" with other federal, state, and local government transportation databases. One reason for multiple, disparate transportation mapping systems is that no universal spatial data model exists for sharing information among organizations. To overcome this problem, the federal government and some states are developing core data standards. The federal government is developing a conceptual spatial identification standard (Appendix H) while some states like Kentucky and Utah already have developed core consensus data standards (Appendices F).

COST-SHARING

Although integrating and sharing transportation data is challenging, this should not prevent WV DOT from utilizing existing digital transportation data, especially road centerline geometry, as it is very expensive to create a fully developed digital road network system. To date, federal, state, regional and local governments have invested millions of dollars in *cost-sharing* programs to create digital transportation data for West Virginia. The U.S. Geological Survey, U.S. Forest Service, and the state have contracted 2.5 million dollars to collect and maintain topographic-based transportation databases for West Virginia. It is estimated the WV E-911 agencies and county tax assessors of West Virginia counties have spent 4 million dollars to develop local transportation databases. In the immediate future both the U.S. Census ($200 million) and Verizon ($15 million) will allocate 215 million to fund address-based transportation databases in West Virginia.

Table 1: WV 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:

1) **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

2) **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/

3) **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)

4) **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/TIGER 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

5) **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

6) **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)

7) **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

8) **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).

9) **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.

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 2: GIS transportation datasets available to WV DOT (sorted by scale). The table lists some of the most common GIS transportation datasets available to WV DOT and the principal advantages and disadvantages of each transportation dataset.

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)	71
	USFS Cartographic Feature Files (CFF)	15
Highway Planning Databases	FHWA National Highway Planning Network (NHPN)	100
	WV DOT transportation databases	?

Table 3: GIS transportation datasets grouped by common functionality and percentage of digital product completed for State. Tax assessor transportation databases may not always have an addressing component.

III. PAPER VERSUS COMPUTER-GENERATED MAPS

WV DOT HIGHWAY MAP SERIES

The WV Department of Transportation publishes state and county general highway maps. A county map (Type A format) consists of one to seven 18" x 36" (height x width) sheets at a scale of 1 inch = 1 mile (1:63,500) and is printed in black or 2-3 colors (Figure 5a). The paper maps contain a rich source of cartographic information, including transportation, boundary, cultural, and environmental features. These paper maps are continuously updated and are a snapshot at the time of creation. Paper highway county maps that have been scanned and then georeferenced are useful as a mapping guide but should not be digitized because other, more spatially accurate digital data, like the DLG, E-911, and GPS road network data, already exist (Appendix B).

OTHER STATE DOTs

With the advent of new computer mapping technologies, more and more state highway offices have moved from paper-generated to computer-generated maps (Figure 5b). Furthermore, the 2002 GIS-T survey reveals that more state transportation departments are publishing computer-generated highway maps on their Internet sites in either a PDF or TIFF file format (Table 4). An official with the Pennsylvania DOT remarked that paper map sales actually increased after making their digital maps available on the Internet; and the only reported problem was that the Internet maps were made available to the public sooner than the printer could produce the paper maps. Many state DOTs also make their GIS transportation data files available for free download to the public. Pennsylvania DOT uses the Pennsylvania Spatial Data Access system (PASDA), Pennsylvania's official geo-spatial information clearinghouse, to provide widespread sharing of transportation GIS files.

State DOT	Map files (County or State)	Public Data Files
KY	Click here	Click here
OH		Click here
NC	Click here	Click here
NJ	Click here	
PA	Click here	Click here

Table 4: Computer-generated GIS maps and data files accessible via the Internet.

For comparative analysis, digital county highway maps were downloaded from state DOT Internet sites of Kentucky, New Jersey, North Carolina, and Pennsylvania (Table 4; Appendix F). Except for Kentucky DOT, which used ESRI ArcView 3.2 software, the other DOTs developed digital county maps using Microstation. After reviewing other state DOT digital highway maps, it was apparent that the feature density, page size, mapping scale, map projection, as well as overall cartographic quality varies from state to state. For instance, the Pennsylvania DOT (PENNDOT) publishes two county map products: County Type 10 and Type 3 Maps (Figure F1). The 1:65,000-scale County Type 10 Maps are full-color, include all public roads, and are designed for 36" x 49" printing; whereas the simplified County Type 3 Maps show only the major roads and features in two colors, and are published at a smaller pager size and mapping scale. To support the different map types, PENNDOT maintains more than one road network file: a spatially accurate master road file for analytical applications and artistically modified cartographic files for digital highway map products. After reviewing other digital DOT county maps, it also was discovered that most DOTs publish Internet county highway maps as single sheets. State DOTs like Kentucky, New Jersey, and Pennsylvania publish their county highway maps as a single sheet, whereas North Carolina DOT produces multiple-sectioned county maps generated at a constant scale.

ADVANTAGES OF DIGITAL MAPS

Digital highway maps have many advantages over manually generated traditional paper maps. Computer-generated maps integrate existing or new digital geographic data more quickly and accurately than manual procedures that scribe geographic data onto paper maps. Digital map files are much easier to edit and revise than paper maps. More printing options are available too, from printed hardcopy to dynamic Internet maps. In a digital environment, spatial analysis and visualization tools extend computer mapping beyond the value of visually appealing cartographic maps. To demonstrate this, the GIS Technical Center utilized geographic information software to create a digital county highway map for Monongalia County, WV, and then conducted spatial analysis of a proposed county expressway (Appendix A).

IV. DIGITAL DATA ACQUISITION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

To save time and money, the first step in creating digital county highway maps is to locate existing GIS data layers. For the Monongalia County highway map demonstration project, most of the digital datasets were downloaded from the WV GIS Technical Center's Data Clearinghouse, the largest repository of geo-spatial data specific to West Virginia. The Data Clearinghouse is accessed primarily by searching the Technical Center's website (http://wvgis.wvu.edu/data/data.php). Presently the Technical Center provides free Internet access to over 180 spatial datasets, and is continually publishing more current and spatially accurate datasets as they become available.

Data originated from a wide range of governmental agencies, academic institutions, and private companies. In fact, over 30 different thematic datasets originating from 17 agencies were processed to create the GIS highway map of Monongalia County (Table 5). Except for the local Morgantown Utility Board, no extensive mapping databases existed at the county government level or from the Region VI Planning and Development Council that serves Monongalia County. Instead, almost all the datasets, including the road network, were collected from state and federal sources. In the future, however, more local government mapping databases should become available, since Metropolitan Planning Organizations, Regional Planning and Development Councils, and county governments like Brooke, Cabell, Hancock, and Kanawha are beginning to develop and maintain comprehensive geographic databases for their localities.

Selected digital datasets for the computer-generated highway map of Monongalia County were a snapshot of the best available geographic data. To compile quality geo-spatial data, an evaluation of each dataset's currency, spatial accuracy, and completeness (geometry and attributes) was made. Where possible, geographic information was collected from the originator or data producer since this data generally was the most current and accurate. Although a majority of the datasets were derived from 1:24,000-scale USGS topographic maps, spatial accuracy of data ranged from highly accurate Global Positioning System (GPS) road data and local 1:600-scale Morgantown Utility Board data to less accurate 1:500,000-scale tax district boundary data. Higher spatial resolution data was preferred because it permitted the viewing of detailed areas, allowed for more accurate linear referencing of the proposed new road, and in most cases, reduced incompatibility errors between different data themes. Certified datasets like USGS Digital Line Graphs (DLG) were chosen because quality-checked data usually adhere to uniform standards as well as being geometrically and topologically clean; clean datasets were easier to integrate with other datasets and across political and collection area boundaries. Lastly, the completeness and number of attributes associated with each data theme were an important consideration for querying subsets of geographic data and for creating map annotation.

Organization Type	Dataset and Source
Federal Government	*U.S. Geological Survey* - roads, trails, bridges, railroads, state/county boundaries, rivers/lakes, churches, cemeteries, populated places; *National Park Service* – historic districts and places; *U.S. Census* – minor civil divisions and municipalities; *U.S. Army Corps Engineers* – dams; *Federal Communications Commission* – towers
State Government	*Health Care Authority* – hospitals, nursing homes; *State Fire Marshal's Office* – fire departments, *State Police* – police detachments; *Department of Education* – schools; *Department of Natural Resources* – boat access, state parks and wildlife management areas; *Department of Tax and Revenue* – tax district boundaries; *Department of Transportation* – scenic byways; *Higher Education Policy Commission* – colleges; *WV GIS Technical Center* – new road (Route 705); airport runway
Local Govt.	*Morgantown Utility Board* – personal rapid transit
Commercial	*Geographic Data Technologies* – parks, retail centers; *Kimley-Horn & Associates* – proposed West-Run Expressway; *National Business Database* - businesses

Table 5: Geographic datasets utilized for digital county highway map. Refer to the GIS Technical Center's Data Clearinghouse for more information on individual datasets.

The most important dataset for highway maps is the road network. Existing USGS DLG transportation data files were chosen for their spatial accuracy and attributes, and because no E-911 digital road data existed for Monongalia County for comparison. Drawbacks of the DLG transportation data for general highway maps are its currency, limited road classification scheme and missing county route numbers. Because existing DLG transportation data is not always current, new roads such as State Route 705 were collected utilizing GPS. Proposed new roads such as the West Run Expressway, a northern outer loop around Morgantown connecting I-68 with I-79, were captured electronically from scanned highway plans provided by the engineering firm Kimley-Horn and Associates.

GIS datasets are available for most features depicted on the paper highway maps except for individual dwellings, farms, and businesses; although these structures are capable of being mapped upon completion of a statewide E-911 addressing and mapping file. While Table 5 reveals that numerous governmental and private agencies are sources for spatial data, occasionally geographic data is not available for certain features. If no existing data source is available, then heads-up digitizing from other reference data sets is an option. Reference data sets also are important for verifying existing geographic data. Two of the most valuable reference datasets utilized for base mapping in this pilot project were "digital" USGS 1:24,000-scale topographic maps and 1:12,000-scale aerial photos valued a 2 million dollars. Only because federal and state agencies formed cost-sharing partnerships are these reference geo-spatial datasets available to the public for free.

V. GIS MAP CREATION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

A computer-generated highway map of Monongalia County was created by integrating georeferenced highway map data with other thematic layers, including topographic maps, aerial photography, tax parcels, and road engineering design drawings. The map includes a general view of the county highway system along with detailed views of the proposed West Run Expressway (Appendix A). A legend shows the map scale and originator of each thematic layer.

The digital county map was created utilizing Environmental Systems Research Institute's (ESRI) ArcGIS 8.2 software. ArcGIS 8.2 is a popular desktop GIS and mapping software that provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit geographic data. During map processing all data were referenced to the Universal Transverse Mercator (UTM) coordinate system, the preferred coordinate system for statewide datasets in West Virginia. To eliminate multiple section maps, the computer-generated map was produced as one section and at the same scale of paper highway maps (1:63,500; 1" = 1 mile). Inset maps of the proposed West Run Expressway were created to show specific areas of interest in more detail. Final processing included adding to the map margin a legend, county location map, and three computer-generated grids: latitude/longitude graticule, measured UTM grid, and reference grid. In addition to printing the computer-generated map on paper, an electronic 41" x 26" Adobe PDF file was made for web publishing.

Map annotation is a vital component of highway maps and is impacted by display scale, feature density, and symbol shape and size. For this pilot project, annotation was computer generated from feature names that existed in attribute tables. This is the most efficient way of creating annotation instead of creating labels manually. Highway shields and route number labels were created automatically from GIS coverage attributes where present. Overpasses were created as a separate coverage to show the proper overpass/underpass road sequencing.

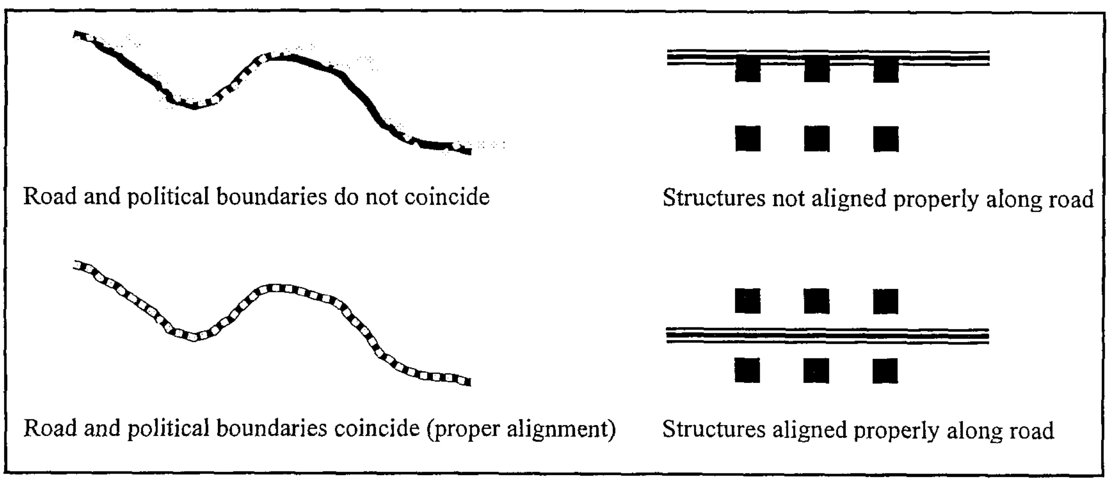


Figure 2: Consistency of road network among other data themes. Data compatibility issues arise when combining multiple themes collected at different positional accuracies.

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WV DOT GIS Implementation Study – August 2002 Report

In cooperation with Rahall Transportation Institute, Marshall University, this preliminary study identifies steps that should be undertaken by the West Virginia Department of Transportation (WV DOT) to implement geographic information system (GIS) technologies. As part of this strategic implementation plan, the WV GIS Technical Center focused on accessible, accurate geo-spatial information available to transportation decision-makers. A demonstration project created a GIS county highway map using the best available digital data and extended the value of the cartographic map with spatial analysis of a proposed expressway. It is hoped that the data development and coordination issues discussed in this report will encourage WV DOT to utilize existing spatial data to create a digital mapping base rather than digitize cartographic features from their paper county highway map series.

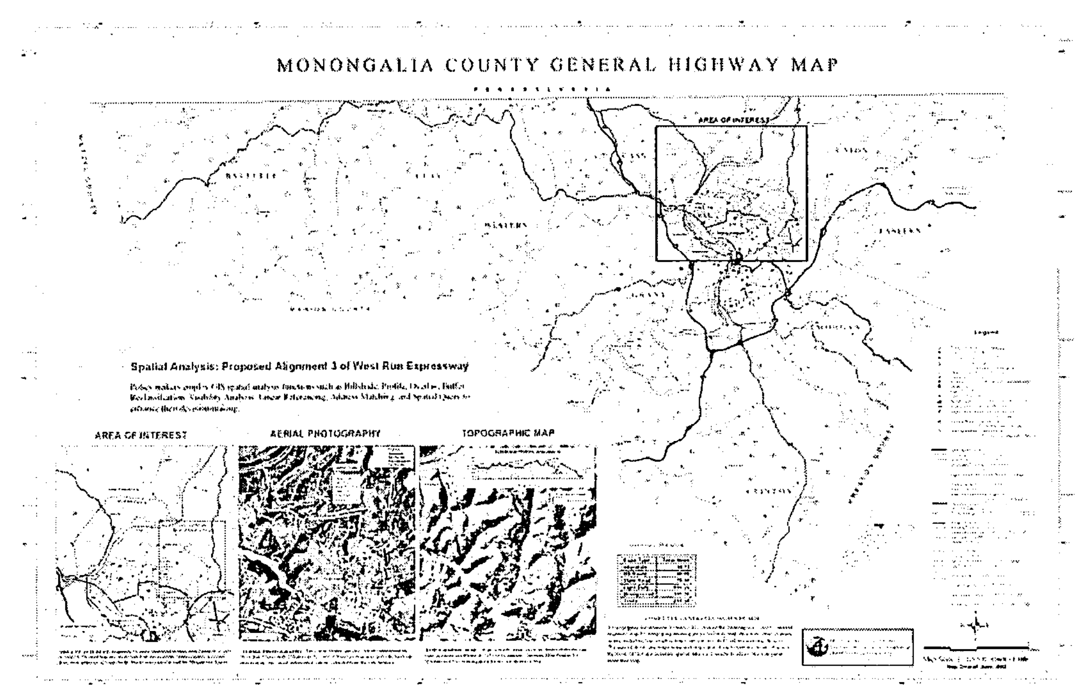

Figure 1: Main Map: GIS computer-generated general highway map for Monongalia County, West Virginia. Inset maps: Spatial analysis of proposed West Run Expressway (Alignment 3).

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I. INTRODUCTION

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 DOTs participate in geo-spatial data sharing activities with other state agencies or organizations (Appendix E). The ability to share spatial databases utilizing geographic information systems (GIS) 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. To demonstrate this concept, georeferenced highway data and other thematic layers were integrated to create a computer-generated highway map (Figure 1) similar to the current WV Department of Transportation's Monongalia County General Highway paper map. In addition to generating an electronic highway county map, spatial analysis was done for Alignment 3 of the West Run Expressway, a new road proposed north of Morgantown in Monongalia County, WV.

II. GIS TRANSPORTATION FRAMEWORK DATA

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, WV DOT 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.

SPATIAL DATA INFRASTRUCTURE

The National Spatial Data Infrastructure (NSDI) encompasses policies, standards, and procedures for organizations to cooperatively produce and share the "best" available geographic data throughout all levels of government, the private and non-profit sectors, and the academic community. One of the core "framework" layers identified by the Federal Geographic Data Committee is transportation, since a map or GIS application almost always incorporates some type of road information. Transportation and other commonly used framework data form the backbone of both the West Virginia and National Spatial Data Infrastructures.

The State GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. This 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 1 depicts the transportation section of the report.

DIGITAL TRANSPORTATION BASE

A digital transportation base serves as the critical foundation for which linear referencing systems and GIS applications are built upon. Therefore, the positional accuracy, currency, completeness, and availability of data are important factors in determining the best transportation base. Both national and state level base mapping viewpoints are discussed below.

National Perspective: Most federal transportation databases adhere to national standards and are accessible to the public (Table 2). In the past, transportation data was produced at the national level and disseminated to state and local government. Now federal agencies such as the U.S. Geological Survey, U.S. Census Bureau, and Federal Highway Administration are implementing programs to incorporate state and local transportation databases of suitable spatial and temporal scale into their national databases. Recently the Geography Division, U.S. Census Bureau, entered into several long-term contracts and partnerships in order to improve the accuracy of the information in its Master Address File (MAF) and associated Topologically Integrated Geographic Encoding and Referencing (TIGER) database. In June 2002 the Census Bureau awarded Harris Corporation an eight-year contract, valued in excess of $200 million, for the Master Address File/Topologically Integrated Geographic Encoding and Referencing Accuracy Improvement Project (MAF/TIGER AIP). The Master Address File (MAF)/TIGER Accuracy Improvement Project will create a complete and current list of all addresses and locations where people live and work. The Census modernization program also will update the TIGER digital database transportation features previously collected at 80-meter accuracy to a much greater spatial accuracy of 3 meters for the entire nation by FY 2008. Likewise, the Federal Highway Administration (FHWA) is incorporating higher resolution data with its existing 1:100,000-scale National Highway Planning Network (NHPN). In addition, national mapping initiatives (Appendix G) like the The National Map and Geospatial One-Stop propose to establish a seamless, continuously maintained, high-resolution transportation mapping database for the nation.

Other State DOT Perspective: Over 95% of the state DOTs have some operational GIS capability (Figure 3), and recent trends show that 89% of state highway departments now use a base mapping scale of 1:24,000-scale or better (Figure 4; Appendix E). State DOTs and their business partners have identified the need for higher spatial resolution transportation data for their mapping and analytical applications and thus are in the process of upgrading their mapping databases to a scale of 1:24,000 (1 inch = 2000 feet) or larger (Appendix F). Until a few years ago, most state DOTs built their digital transportation databases from 1:24,000-scale USGS topographic maps, but now the 1:24,000-scale standard (+/- 40 feet accuracy) is being superceded with geographic data collected from detailed photography or from Global Positioning System (GPS) centerlines (< 2 meter accuracy). State DOTs such as Pennsylvania, New Jersey, and North Carolina are using aerial photography, collected at mapping scales of 1:12,000 or larger, to revise their topographic-based linear transportation features, while Kentucky is implementing an accuracy improvement program utilizing GPS (Appendix F).

WV DOT Perspective: WV DOT should follow the national trend of building comprehensive, statewide transportation databases with more accurate spatial data. In addition to high-resolution digital data (i.e., GPS, engineer surveys) collected by the WV DOT highway survey crews and its subcontractors, the WV DOT should consider both (1) topographic-based and (2) address-based transportation databases as a framework for its digital map base (Table 3). Two *topographic-based* transportation databases, U.S. Geological Survey Digital Line Graphs (DLG) and U.S. Forest Service Cartographic Feature Files (CFF), are very similar geometrically in that they are digital representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from 1:24,000-scale topographic maps. At present, digital transportation features from 1:24,000-scale topographic maps are available for 85% of the state from the WV GIS Technical Center. The WV GIS Technical Center may complete the remaining 15% topographic-based, digital transportation files by summer 2003.

To access highly accurate road centerline data, consideration should be given to incorporating *address-based* transportation databases currently being developed in West Virginia. E-911/local government transportation datasets usually are more current and spatially accurate than other transportation databases, although each county has unique mapping standards and data sharing agreements. Often the local assessor and E-911 director do not collaborate or cost-share but produce independent transportation databases. Another barrier is that county governments may not release their transportation databases without cost-sharing agreements to recover data development and maintenance costs. With the advent of new mapping programs, the address-based transportation databases in West Virginia could become more uniform and accessible. To improve the delivery of emergency services in the state, the Legislature in 2001 established a Statewide Addressing and Mapping Board to provide city-style addresses for every identifiable structure in the rural areas of West Virginia. The board has formed a $15 million partnership with Verizon to map the state and create E-911 addresses. Another program already mentioned, the Census Bureaus' Master Address File (MAF)/TIGER Accuracy Improvement Project, will also make current transportation addressing and mapping databases more spatially accurate. Although specific details regarding the data collection and coverage extent have not been released, these two important programs could lead to a single, uniform addressing and mapping transportation database for the state.

DATA INTEGRATION AND SHARABILITY

Presently there is no single agency that *integrates* all transportation information nationwide, nor likely will there ever be one. In most states, including West Virginia, transportation data is developed and maintained at different spatial and temporal accuracies by federal, state and local entities to support their existing business requirements for information, reporting, and management of their road network system. As more accurate transportation data becomes available, it is very challenging to integrate transportation data of different positional accuracies (Figure 2), detail, coverage, and currency, while retaining the value of existing data investments.

Geographic data must not only be available and in a seamless, consistent format, but it must be adequately attributed and *sharable* with other computer systems. Because over 84% of state DOTs use more than one software product for their GIS applications, with ESRI GIS the most popular, followed by Intergraph/Microstation and TransCad, transportation databases must be properly designed to exchange attribute information. At the North Carolina DOT, for example, the Mapping Section uses Microstation software to develop and maintain digital county, urban, and state travel maps; while the GIS Programming & Analysis Section uses ESRI ArcGIS software to create specialized analytical map products. So information could be easily shared accross different software platforms, the North Carolina DOT GIS Unit implemented an appropriate database design along with a set of conversion programs.

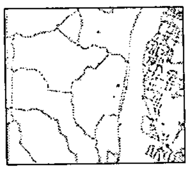
Unfortunately, some state highway computer mapping systems are like "islands" of technology because these systems cannot share information, either "horizontally" across DOT databases or "vertically" with other federal, state, and local government transportation databases. One reason for multiple, disparate transportation mapping systems is that no universal spatial data model exists for sharing information among organizations. To overcome this problem, the federal government and some states are developing core data standards. The federal government is developing a conceptual spatial identification standard (Appendix H) while some states like Kentucky and Utah already have developed core consensus data standards (Appendices F).

COST-SHARING

Although integrating and sharing transportation data is challenging, this should not prevent WV DOT from utilizing existing digital transportation data, especially road centerline geometry, as it is very expensive to create a fully developed digital road network system. To date, federal, state, regional and local governments have invested millions of dollars in *cost-sharing* programs to create digital transportation data for West Virginia. The U.S. Geological Survey, U.S. Forest Service, and the state have contracted 2.5 million dollars to collect and maintain topographic-based transportation databases for West Virginia. It is estimated the WV E-911 agencies and county tax assessors of West Virginia counties have spent 4 million dollars to develop local transportation databases. In the immediate future both the U.S. Census ($200 million) and Verizon ($15 million) will allocate 215 million to fund address-based transportation databases in West Virginia.

Table 1: WV 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:

1) **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

2) **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/

3) **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)

4) **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/TIGER 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

5) **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

6) **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)

7) **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

8) **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).

9) **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.

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 2: GIS transportation datasets available to WV DOT (sorted by scale). The table lists some of the most common GIS transportation datasets available to WV DOT and the principal advantages and disadvantages of each transportation dataset.

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)	71
	USFS Cartographic Feature Files (CFF)	15
Highway Planning Databases	FHWA National Highway Planning Network (NHPN)	100
	WV DOT transportation databases	?

Table 3: GIS transportation datasets grouped by common functionality and percentage of digital product completed for State. Tax assessor transportation databases may not always have an addressing component.

III. PAPER VERSUS COMPUTER-GENERATED MAPS

WV DOT HIGHWAY MAP SERIES

The WV Department of Transportation publishes state and county general highway maps. A county map (Type A format) consists of one to seven 18" x 36" (height x width) sheets at a scale of 1 inch = 1 mile (1:63,500) and is printed in black or 2-3 colors (Figure 5a). The paper maps contain a rich source of cartographic information, including transportation, boundary, cultural, and environmental features. These paper maps are continuously updated and are a snapshot at the time of creation. Paper highway county maps that have been scanned and then georeferenced are useful as a mapping guide but should not be digitized because other, more spatially accurate digital data, like the DLG, E-911, and GPS road network data, already exist (Appendix B).

OTHER STATE DOTs

With the advent of new computer mapping technologies, more and more state highway offices have moved from paper-generated to computer-generated maps (Figure 5b). Furthermore, the 2002 GIS-T survey reveals that more state transportation departments are publishing computer-generated highway maps on their Internet sites in either a PDF or TIFF file format (Table 4). An official with the Pennsylvania DOT remarked that paper map sales actually increased after making their digital maps available on the Internet; and the only reported problem was that the Internet maps were made available to the public sooner than the printer could produce the paper maps. Many state DOTs also make their GIS transportation data files available for free download to the public. Pennsylvania DOT uses the Pennsylvania Spatial Data Access system (PASDA), Pennsylvania's official geo-spatial information clearinghouse, to provide widespread sharing of transportation GIS files.

State DOT	**Map files (County or State)**	**Public Data Files**
KY	Click here	Click here
OH		Click here
NC	Click here	Click here
NJ	Click here	
PA	Click here	Click here

Table 4: Computer-generated GIS maps and data files accessible via the Internet.

For comparative analysis, digital county highway maps were downloaded from state DOT Internet sites of Kentucky, New Jersey, North Carolina, and Pennsylvania (Table 4; Appendix F). Except for Kentucky DOT, which used ESRI ArcView 3.2 software, the other DOTs developed digital county maps using Microstation. After reviewing other state DOT digital highway maps, it was apparent that the feature density, page size, mapping scale, map projection, as well as overall cartographic quality varies from state to state. For instance, the Pennsylvania DOT (PENNDOT) publishes two county map products: County Type 10 and Type 3 Maps (Figure F1). The 1:65,000-scale County Type 10 Maps are full-color, include all public roads, and are designed for 36" x 49" printing; whereas the simplified County Type 3 Maps show only the major roads and features in two colors, and are published at a smaller pager size and mapping scale. To support the different map types, PENNDOT maintains more than one road network file: a spatially accurate master road file for analytical applications and artistically modified cartographic files for digital highway map products. After reviewing other digital DOT county maps, it also was discovered that most DOTs publish Internet county highway maps as single sheets. State DOTs like Kentucky, New Jersey, and Pennsylvania publish their county highway maps as a single sheet, whereas North Carolina DOT produces multiple-sectioned county maps generated at a constant scale.

ADVANTAGES OF DIGITAL MAPS

Digital highway maps have many advantages over manually generated traditional paper maps. Computer-generated maps integrate existing or new digital geographic data more quickly and accurately than manual procedures that scribe geographic data onto paper maps. Digital map files are much easier to edit and revise than paper maps. More printing options are available too, from printed hardcopy to dynamic Internet maps. In a digital environment, spatial analysis and visualization tools extend computer mapping beyond the value of visually appealing cartographic maps. To demonstrate this, the GIS Technical Center utilized geographic information software to create a digital county highway map for Monongalia County, WV, and then conducted spatial analysis of a proposed county expressway (Appendix A).

IV. DIGITAL DATA ACQUISITION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

To save time and money, the first step in creating digital county highway maps is to locate existing GIS data layers. For the Monongalia County highway map demonstration project, most of the digital datasets were downloaded from the WV GIS Technical Center's Data Clearinghouse, the largest repository of geo-spatial data specific to West Virginia. The Data Clearinghouse is accessed primarily by searching the Technical Center's website (http://wvgis.wvu.edu/data/data.php). Presently the Technical Center provides free Internet access to over 180 spatial datasets, and is continually publishing more current and spatially accurate datasets as they become available.

Data originated from a wide range of governmental agencies, academic institutions, and private companies. In fact, over 30 different thematic datasets originating from 17 agencies were processed to create the GIS highway map of Monongalia County (Table 5). Except for the local Morgantown Utility Board, no extensive mapping databases existed at the county government level or from the Region VI Planning and Development Council that serves Monongalia County. Instead, almost all the datasets, including the road network, were collected from state and federal sources. In the future, however, more local government mapping databases should become available, since Metropolitan Planning Organizations, Regional Planning and Development Councils, and county governments like Brooke, Cabell, Hancock, and Kanawha are beginning to develop and maintain comprehensive geographic databases for their localities.

Selected digital datasets for the computer-generated highway map of Monongalia County were a snapshot of the best available geographic data. To compile quality geo-spatial data, an evaluation of each dataset's currency, spatial accuracy, and completeness (geometry and attributes) was made. Where possible, geographic information was collected from the originator or data producer since this data generally was the most current and accurate. Although a majority of the datasets were derived from 1:24,000-scale USGS topographic maps, spatial accuracy of data ranged from highly accurate Global Positioning System (GPS) road data and local 1:600-scale Morgantown Utility Board data to less accurate 1:500,000-scale tax district boundary data. Higher spatial resolution data was preferred because it permitted the viewing of detailed areas, allowed for more accurate linear referencing of the proposed new road, and in most cases, reduced incompatibility errors between different data themes. Certified datasets like USGS Digital Line Graphs (DLG) were chosen because quality-checked data usually adhere to uniform standards as well as being geometrically and topologically clean; clean datasets were easier to integrate with other datasets and across political and collection area boundaries. Lastly, the completeness and number of attributes associated with each data theme were an important consideration for querying subsets of geographic data and for creating map annotation.

Organization Type	Dataset and Source
Federal Government	*U.S. Geological Survey* - roads, trails, bridges, railroads, state/county boundaries, rivers/lakes, churches, cemeteries, populated places; *National Park Service* – historic districts and places; *U.S. Census* – minor civil divisions and municipalities; *U.S. Army Corps Engineers* – dams; *Federal Communications Commission* – towers
State Government	*Health Care Authority* – hospitals, nursing homes; *State Fire Marshal's Office* – fire departments, *State Police* – police detachments; *Department of Education* – schools; *Department of Natural Resources* – boat access, state parks and wildlife management areas; *Department of Tax and Revenue* – tax district boundaries; *Department of Transportation* – scenic byways; *Higher Education Policy Commission* – colleges; *WV GIS Technical Center* – new road (Route 705); airport runway
Local Govt.	*Morgantown Utility Board* – personal rapid transit
Commercial	*Geographic Data Technologies* – parks, retail centers; *Kimley-Horn & Associates* – proposed West-Run Expressway; *National Business Database* - businesses

Table 5: Geographic datasets utilized for digital county highway map. Refer to the GIS Technical Center's Data Clearinghouse for more information on individual datasets.

The most important dataset for highway maps is the road network. Existing USGS DLG transportation data files were chosen for their spatial accuracy and attributes, and because no E-911 digital road data existed for Monongalia County for comparison. Drawbacks of the DLG transportation data for general highway maps are its currency, limited road classification scheme and missing county route numbers. Because existing DLG transportation data is not always current, new roads such as State Route 705 were collected utilizing GPS. Proposed new roads such as the West Run Expressway, a northern outer loop around Morgantown connecting I-68 with I-79, were captured electronically from scanned highway plans provided by the engineering firm Kimley-Horn and Associates.

GIS datasets are available for most features depicted on the paper highway maps except for individual dwellings, farms, and businesses; although these structures are capable of being mapped upon completion of a statewide E-911 addressing and mapping file. While Table 5 reveals that numerous governmental and private agencies are sources for spatial data, occasionally geographic data is not available for certain features. If no existing data source is available, then heads-up digitizing from other reference data sets is an option. Reference data sets also are important for verifying existing geographic data. Two of the most valuable reference datasets utilized for base mapping in this pilot project were "digital" USGS 1:24,000-scale topographic maps and 1:12,000-scale aerial photos valued a 2 million dollars. Only because federal and state agencies formed cost-sharing partnerships are these reference geo-spatial datasets available to the public for free.

V. GIS MAP CREATION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

A computer-generated highway map of Monongalia County was created by integrating georeferenced highway map data with other thematic layers, including topographic maps, aerial photography, tax parcels, and road engineering design drawings. The map includes a general view of the county highway system along with detailed views of the proposed West Run Expressway (Appendix A). A legend shows the map scale and originator of each thematic layer.

The digital county map was created utilizing Environmental Systems Research Institute's (ESRI) ArcGIS 8.2 software. ArcGIS 8.2 is a popular desktop GIS and mapping software that provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit geographic data. During map processing all data were referenced to the Universal Transverse Mercator (UTM) coordinate system, the preferred coordinate system for statewide datasets in West Virginia. To eliminate multiple section maps, the computer-generated map was produced as one section and at the same scale of paper highway maps (1:63,500; 1" = 1 mile). Inset maps of the proposed West Run Expressway were created to show specific areas of interest in more detail. Final processing included adding to the map margin a legend, county location map, and three computer-generated grids: latitude/longitude graticule, measured UTM grid, and reference grid. In addition to printing the computer-generated map on paper, an electronic 41" x 26" Adobe PDF file was made for web publishing.

Map annotation is a vital component of highway maps and is impacted by display scale, feature density, and symbol shape and size. For this pilot project, annotation was computer generated from feature names that existed in attribute tables. This is the most efficient way of creating annotation instead of creating labels manually. Highway shields and route number labels were created automatically from GIS coverage attributes where present. Overpasses were created as a separate coverage to show the proper overpass/underpass road sequencing.

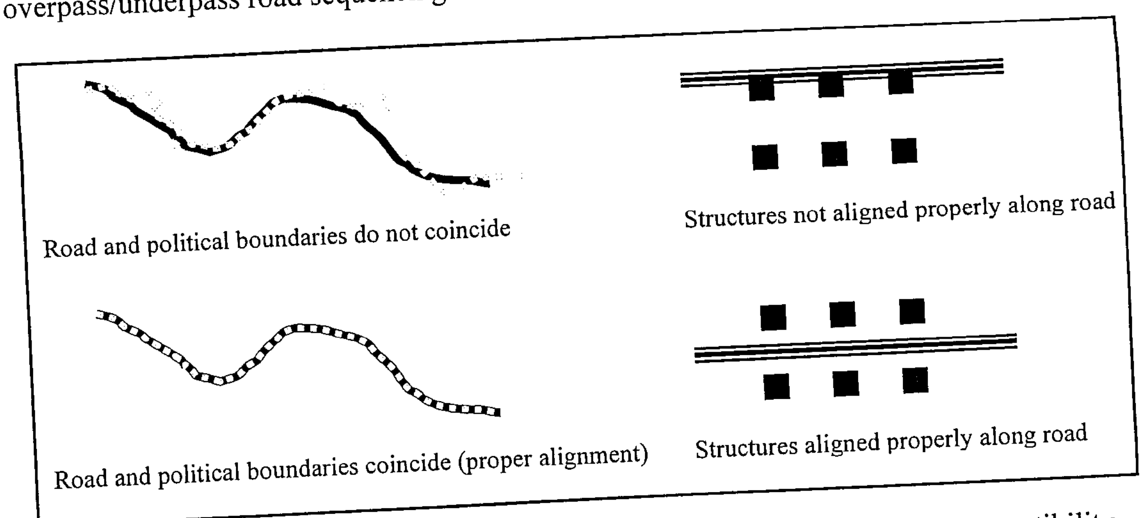


Figure 2: Consistency of road network among other data themes. Data compatibility issues arise when combining multiple themes collected at different positional accuracies.

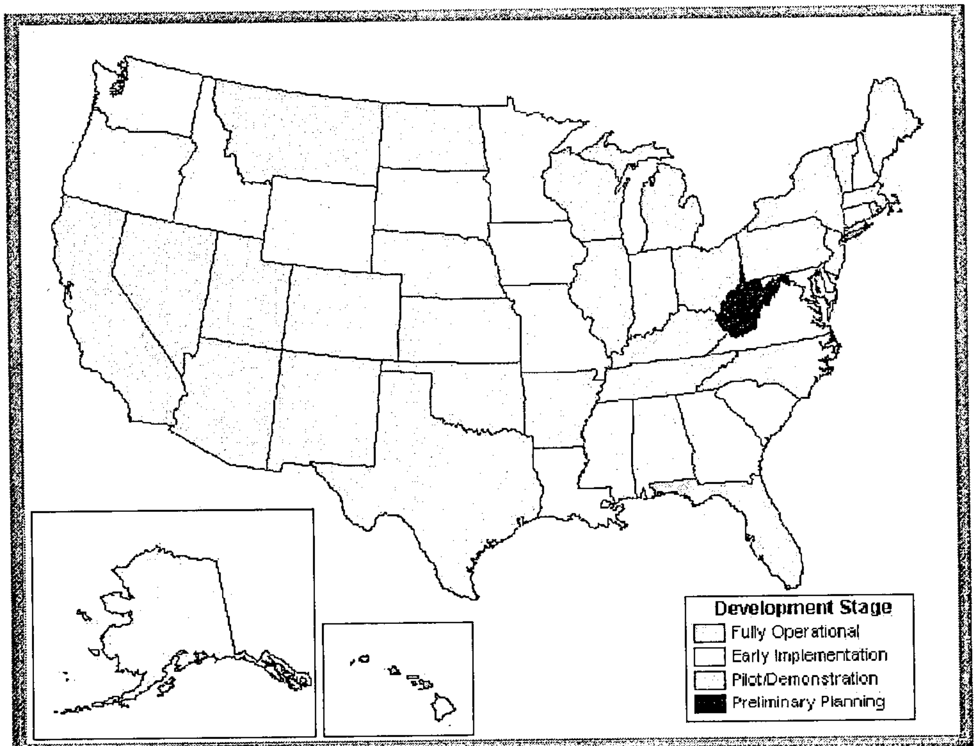


Figure 3: Development stage of state DOTs (Spear, 2002). Over 95% of state DOTs have some operational GIS capability.

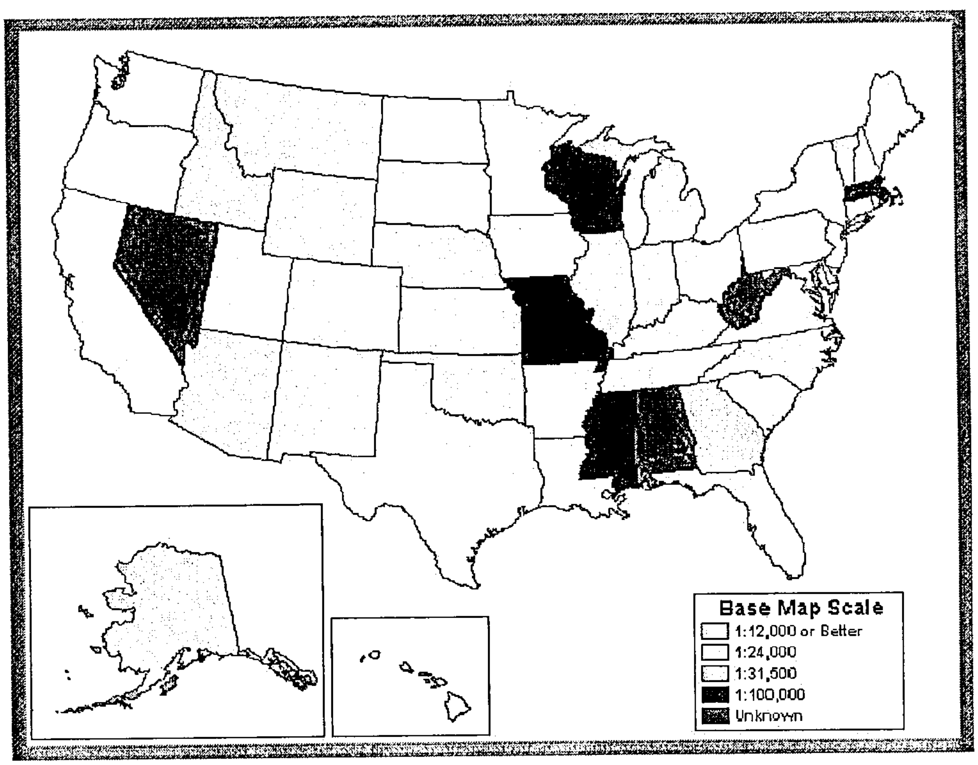


Figure 4: Base map scale of state DOTs (Spear, 2002). 89% of state DOTs use a base mapping scale of 1:24,000-scale or better.

Figure 5a: Current Monongalia County General Highway Map (Non-digital)

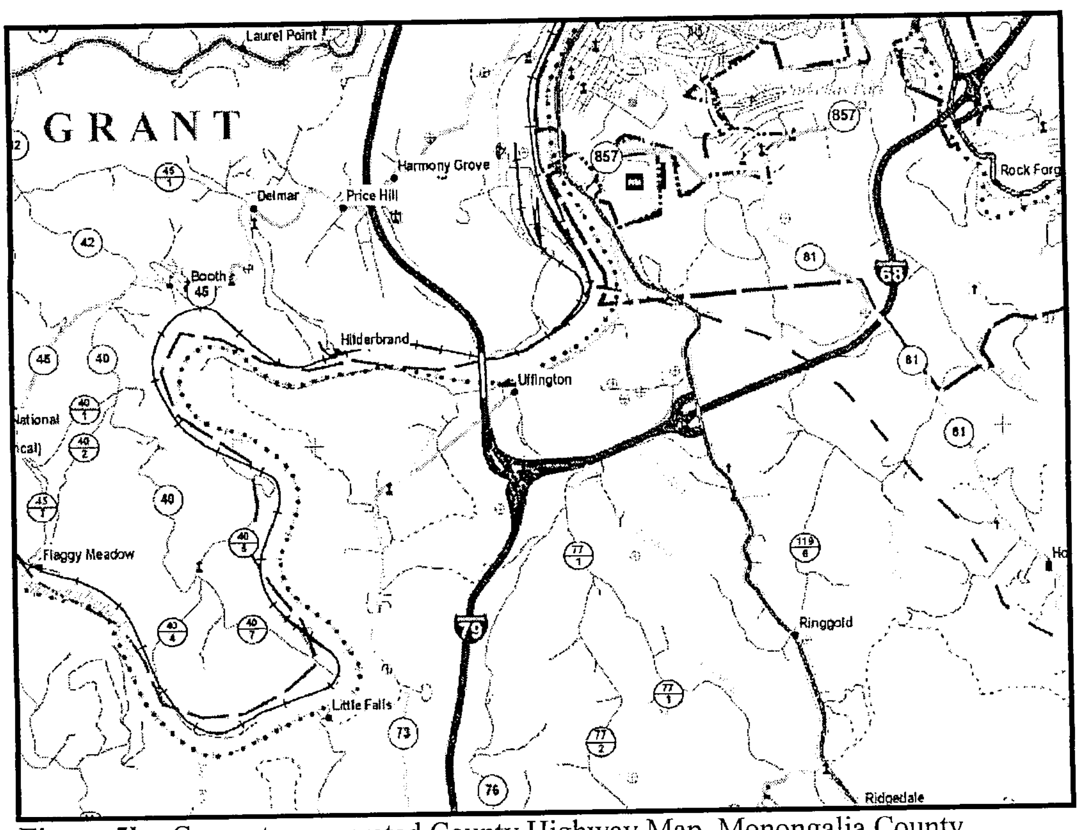


Figure 5b: Computer-generated County Highway Map, Monongalia County.

VI. RECOMMENDATIONS

(1) Establish an interagency transportation task force and lead agency to coordinate data sharing and to implement a transportation framework for the state.

- *Transportation Task Force:* Many states have organized a task force of transportation data producers and users to determine an optimum model for data creation, maintenance, and distribution. The task force should include selective members from county government, Metropolitan Planning Organizations, Planning and Development Councils, WV Department of Transportation, Rahall Transportation Institute, State GIS Technical Center, Statewide Addressing and Mapping Board, Monongalia National Forest, Federal Highways Administration, and U.S. Census Bureau. Transportation mapping experts from the private sector should also be consulted.

- *Data Exchange among Multiple Transportation Databases*: The proposed interagency task force should review technical and business relationships of independently maintained transportation databases at the federal, state, and local levels, and 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 (Appendix H) 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 (Appendix F); (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 (Appendix I) 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.

- *Area Integrator at State Level:* No federal agency such as the U.S. Geological Survey or U.S. DOT is taking the lead to develop a comprehensive road network transportation dataset, probably because most state DOTs already have developed detailed, high resolution transportation databases and because no universal data model exists. Although local governments will create transportation data, as they are most familiar with what is in their locality, a central coordinating agency at the state level should 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.

(2) Identify 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: Do NOT create a digital mapping base from existing WV DOT general highway reference maps (1:63,500; 1" = 1 mile; Figure 5a) because these maps are spatially inaccurate, incompatible with more accurate geographic datasets, and not seamless across sheet and county boundaries.

    - Spatially Inaccurate: In many cases the current WV DOT general highway map features are cartographic or artistic in nature and not of true mapping accuracy (Figure B2). If cartographic coverages (streams, roads, etc.) must be made for map-making purposes, first develop and maintain spatially accurate master GIS datasets for analytical and referencing applications. Then derive visually appealing cartographic files from these spatially accurate master GIS datasets.

    - Incompatible with other Data Themes: The positional accuracy of digitized WV DOT road centerlines would be inconsistent with other, more accurate data themes. Coincidental features like roads and political boundaries would not share the same geographic space, nor would geocoded structures like schools and churches be positioned properly along roads (Figure 2).

    - Edge-Matching Errors: Road centerline gaps occur when edge-matching digitized WV DOT road centerlines of cartographic maps across county and sheet map boundaries (Figure B1).

- 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 (Table 3). The WV DOT digital road network base should include ALL public roads for analytical applications and linear referencing systems.

(3) Employ GIS technologies to store, maintain, and publish both paper and electronic highway maps. As WV DOT migrates to a digital mapping environment, it can achieve major cost savings through overhauling the design, content, and printing process of its current county highway map series. Suggestions for revamping the county general highway map series:

- MAP DESIGN

  - *GIS Personnel and Software:* Consider organizational impacts of requiring technically advanced staff and equipment to implement a GIS mapping system. GIS software and its application can be complex and not always intuitive.

    - Personnel: An expert mapping/applications team can involve several technical specialties, including cartographers, GIS analysts and programmers, and system/database administrators. Computer-generated highway maps and analytical applications should be done by experienced professionals or outsourced to the private sector.

    - Software: Most likely more than one software application will be required for cartographic maps and analytical applications. Computer-Aided Design (CAD) software such as Microstation or AutoCAD should be complemented with ESRI ArcGIS 8.2 to implement a robust GIS mapping program.

  - *Best-Available Data:* Choose the best-available data for making digital highway maps. Where possible, data should be collected in a GIS format from the originator or maintainer of that particular dataset (Table 5). The best available geographic data can be collected from existing digital databases, new data sources via GPS, engineering and survey design files, or from reference digital map sources such as digital aerial photography and topographic maps. Desirable data should be accessible, seamless, and consistent among themes, as well as certified and documented to prescribed metadata standards.

  - *Database Development:* Properly designed, fully attributed transportation databases will serve as a critical foundation for cartographic maps and analytical applications. Review functional requirements for road centerline databases (cartography, geo-referencing, network application) and sharable databases. Develop a road network database so that attributes can be transferred or cross-linked between different software applications. Where economical, conflate or transfer road surface types, county highway route numbers, and other useful road attribute features from suitable sources to the selected digital road network base. Migrate from existing legacy (non-graphical) databases to geographic information systems.

  - *Coordinate System:* Reference map data to the Universal Transverse Mercator (UTM) Coordinate System, Zone 17 North, North American Datum of 1983, with map units in meters. The UTM Zone 17 projection, which covers almost the entire geographic extent of West Virginia, is the preferred coordinate system of most state agencies.

- *Geographic Extent of Data*: Maintain and update master road files at county level or higher to provide flexibility for creating both statewide and county general reference highway maps. Coverage extent of major highway routes should be statewide. When creating digital county highway maps, statewide GIS coverages should be clipped to the county extent with existing annotation attached to the updated coverages.

- MAP CONTENT

  - *Reduce Map Content*: After the road network, prioritize which datasets are absolutely necessary on general highway maps.

    - Road Network: Reduce the number of surface types (i.e., bituminous road and soil surfaced roads) depicted on general highway maps. Leave detailed road classifications for internal WV Department of Transportation maps.

    - Individual Structures: Eliminate individual dwellings like houses and farms that are exaggerated, cartographic representations on the map and do not represent true map scale. (Only for specialized maps capture individual structures using digital aerial photography or address databases.) Landmark features like churches, schools, or major buildings should be sufficient.

  - *Page Size, Map Scale, and Feature Density:* Re-evaluate page size, map scale, and feature density of county highway maps series, as this adversely affects the map content and visual appearance of the map. If a constant scale/multiple sections format is chosen, the maximum number of paper sections should not exceed two.

  - *Map Annotation:* Automatically generate map annotation from feature names that exist in the attribute tables. Annotation for large counties like Randolph County must be big enough to be readable if reduced to a standard page size for publishing.

- MAP PUBLISHING

  - *Single Sheet County Maps:* Publish county highway maps to a single, standard page size instead of using a multiple sections format (Appendix D). Map rescaling is easily accomplished in a computer environment.

  - *Export Map to other Software:* Export digital highway maps to other software in a variety of formats. For example, GIS maps can be exported to vector-graphics software like Freehand or Illustrator in case cartographic enhancements are needed.

  - *Public Access:* Make computer-generated maps available free to the public in PDF format (D or E paper size) via the Internet. In addition, transportation GIS files used to generate these maps should be made available to the public (Table 4).

(4) Extend computer mapping beyond value of cartographic maps.
Geographic Information Systems can do more than just make pretty maps. As demonstrated with the West Run Expressway inset maps, GIS software allows users to perform spatial analysis along transportation corridors. Transportation corridors can be dynamically segmented and referenced to mile markers for traffic accidents or pavement conditions. Street addresses for bridges or street intersections can be geocoded or converted to geographic locations. Visibility analyses can determine viewshed areas impacted by a proposed highway. A proposed highway can be buffered to a specific right-of-way distance and then intersected with tax parcels to determine which property owners are affected. Spatial statistics can quickly sum the different highway surface types. In summary, there are a broad range of GIS applications, from asset management and inventory, visualization of features and event, to complex spatial analysis applications.

(5) Develop a multi-phased modular approach to implementing GIS similar to Pennsylvania DOT's GIS Strategic Plan (Appendix F).

- Incorporate the GIS Strategic Plan into other WV DOT automated technology plans.
- Avoid sinking into big "money pits." As evident by the State DOT Roll Call, each DOT has unique goals and interests and is in different stages of GIS development. Some DOTs have been developing their GIS capabilities for 10-15 years, and now are undertaking complex, enterprise database integration and application projects. Also consider that it may be cheaper to migrate to new database solutions than to incorporate "legacy" databases into GIS applications.
- Early implementation of GIS should focus on pilot/demonstration projects, base map development, data integration, and a few, targeted applications such as planning, road inventory, federal reporting, or general highway map production. Identify a few applications that allow WV DOT to work cheaper and faster, thus realizing the benefits of GIS. Follow the stages of GIS development as defined in the 2002 GIS-T State DOT Survey (Figure 3 and Appendix E).

    1. ***Preliminary Planning*** (no operational GIS capability, but evaluating other states' programs, talking with software vendors, etc.)
    2. ***Pilot/Demonstration*** (no officially recognized GIS unit(s), but one or more GIS demonstration projects underway)
    3. ***Early Implementation*** (one or more officially recognized GIS units, primary focus on base map development, data integration, and a few, targeted applications)
    4. ***Fully Operational*** (widespread use of GIS throughout the agency, core GIS functions include base map maintenance, training, technical support, and intra-agency coordination)

GENERAL REFERENCES:

(1) NSDI Framework Transportation Identification Standard (Appendix H)

(2) State I-Team Plans posted at http://www.fgdc.gov/I-Team/ (Appendix F)

(3) Spear, Bruce; Federal Highway Administration, Washington, DC; presented at the 2002 AASHTO GIS-T Symposium, Atlanta, GA (Appendix E)

APPENDICES:

APPENDIX A: Spatial Analysis – Proposed West Run Expressway

APPENDIX B: Scanned WV DOT General Highway County Paper Maps

APPENDIX C: Relationship between WV DOT General Highway Map Symbols and DLG Codes

APPENDIX D: Map Scale, Page Size, and Sheet Number of State DOT County Series Maps

APPENDIX E: GIS-T 2002 State DOT Survey and GIS Trends/Barriers

APPENDIX F: State DOT GIS Implementation Plans (Excerpts from Kentucky, Maryland, New Jersey, Pennsylvania, and Utah plans)

APPENDIX G: National Mapping Initiatives

APPENDIX H: Federal Identification and Core Content Transportation Standards

APPENDIX I: Linear Referencing Systems (LRS)

APPENDIX A: SPATIAL ANAYSIS – PROPOSED WEST RUN EXPRESSWAY

For transportation studies, GIS software provides a variety of indirect location referencing systems and spatial analysis tools to enhance the decision-making process. Some of these GIS functions were used to evaluate the proposed Alignment 3 of West Run Expressway, a northern bypass located north of Morgantown between I-68 and I-79.

Area of Interest Inset Map: The Area of Interest Map (Figure A1) demonstrates how a zoomed-in view of the proposed expressway can be displayed without having to create a totally new map. The inset map also demonstrates how road networks provide the basis for several indirect location referencing systems to locate point or linear features like bridges, signs, pavement conditions, and traffic incidents. Two referencing methods utilized in the mapping project are address geocoding and linear referencing, both shown on the Area of Interest inset map. Geocoding converts street addresses of a road network file into geographic coordinates. The Area of Interest inset map demonstrates how street addresses of respondents for a local rail-trail recreational survey were converted to a point GIS coverage. Spatial statistics can now be conducted on the survey variables. Another type of location referencing system uses measured routes created by dynamic segmentation to depict geographic information. In ArcGIS the linear route-measure system builds upon ARC/INFO's arc-node topological model to provide a linear route-measure system for modeling and analyzing linear features. Transportation attributes can be defined along a route spanning many arcs or a route that spans part of a single arc. For example, Alignment 3 of the proposed expressway was dynamically segmented into mile markers for easier referencing, beginning with mile marker 0 (Easton) and ending at mile marker 3.0 (Monongahela River). Point attributes like proposed signs at mile markers 1.2 and 3.5 could be indirectly referenced to the expressway. The Area of Interest Map also demonstrates how the spatial analysis buffer function created a 1-mile exclusion zone around the municipal airport.

Topographic Map Inset Map: The map inset labeled Topographic Map (Figure A2) depicts three spatial functions based upon 10-meter digital elevation data: profile, hillshade, and visibility. An elevation profile of Alignment 3 shows change in surface elevation between Easton and the Monongahela River. The hillshade function creates a shaded relief map to enhance the topography of the area. A visibility analysis on the elevation grid generates high visibility areas, locations on the ground where observers can view, in barren conditions (no trees or houses blocking view), 30-50% of Alignment 3 between mile markers 0.0 (Easton) and 3.0 (Monongahela River). As expected, much of the proposed expressway will be visible to observers located on hilltops positioned close to the proposed expressway.

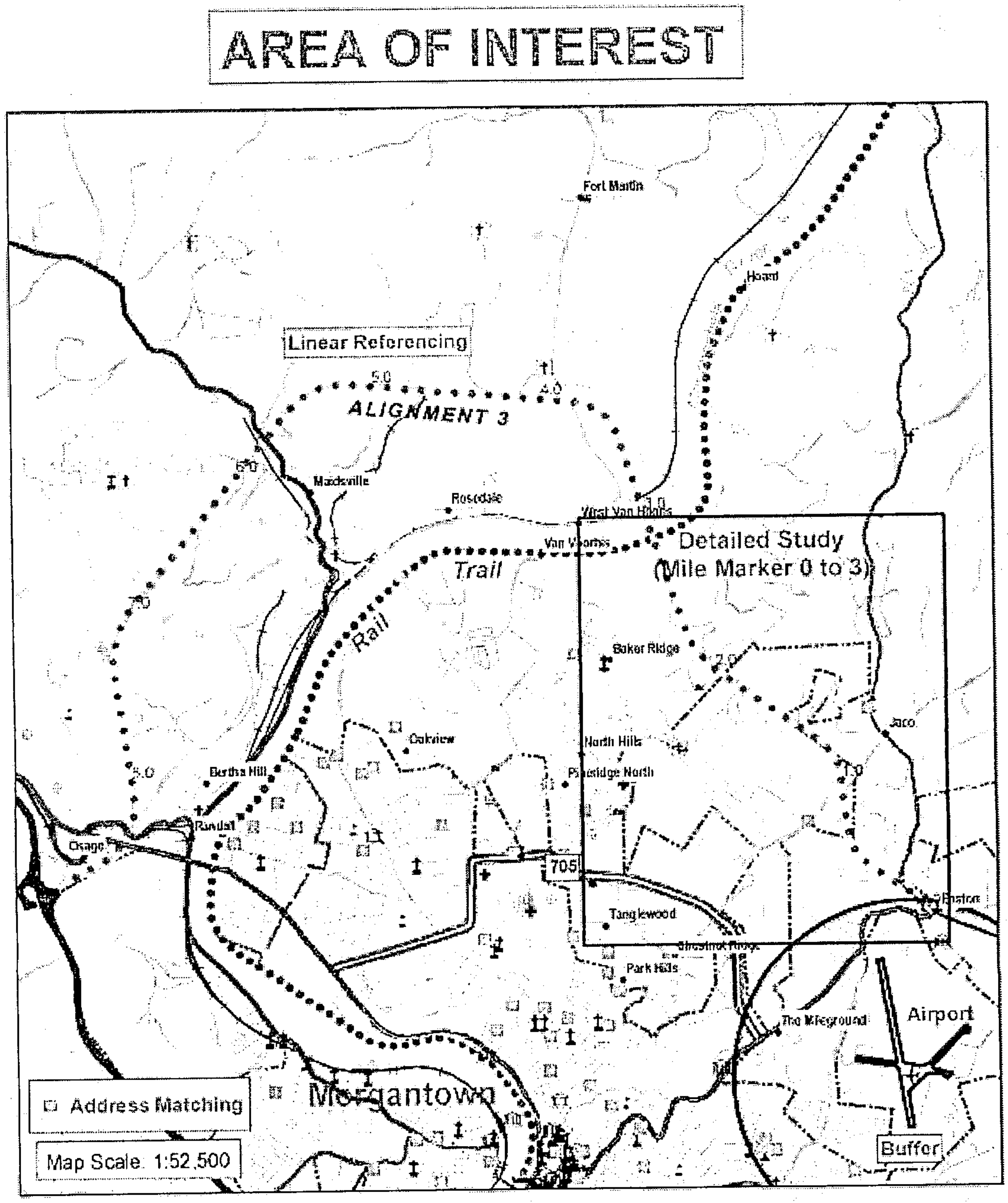
Aerial Photography Inset Map: Color-infrared aerial photography serves a variety of purposes, from information about land use to field references for transportation studies. In this map inset (Figure A3), the spatial analysis overlay function intersects Alignment 3 with the tax parcel polygons to determine which properties the proposed highway directly affects. A spatial query demonstrates how to identify the name of the owner or any other relevant information for a particular parcel.

Summary Statistics Table: Statistics are generated easily from the road network database tables to summarize road surfaces in total miles (Table A1).

Summary Statistics

Road Type	Total Miles
Interstate	44.13
US Route	46.08
State Road	76.99
Light Duty	655.25
Unimproved	345.30
Trails	216.54

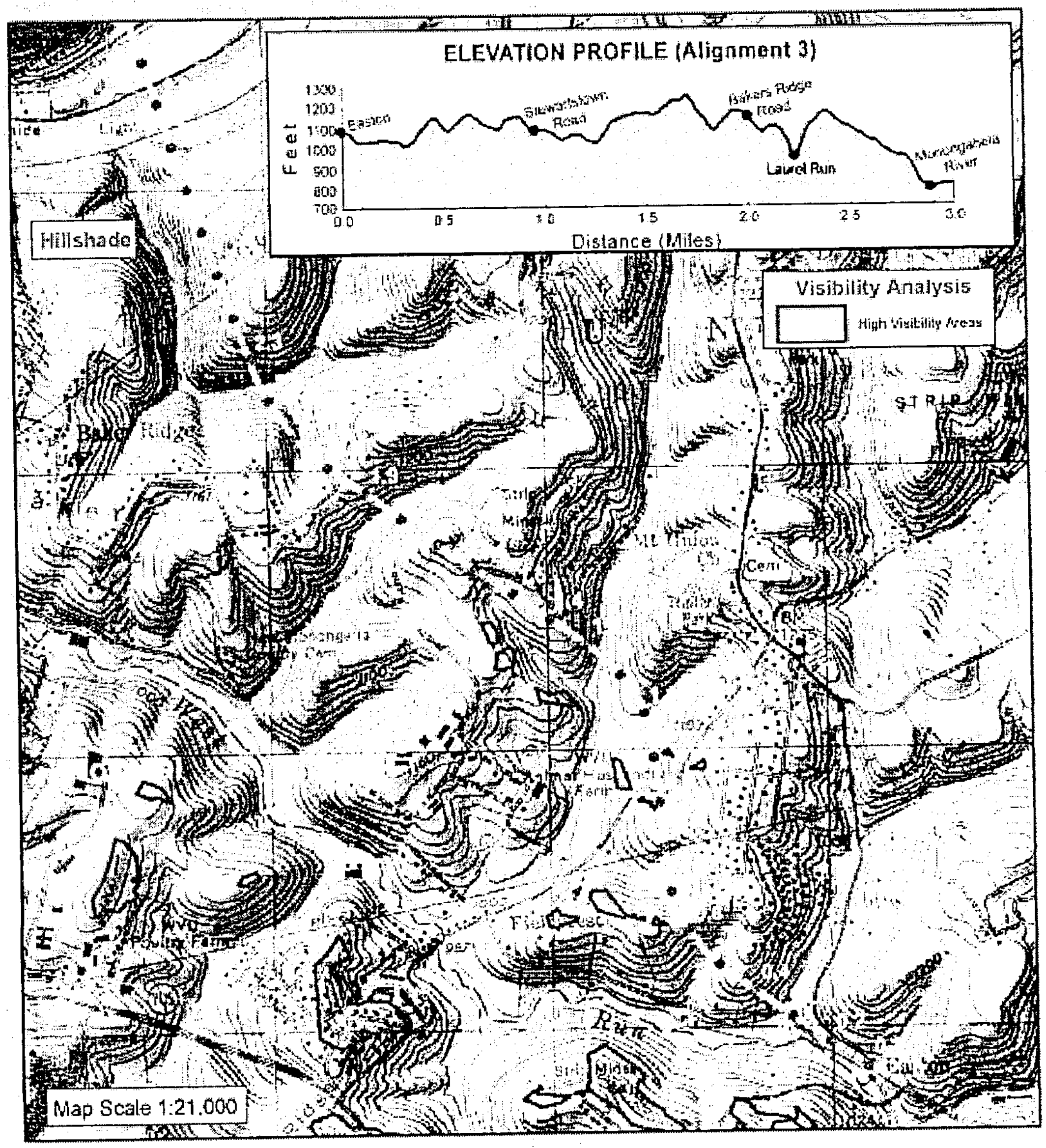
Table A1: Summary Statistics. Spatial analysis of proposed West Run Expressway.



AREA OF INTEREST: Alignment 3 is linear referenced in miles from Easton (U.S. 119) to Osage (I-79). Inset map also shows Rail Trail survey points (orange squares) geocoded from street addresses. A 1-mile buffer (black) was created around the Morgantown Airport.

Figure A1: Area of Interest Inset Map. Spatial analysis of proposed West Run Expressway.

TOPOGRAPHIC MAP



TOPOGRAPHIC MAP: High visibility areas, locations where observers can view in barren conditions 30-50% of Alignment 3 between Mile Marker 0.0 (Easton) and 3.0 (Monongahela River), are shown in blue.

Figure A2: Topographic Map Inset. Spatial analysis of proposed West Run Expressway.

AERIAL PHOTOGRAPHY

AERIAL PHOTOGRAPHY: Tax Union District parcels (yellow) intersected by West Run Expressway (Alignment 3). Color infrared photography provides land use information. Tax parcel information can be extracted from the GIS database.

Figure A3: Aerial Photography Inset Map. Spatial analysis of proposed West Run Expressway.

APPENDIX B: Scanned WV DOT General Highway County Paper Maps

Utilize WV DOT Paper Highway Maps for Reference Only: Paper highway county maps that have been scanned and then georeferenced to become GIS images are useful as a mapping *reference* guide but should not be digitized to serve as a base map because other, more spatially accurate digital data, like the DLG, E-911, and GPS road network data, already exist. Not only are the 1:63,500-scale county highway maps spatially inaccurate, these maps do not always edge-match correctly across sectional and county boundaries, nor are they spatially compatible with other themes that are more accurate and current (Figures B1-B3). Consequently, georeferenced, scanned images of county highway maps should only be used as *reference* layer for content and map symbology.

Figure B1: Scanned and georeferenced general county highway maps converted to GIS mapping files for three counties, Monongalia, Marion, and Taylor, and overlaid onto 10-meter panchromatic SPOT satellite imagery. Edge matching is a problem across sheet and county boundaries.

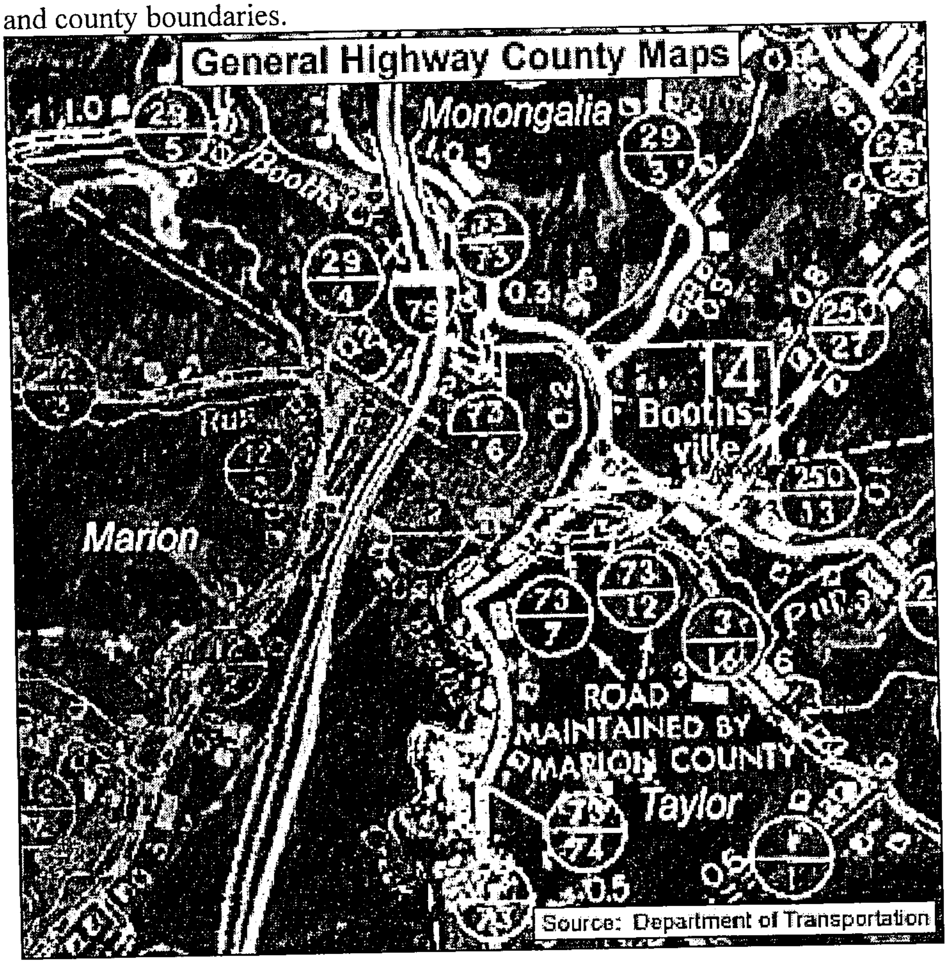


Figure B2: Scanned and georeferenced general county highway maps converted to GIS mapping files for Monongalia County, overlaid onto 1:24,000-scale USGS topographic map. Cartographic representation of man-made features like houses and buildings are exaggerated when compared to true horizontal scale. At true map scale, for example, individual houses cover the geographic area of a city block. The positional spatial accuracy of paper general highway maps is not suitable for detailed mapping projects (note offset of airport and I-68; houses represent city blocks).

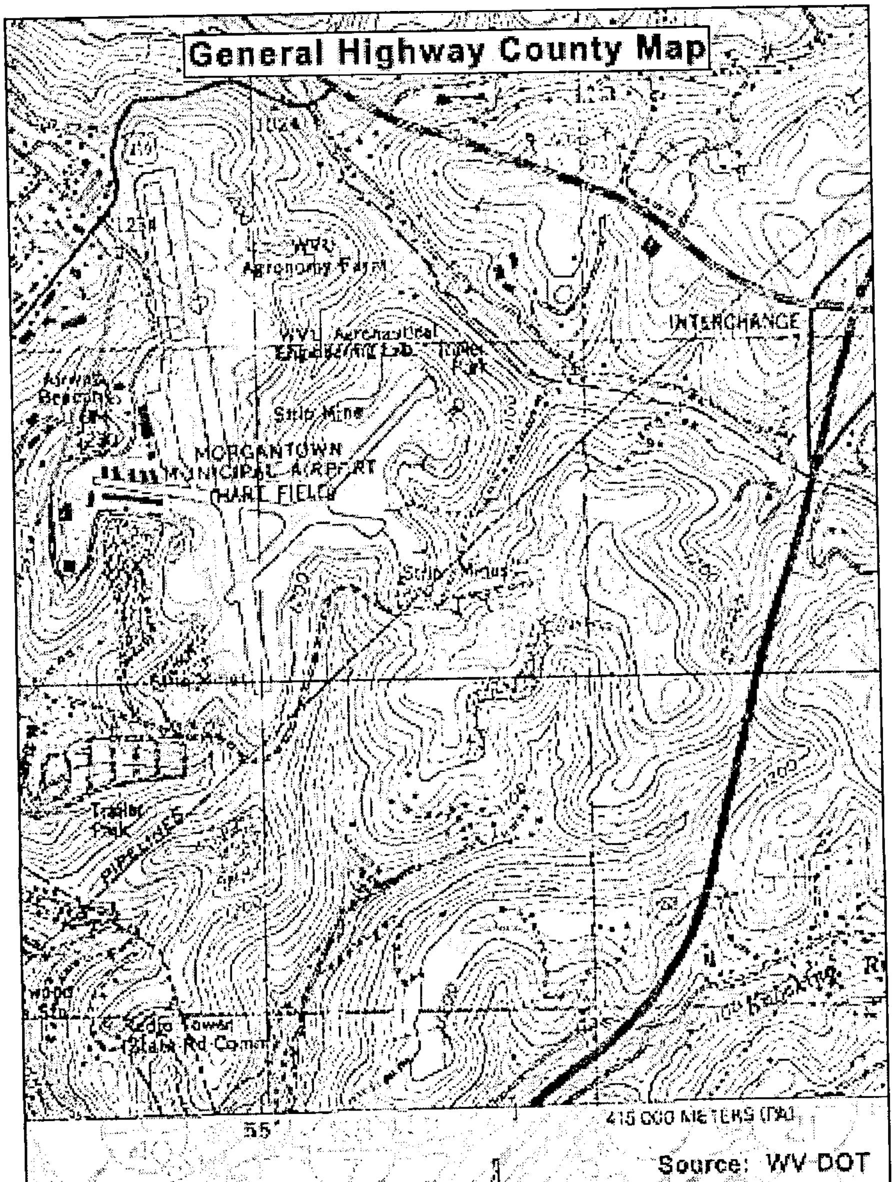


Figure B3: Scanned and georeferenced general county highway maps converted to GIS mapping files for Monongalia County, overlaid onto 1-meter color-infrared digital orthophoto.

<u>*How Paper Highway Maps were Georeferenced:*</u> District 4 Headquarters of the WV Department of Transportation provided scanned images (~ 200 dpi) of the paper 18" x 36" General Highway County Maps (Type A--Flat maps). The GIS Technical Center mosaicked the county sections together into a single county image, erased all information outside of the county border (insets, legend, etc.), and then georeferenced the image to a computer-generated 5-minute latitude / longitude grid. To make other datasets viewable underneath the digital scanned county highway map, the background white color was made transparent.

APPENDIX C: Relationship between WV DOT General Highway Map Symbols and USGS DLG Codes

None of the existing topographic or address-based GIS databases identified in Table 3 will satisfy current attribution requirements of WV DOT's highway map series. The geometry or digital vector representations are suitable if current and complete but in most cases the attribution is lacking or insufficient. Non-WV DOT transportation databases have different road classification schemes and thus are difficult to merge with WV DOT's scheme. Another problem is that other non-WV DOT databases lack the comprehensive county route numbers typically found on WV DOT highway paper maps. The following discussion explores the different road classification schemes of USGS Digital Line Graphs and WVDOT county highway maps.

The USGS Digital Line Graph (DLG) files are digital representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from USGS 1:24,000-scale topographic maps. All DLG data distributed by the USGS are DLG - Level 3 (DLG-3), which means the data contain a full range of attribute codes, have full topological structuring, and have passed certain quality-control checks. Numeric DLG attribute codes describe the physical and cultural characteristics of DLG node, line, and area elements. Each DLG element has one or more attribute codes composed of a three-digit major code and a four-digit minor code, and follow the legend classification located on USGS topographic maps. A Spatial Data Transfer Standard (SDTS) format of these codes was chosen because it combines the major and minor codes into a unique feature identification code that allows for easier classification.

DLG files do not contain the detailed surface types and county numbers that are found on the WV Division of Highway's County General Highway maps. Consequently, DLG road surface types cannot be satisfactorily matched to the surface types denoted on the general highway maps. Table C (DLG_STDS_Codes.xls) shows the correlation between the DLG codes and highway map symbols for road surfaces, signage systems, railroads, and structures. For example, the DLG code 1700209, for "light duty, hard or improved road," represents four WV general highway map road surface classifications: bituminous road, gravel or stone road, soil surface road, and graded and drained road. In addition no county route numbers are collected as DLG attributes.

Since it is difficult to create surface types from DLG attributes, in this pilot mapping project we created separate GIS coverages for Interstates, federal, and state highways from the signage or route number attribute field. It is assumed that these roads have similar road surfaces. Secondary highways (hard surface), light duty roads (hard or improved surface), unimproved roads and trails were classified according to DLG surface type codes.

Table C: Comparison of WV DOT highway map and USGS DLG symbology

Relationship between DOT General Highway Map Symbology and DLG Codes
For the Monongalia County, West Virginia, Highway Map

DOT Symbol Type/Name	DLG Code(s) in SDTS	DLG Code Explanation
Roads and roadways		
Trail	1700212 or 1700211	211=regular; 212=4 wheel drive
Impassable Road	No match	
Primitive Road	1700210	unimproved road, generally dirt
Unimproved Road	1700210	unimproved road, generally dirt
Graded and Drained Road	1700209	light duty, hard or improved
Soil Surfaced Road	1700209	light duty, hard or improved
Gravel or Stone Road	1700209	light duty, hard or improved
Bituminous Road	1700209	light duty, hard or improved
Paved Road	1700205 or 1700201	205=hard surface secondary highway, undivided; 201=hard surface primary highway, undivided
Divided Highway	1700203 or 1700201	203=hard surface primary highway, divided; 201=hard surface primary highway, undivided--will depend on scale collected
Sign Systems		
Interstate Route	SR ###	DLG code is 172.xxx, but in SDTS they translated
U.S. Numbered Highway	I ##	DLG code is 173.xxx, but in SDTS they translated
WV Numbered Highway	US ###	DLG code is 174.xxx, but in SDTS they translated
Railroads		
Railroad	1800201	181.x added to encode number of tracks when multiple track symbol used
Narrow gauge railroad	1800201 and 1800606	606 added to 201 when symbology is narrow gauge
Railroad station	1800400	Node or point, depending on location
Railroad bridge	vertical=O	On bridge 1800602 is added to 201, in SDTS have depicted as O
Railroad Tunnel	?	In tunnel 1800601is added to 201, in SDTS not known how shown
Structures		
Bridge, General	vertical=O	On bridge for road layer=1700602, added to road code; SDTS uses a vertical field
Dam	?	Collected on hydro 0500406, not known how show in SDTS
Tunnel	?	For roads, in tunnel 1700601 is added to road code, in SDTD don't know how show
Ford	?	On road layer 1700606 is added to road code; don't know how shown in SDTS
Other DLG Codes		
	Bridge abutments	1700001 on roads layer; points collected where bridge abutments cross roads
	tunnel portals	1700002 on roads layer; points collected where tunnel portals cross roads
	rest area	1700223 on road through rest area
	ramp in interchange	1700402 on ramp

APPENDIX D: Map Scale, Page Size, and Sheet Number of State DOT County Series Maps

State DOTs use either a (1) variable scale/constant page size/single sheet, (2) constant scale/variable page size/single sheet, or (3) constant scale/constant page size/multiple sheets format for their county highway map series. WV DOT presently uses format 3: the county map (Type A format) consists of one to seven 18" x 36" (height x width) sheets at a scale of 1 inch = 1 mile (1:63,500), printed in black or 2-3 colors.

Most state DOTs publish on the Internet single sheet maps, not multiple sheets, because it is a more desirable format for the public to download and view. Single sheet maps can include detailed city inset maps in the map margins. WV DOT should also publish single sheet maps, either at a variable scale/constant page size or constant scale/variable page size. If the constant scale/variable page size option is chosen, in a digital environment, computer-generated maps can be easily rescaled to a standard page size as long as the map annotation and symbols remain legible. In West Virginia, if single sheet maps are generated at a constant map scale of 1:63,500, then the approximate page size for Randolph County would be 54 x 76 inches, Monongalia County 48 x 36 inches, and Hancock County 18 x 24 inches. Unlike paper maps, the larger county maps like Randolph County could be reduced to a smaller page size for publication purposes.

Table D: File and page sizes of other state highway maps.

Producer	File name	File size	Page size
PA DOT	allegheny_GHSN.pdf (Type 10)	7907 KB	36.24 x 49.25 in
	indiana_GHSN.PDF (Type 10)	5338 KB	36.15 x 49.17 in
	lycoming_GHSN.pdf (Type 10)	4275 KB	38.6 x 29.79 in
	allegheny_T3.pdf (Type 3)	2714 KB	23.99 x 18 in
	indiana_T3.pdf (Type 3)	1977 KB	20.02 x 25.47 in
	lycoming_T3.pdf (Type 3)	1376 KB	24.09 x 18.31 in
NJ DOT	atlantic.pdf	1857 KB	22.65 x 20 in
	essex.pdf	1190 KB	20 x 20.85 in
	sussex.pdf	2769 KB	20.97 x 20 in
	hudson.pdf	604 KB	18.21 x 20.29 in
	cumberland.pdf	1628 KB	20.18 x 20 in
KY DOT	adair.pdf	621 KB	27.64 x 16.78 in
	anderson.pdf	456 KB	27.6 x 16.78 in
	barren.pdf	961 KB	27.58 x 17 in
	edmonson.pdf	473 KB	27.65 x 16.78 in
	hardin.pdf	614 KB	18.5 x 28.13 in
NC DOT	alexa_plt01tif600.tif	969 KB	30.187 x 17.5 in
	alexa_plt02tif600.tif	879 KB	30.187 x 17.5 in
WVGISTC	County_highway_map_demo_41x26ls.pdf	4248 KB	41 x 26 in

APPENDIX E: GIS-T 2002 State DOT Survey and GIS Trends/Barriers

Source: Bruce Spear, Federal Highway Administration, Washington, DC; presented at the 2002 AASHTO GIS-T Symposium, Atlanta, GA.

- *2002 Summary of State DOT GIS Activities*
- *2002 summary spreadsheet and survey form sent out to state DOTs*
- *2002 Roll Call of State DOT Activities*
- *What is GIS-T? Beyond the State DOTs*

GIS-T 2002 Survey of State DOTs

- GIS Capability: Over 95% of state DOTs have some operational GIS capability.
- GIS Budget: 30% of state DOTs have GIS budgets over $1 million.
- GIS Core Staff: Full-time GIS core staff members are usually located in either the Information Services or Planning Divisions. The number of GIS professionals employed at state DOTs range from none to 52 (North Carolina), with a national average of 7 GIS professionals assigned to each state DOT.
- Digital Mapping Base: 95% of state DOTs have a digital mapping base, of which 36% of these mapping bases include all public roads.
- Base Mapping Scale: 89% of state DOTs use a base mapping scale of 1:24,000-scale or larger.
- Data Sharing: 83% of state DOTs participate in geo-spatial data sharing activities with other state agencies or organizations.
- GIS Software: Over 84% of state DOTs use more than one GIS software product, with ESRI GIS the most popular, followed by Intergraph/Microstation and TransCad.
- Database Software: Most DOTs utilize Oracle or Access for database management software.

Trends of GIS use in State DOTs

- Locating GIS core staff in Information Services
- Increasing budgets for GIS activities
- Decentralizing GIS applications to end users throughout the agency
- Making transportation databases more accurate and accessible to public
- Sharing of geographic data between county and state agencies
- Significant growth in web-based GIS
- Migrating to enterprise data integration systems

Barriers to GIS use in State DOTs

- Benefits not well articulated
- High costs for geo-spatial data development or conversion
- Competing non-GIS "legacy tools"
- No standard feature / attribute definitions
- Different accuracy / detail requirements for network database

Current GIS Applications

- Road feature inventory
- Highway asset management
- Safety management / crash analysis
- Highway project locations
- Traffic incident monitoring
- Road conditions / weather
- State highway map / atlas
- Road construction / detours
- Truck permitting / routing
- Environmental impact analysis conversion
- Competing non-GIS "legacy tools"
- No standard feature / attribute definitions
- Different accuracy / detail requirements for network database

APPENDIX F: State DOT GIS Implementation Plans (Excerpts from Kentucky, Maryland, New Jersey, Pennsylvania, and Utah plans)

Every state is unique in its mapping guidelines, digital base map development, database architecture, data sharing protocol, mapping project(s)/application(s), and stage of GIS development. Just from reviewing other state's county highway maps (Figures F1-F4), it is evident that variables such as the feature density, page size, mapping scale, map projection, as well as overall cartographic quality varies among state DOTs.

(1) KENTUCKY

Kentucky DOT Centerline Standards

On December 20, 2001, the Geographic Information Advisory Council (GIAC) adopted the Kentucky Transportation Cabinet's standard for the development of a highly accurate road centerline dataset. This will support state and local level GIS development since transportation is a critical infrastructure layer. This standard (and its associate data) supersedes the existing 1:24,000 scale coverages, which were based from USGS topographic maps. The new data is available as individual county coverages or as part of a statewide coverage. The county level coverages are made available as they are completed, with all counties scheduled for completion near the end of calendar year 2003. The statewide coverages contain the new centerlines where available with the older version data to complete the statewide coverage. These datasets can be downloaded from the Office of Geographic Information web site… http://ogis.state.ky.us/

A comprehensive description of the collection standards and methodologies can be found here: http://giac.state.ky.us/giac_road_centerline_standard_v1_0.pdf (1.6mb file)

(2) MARYLAND

Maryland I-Team Plan (pages 51-52)

General Discussion: Maintenance of the Transportation layer is a good candidate for vertical data integration. In a vertical integration scenario, new features are added at the local level to a high level of spatial accuracy, then migrated through State and Federal government levels, generalizing as needed. Due to its dynamic nature, the transportation layer requires daily maintenance and a data architecture needs to be designed in a manner which encourages and enhances the effectiveness of this data stream while helping to fulfill the requirements of TBTP and Smart Growth. There are also requirements for the ability to query and display information about incidents in a real time environment from both the State (CHART) and from local governments (E-911) which demand accurate and timely data. From the standpoint of information flow, vertical integration of this data layer is already in place. Local governments annually provide information to the Maryland State Highway Administration on new roads within their jurisdictions. Similarly, the State provides information to the Federal Highway Administration through both electronic and paper transactions. For true vertical integration this process needs only to be standardized and applied uniformly.

Existing Product: The Maryland State Highway Administration maintains 1:24,000 scale transportation data as part of its GRID map series. The files are produced and maintained in CADD formats and converted, by others, to GIS formats as required. Data collected for Maryland's report on the Vertical Integration of Spatial Data shows that the State Highway Administration spent approximately $110.00 per square mile to create the road centerline file. This equals approximately $1,067,000 for the entire state. Again looking at the Vertical Integration of Spatial Data Report, they spend an additional $194,000 maintaining the file each year.

Product Specification: Digital vector graphic features representing transportation elements shall be captured from aerial photography. Photography used will be suitable for capture of road centerlines, medians, edge of pavement, edge of travelway, rail lines, airport facilities and other transportation features as needed. Data spatial accuracy shall meet the parameters of National map Accuracy Standards (NMAS) for 1" = 200' (1:2,400) scale mapping.

(3) NEW JERSEY

New Jersey I-Team Plan (Chapter 6)

To meet the immediate business needs of multiple state, regional, and local government agencies, the State of New Jersey plans to license a statewide commercial transportation dataset that includes street centerlines with address locating capabilities. Funding for this data has been included in the State of New Jersey, Office of Information Technology Fiscal Year 2002 Budget. Acquisition of a commercial street centerline dataset is intended to augment rather than supplant the NSDI transportation framework.

New Jersey DOT Mapping Summary (Word Document)

All base maps regardless of scale must meet a definable standard, such as the United States National Map Accuracy Standard (NMAS) referenced in this document. This will guarantee true positional accuracy of data layers. The NJDOT has produced a series of maps at quad (1:24000) scale which meet NMAS standards.

New Jersey DOT utilizes Intergraph GIS software and Bentley's Microstation for their GIS-Transportation system.

(4) PENNSYLVANIA

PENNDOT's GEOGRAPHIC INFORMATION SYSTEM

Initial Strategic Plan: In September 1991, a GIS Strategic Plan was adopted and incorporated into the Department's Automated Technology Strategic Plan. The plan proposed a phased modular approach to implementing GIS. This allowed tasks to be completed and applications to be developed as technology, funding, and resources became available. The success of this GIS project was attributed to close cooperation among the Bureau of Planning and Research, Bureau of Information Systems, and a

Department-wide GIS Steering Committee. The Committee was instrumental in exploring key GIS issues and ensuring the successful implementation of a Department-wide GIS. The Development and Demonstration Division contracted for a competitive selection of GIS software in 1993. A consultant was hired to sort through the vendors responding to a Request for Information and arranged demonstrations from the top contenders. Intergraph, already used extensively within PennDOT for engineering Computer Aided Drafting Design (CADD), was selected as the GIS software, along with ORACLE for the Database Management Software (DBMS).

Base Map Development: Routine base-map maintenance activities are a coordinated effort between the Geographic Information and the Cartographic Information Sections. Both GIS and cartographic activities use a single set of digital road centerline base maps first developed during the mid-1980s from USGS 1:24,000 scale quadrangle maps. Railroad centerlines, legislative districts, airports, school districts, soils, urbanized areas, and intermodal facilities have also been added to the spatial database. The map projection is polyconic; the map datum is 1983. PennDOT does not use Census TIGER files or most national spatial data, nor do they generally digitize new spatial data. The philosophy of the GID is not to create data; rather integrate data from existing sources. Other data provided for District Office use include Digital Ortho-photo Quarter Quads (DOQs) from the mid 1990's and Digital Raster Graphics (DRGs). Both sets of data are stored in MrSID format by county.

Linear Referencing System: A single linear referencing system (LRS) is used throughout PennDOT to link the corporate databases to the road centerline base maps. The LRS is defined in the Department's Roadway Management System (RMS) as a county-route-segment-offset address. Each segment is roughly one-half mile in length.

(5) UTAH

Utah I-Team Plan (Section 8)

Theme Description: The transportation layers often include many features of transportation networks and facilities. For the purpose of this initial plan, only roads are included. For transportation issues related to growth, economic development, disaster preparedness, emergency response (especially wildfires) and public land management, all roads must be included in the transportation framework.

There are multiple versions of roads data maintained in Utah. One is a comprehensive GIS version that is a collaboration of state, federal, and local government agencies which complies to the Utah Transportation Data Model. Another is a derivative of that, maintained by the Utah Department of Transportations that is used for network analysis of state and federal routes, and which carries some additional attributes. Utah's Automated Geographic Reference Center (AGRC), a Division of Information Technology Services (ITS) of the Department of Administrative Services, currently maintains a version of 1:24,000 scale roads derived from USGS Digital Line Graph (DLG) and Forest Service Cartographic Feature File (CFF) data, which will be replaced by the collaborative version described above. There is also the transportation data available from U. S. Census Bureau Tiger Files, which currently supplies the best version of address data for the state.

Data Sources: There are many sources for this data. The State of Utah, U. S. Geological Survey, Forest Service, and the Bureau of Land Management have cooperated over the last several years to complete the initial digitizing of roads from the 1:24,000 map sheets. This data, which has a nominal positional accuracy of 20 meters, meets the traditional needs of many state and federal agencies. Because many of these maps were 20 – 50 years old, a revision process has started to bring them up to date. Revising those old maps from DOQs and other photographic sources, has been necessary to make them more accurate, complete, and current.

State policy for GIS implementation has recognized that users close to the geographic features usually have first hand knowledge of the data and can provide more accurate and timely data. Many rural counties have not had the resources to fully participate and provide accurate credible data to this effort without assistance however. To that end, the State Legislature has provided funding for the counties to purchase GIS and GPS equipment and begin a process to inventory and map every road in the county. For a variety of county responsibilities, sub meter GPS generated roads centerline data is required. This data, which incorporates the Utah Transportation Data Model, will contribute to the State Geographic Information Database (SGID) and the NSDI. Even though state and federal agencies traditionally relied on the 1:24,000 data described above, this sub-meter fully attributed data will provide much more useful information for them. From the start, this process has adhered to the Framework principles initially defined by the FGDC. The most important concept being the use of the best available data for the NSDI.

The State is also working with the Utah Association of Counties and the Census Bureau to identify and integrate address information tied to transportation systems. The Utah Association of Counties has been instrumental in engaging the counties in a discussion about rural addressing standards relative to transportation. The Census Bureau has talked to state and local agencies about options for improvement and modernization of information about transportation features in TIGER.

Most Appropriate Data Steward: After many years of meetings in Utah about transportation data, we feel we have arrived on an optimum model for data creation, maintenance, and distribution. Our intention is to have local government create data, as they are most familiar with what is on the ground. AGRC will integrate this locally generated data and do the quality control necessary to insure accuracy and completeness. State and federal agencies will then have access to it to use in their products. An example of this is the Forest Service is currently using data from the counties in conjunction with their revision of the maps on the Fish Lake National Forest with AGRC doing the QA/QC. All current data will be catalogued, documented, and distributed through the SGID as outlined in the Data Sharing MOU.

Census must continue to update and maintain address ranges for their products but the primary custodian of this data should be local government. Since there is currently no federal agency that has overall responsibility for all roads features, it makes sense that the Census Bureau be given that responsibility through the revised OMB Circular A-16.

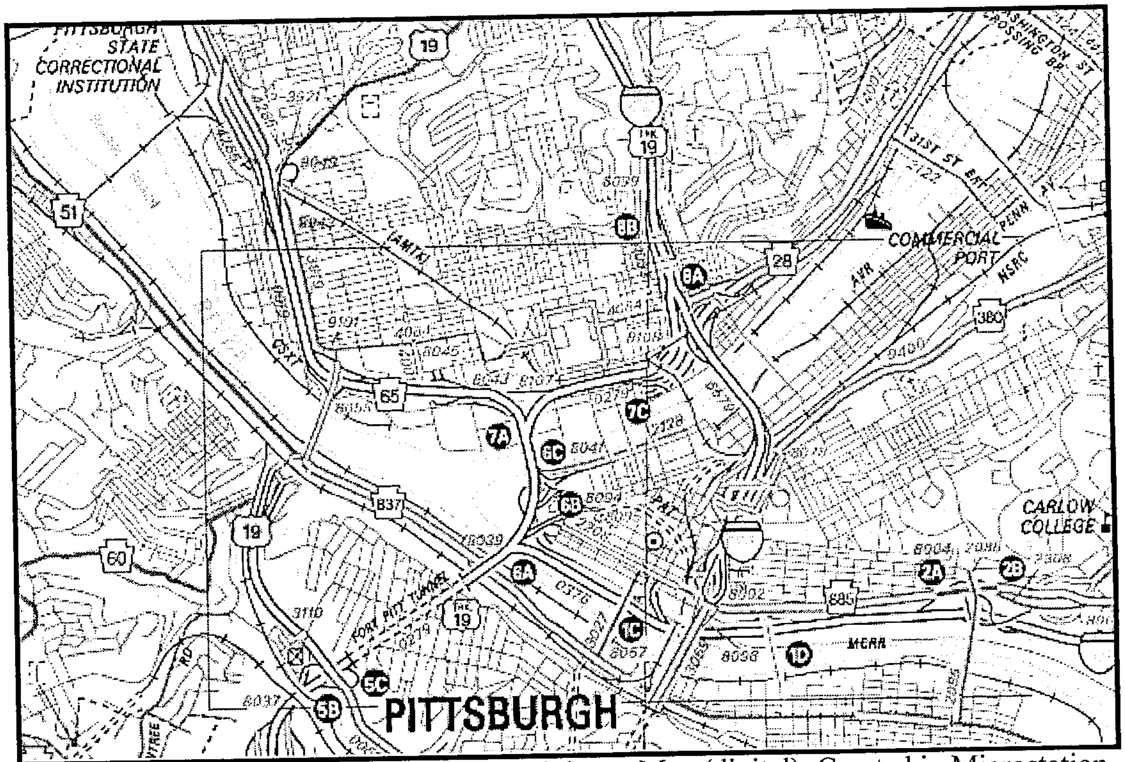


Figure F1-A: PA DOT Type 10 County Highway Map (digital). Created in Microstation.

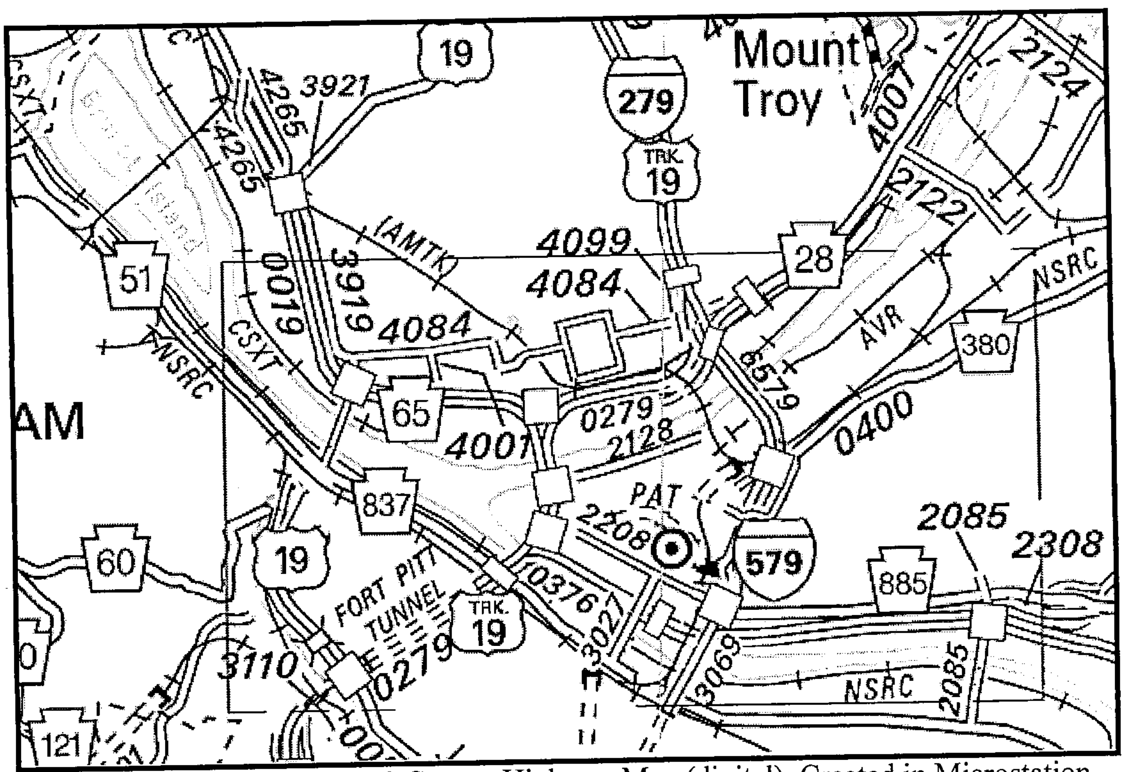


Figure F1-B: PA DOT Type 3 County Highway Map (digital). Created in Microstation.

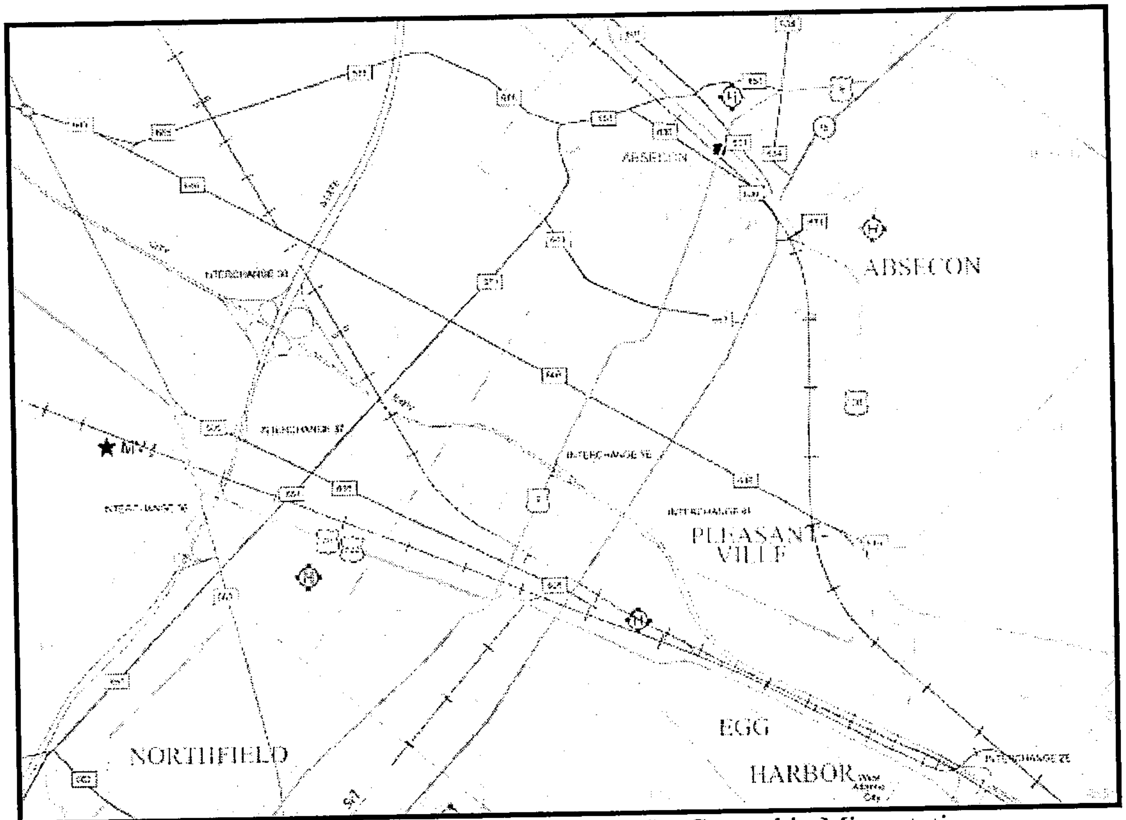


Figure F2: NJ DOT County Highway Map (digital). Created in Microstation.

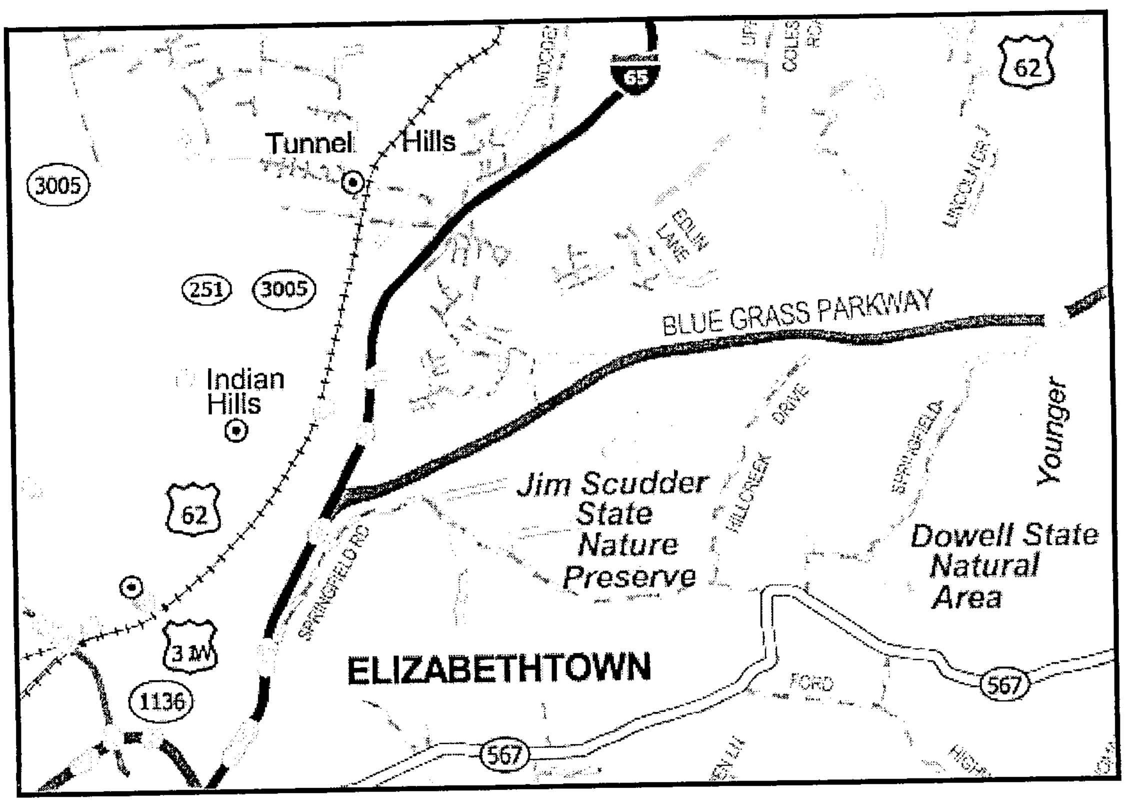


Figure F3: KY DOT County Highway Map (digital). Created with ArcView. Annotation must be redone for ArcGIS 8.2 software upgrade.

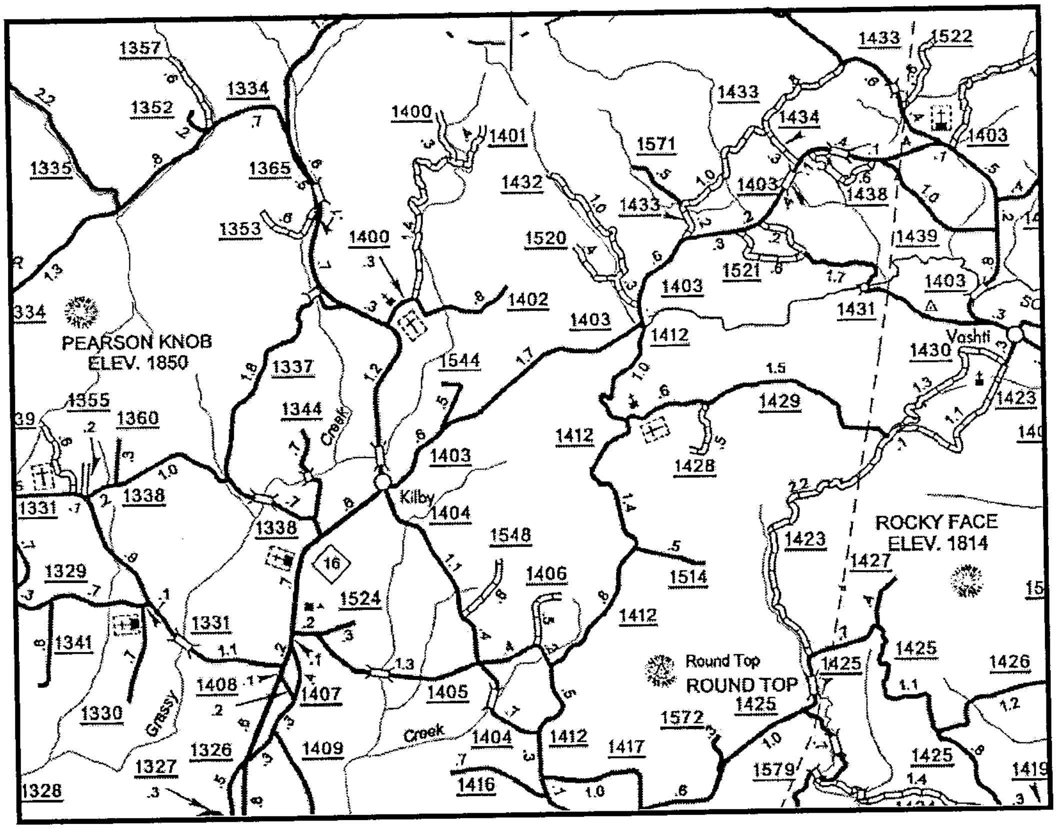


Figure F4: NC DOT County Highway Map (digital). Evident by mileages displayed on map, the NCDOT emphasizes linear referencing. Created in Microstation.

APPENDIX G: National Mapping Initiatives

(1) National Spatial Data Infrastructure (NSDI): The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 17 federal agencies that make up the Federal Geographic Data Committee (FGDC) are developing the NSDI in cooperation with organizations from state, local and tribal governments, the academic community, and the private sector. http://www.fgdc.gov/nsdi/nsdi.html

(2) I-Team GeoSpatial Information Initiative: The *I-Team Geospatial Information Initiative* (I-Team Initiative) is a joint project of the Federal Geographic Data Committee (FGDC), Federal Office of Management and Budget (OMB), the Council for Excellence in Government, Urban Logic, TIE, NSGIC, NACO, and other strategic partners. To build a National Spatial Data Infrastructure (NSDI), the I-Team Initiative addresses the institutional and financial barriers to development of the NSDI. It aims to offer a coherent set of institutional and financial incentives to make it easier for all levels of government and the private sector to collaborate in the building of the next generation of framework data. By aligning participant needs and resources, the I-Team Initiative will help all levels of government and the private sector to save money, migrate from existing legacy systems, make better user of existing resources, and develop the business case for additional public and private resources. http://www.fgdc.gov/I-Team/

(3) The National Map: Sponsored by the U.S. Geological Survey, *The National Map*, will be a seamless, continuously maintained set of geographic base information that will serve as a foundation for integrating, sharing, and using other data easily and consistently. http://nationalmap.usgs.gov/

(4) Geospatial One-Stop: The *Geospatial One-Stop* is a part of the new Office of Management and Budget (OMB) E-Government initiative to improve the effectiveness, efficiency, and customer service throughout the Federal Government. *Geospatial One-Stop* will revolutionize E-Government by providing a geographic component for use in all Internet based E-Government activities across local, state, tribal and federal government. http://www.fgdc.gov/geo-one-stop/index.html

Bureau of Transportation Statistics (BTS): Within the NSDI Transportation theme, the Bureau of Transportation Statistics will be responsible for coordinating the development of its content standard. Transportation is also unique since different modes use different transportation networks. This will be reflected in the development of content standards, in that a separate standard will be developed for each mode (highways, railways, air, and transit). http://www.bts.gov/gis/geospatial_onestop/index.html

Open GIS Consortiums (OGC): OGC is an international industry consortium of more than 220 companies, government agencies and universities participating in a consensus process to develop publicly available geoprocessing specifications. OGC Seeks Interested Parties for Geospatial One-Stop Transportation Pilot Activity.

APPENDIX H: Federal Identification and Core Content Transportation Standards

NSDI Framework Transportation Identification Standard

The FGDC Ground Transportation Subcommittee is sponsoring the development of a conceptual data model standard for identifying road segments as unique geo-spatial features which are independent of any cartographic or analytic network representation. These road segments will form the basis for maintenance of NSDI framework road data (through transactions and other means), and for establishing relationships between road segments and attribute data.

The BTS has identified four dominant transportation modes that comprise the NSDI Transportation layer: roads, rail, transit, and air. Because each mode is slightly different from each other, a separate standard will be developed for each.

Roads - Two standards are currently under development, the *NSDI Framework Transportation Identification Standard* (completed public review) and the Framework content standard for roads. The Identification Standard has been in development for approximately three years and was designed to enhance the sharing of data about transportation features. The Identification Standard was developed with little input from the vendor community and is technology and software neutral. Applications for the standard have not been developed nor has a mechanism to demonstrate its use and benefit been established. The FGDC Ground Transportation Subcommittee hopes to complete final modification and submit a final draft to FGDC by the summer of 2002.
The Framework content standard for roads will be designed to enhance data sharing. BTS has put out for bid a contract that will assist in the standard's development; also BTS is preparing to underwrite some expenses for application development and advertisement. Finally the USDOT is actively seeking individuals for participation in becoming either a Model Advisory Team member or joining the process in some other capacity.

Railroads, Transit, Air - The process for developing Framework content standards for the other transportation modes (Railroads, Transit, and Air) are just beginning. The USDOT is actively seeking individuals interested in contributing to the development of these standards.

For more information search FGDC and BTS websites:
(1) http://www.fgdc.gov/standards/status/sub5_7.html
(2) http://www.bts.gov/gis/fgdc/web_intr.html
(3) http://www.bts.gov/gis/fgdc/comments/index.html

APPENDIX I: Linear Referencing Systems (LRS)

A linear referencing system is a set of datums, networks, and linear referencing methods, whereby each point along a network can be identified uniquely by specifying the direction and distance form any known point on the network.

Linear reference systems, an essential component of transportation management applications, are complex, vendor specific, user specific, and difficult to transfer information between different computer mapping systems. Below are some articles about this subject and research on developing industry standards.

Roadway Inventory and Linear Referencing System
Identify a primary linear reference system (LRS) that can provide a valid platform for the Asset Management and TSIMS efforts. Identified a need for a "Best Practices" model for the Linear Reference System

On The Results of a Workshop on Generic Data Model for Linear Referencing Systems, Program (NCHRP), Project No. 20-27, Alan Vonderohe (editor), University of Wisconsin, Madison, WI, 1995. Summary of a workshop sponsored by the National Cooperative Highway Research

Guidelines for the Implementation of Multimodal Transportation Location Referencing Systems, National Cooperative Highway Research Program, Project 20-27(3), FY 1996. Further research is necessary to develop a comprehensive LRS data model that encompasses multimodal, multi-dimensional locations of stationary objects as well as moving vehicles.

(PDF] NCHRP 20-27(3) Multi-Modal Transportation LRS Data Model and Implementation Guidelines...
Administered by the Transportation Research Board (TRB) and sponsored by the member departments (i.e., individual state departments of transportation) of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA), the National Cooperative Highway Research Program (NCHRP) was created in 1962 as a means to conduct research in acute problem areas that affect highway planning, design, construction, operation, and maintenance nationwide.

LINEAR REFERENCING SYSTEM REQUIREMENTS: Chapter V: HPMS Field Manual Chapter V HPMS Field Manual December 2000 CHAPTER V LINEAR REFERENCING SYSTEM REQUIREMENTS In the past, HPMS data has been analyzed and viewed as tables, charts, and graphs. Furthermore, any

[PDF] A Conceptual Design for the Iowa DOT Linear Referencing System
Iowa Department of Transportation LRS Development Project Page 7 Figure 2 LRS Operational

[PDF] GIS FOR TRANSPORTATION GIS FOR TRANSPORTATION
Understanding LRS. Linear Reference Systems by Geoanalytics

Support and Build the New LRS
NCDOT adopted a standard organizational LRS in 1998. Uses a single permanent LRS ID for each roadway length.

Functional Requirements for Road Centerline Databases
Cartography, georeferencing, network applications. Bruce Spear, Bureau of Transportation Statistics

LINEAR REFERENCING SYSTEMS 10/01/94 Report
FGDC Ground Transportation Subcommittee Position and Recommendations