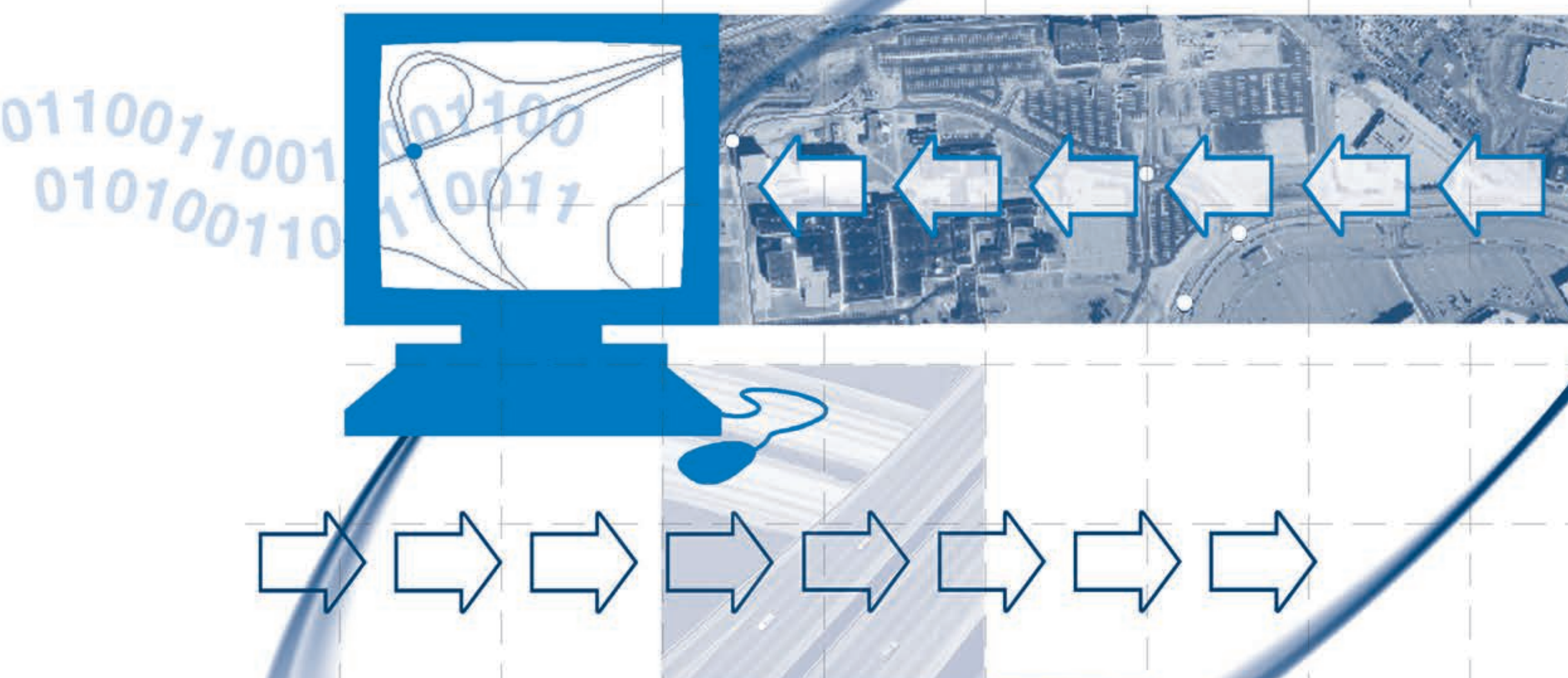
VOLUME V - EXECUTIVE SUMMARY

Region-wide Transportation GIS Project Design and File Architecture



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DELAWARE VALLEY REGIONAL PLANNING COMMISSION

Created in 1965, the Delaware Valley Regional Planning Commission (DVRPC) is an interstate, intercounty and intercity agency that provides continuing, comprehensive and coordinated planning to shape a vision for the future growth of the Delaware Valley region. The region includes Bucks, Chester, Delaware, and Montgomery counties, as well as the City of Philadelphia, in Pennsylvania; and Burlington, Camden, Gloucester and Mercer counties in New Jersey. DVRPC provides technical assistance and services; conducts high priority studies that respond to the requests and demands of member state and local governments; fosters cooperation among various constituents to forge a consensus on diverse regional issues; determines and meets the needs of the private sector; and practices public outreach efforts to promote two-way communication and public awareness of regional issues and the Commission.

Our logo is adapted from the official DVRPC seal, and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole, while the diagonal bar signifies the Delaware River. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

DVRPC is funded by a variety of funding sources including federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA), the Pennsylvania and New Jersey departments of transportation, as well as by DVRPC's state and local member governments. The preparation of this document was funded by grants from the Federal Highway Administration and the Pennsylvania Department of Transportation. The authors, however, are solely responsible for its findings and conclusions, which may not represent the official views or policies of the funding agencies.

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I. Background

As the federally designated Metropolitan Planning Organization (MPO) for the Philadelphia Metropolitan Area, the Delaware Valley Regional Planning Commission (DVRPC) is responsible for working on a variety of issues with the Commonwealth of Pennsylvania, the State of New Jersey, the City of Philadelphia, four suburban Southeastern Pennsylvania and four suburban Southern New Jersey Counties that comprise the Region. Among the most critical of these issues are those pertaining to transportation and transportation planning.

In order to support required activities and functions related to the agency's core responsibilities, DVRPC has adopted a number of advanced technologies including a geographic information system (GIS). By implementing a GIS, DVRPC has been able to enhance and extend the analytical capabilities of its technical staff, while also providing a framework for creating and maintaining regional-scale digital mapping.

Coincidentally with DVRPC's development of a GIS, a number of local and state government entities and transportation operating agencies throughout the region have implemented similar systems and databases of their own. In most cases, these systems have been developed independently, with limited consideration given to regional cooperation and coordination. In order for DVRPC, its member organizations, transportation operating agencies, and other local and state entities holding a stake in the region's transportation infrastructure to fully realize the benefits of GIS, it is necessary for there to be region-wide continuity in the transportation GIS process. This continuity is far more achievable when a common technical basis is established and maintained.

I-1 Project Purpose

The primary purpose of this project is to "assure that each of these entities (DVRPC, its member city and county governments, and transportation operating agencies) has a GIS and data files that can be developed and seamlessly shared with each other to facilitate better transportation planning analysis and decision-making among the counties, the regions, and the states." It is the anticipation of DVRPC that accomplishing this purpose will require efforts on the part of all participants to supplement whatever data systems may be available from state, regional or federal sources. The purpose of the work to be performed for this project is to lay the foundation and establish the basic systemic and operational framework for these efforts.

I-2 Project Goals

In formulating the requirements of this project, DVRPC has focused on four major project goals. These goals are stated below.

Goal No.1: "Expand the use of GIS among all transportation planning partners and assist all members to improve their capacity as needed to reach a common operational level."

DVRPC recognizes that in order to expand and support the use of GIS by its members and others within the region, it is first essential to fully understand the needs for GIS among those entities. A primary stumbling block for most failed GIS implementations has been a fundamental failure to identify and define the basic needs for GIS of the organization for which the implementation has failed. Before GIS use can be expanded and enhanced within the region, it will be paramount for true needs of the end user organizations to be determined and documented. This project is designed to accomplish this.

Goal No. 2: "Evaluate the transportation GIS files developed and maintained by federal and state agencies, DVRPC member governments and transit operators to determine how they can be used in an accurate and regionally consistent manner."

DVRPC recognizes that there exists a large amount of GIS data among its members, in a variety of base scales, resolutions and formats. This applies to federal and state agencies, as well. It is critical that DVRPC does not waste substantial resources in "reinventing wheels" in its efforts to implement a region-wide transportation GIS. For this reason, DVRPC has established a goal for optimizing the considerable investments that have been made in developing and refining these various data sets. Through a process of careful needs assessment and relevant data gathering, DVRPC is promoting the concept.

Goal No.3: "Provide for the seamless exchange of GIS data files and the integration of planning infrastructure among all member governments and operating agencies."

A substantial amount of effort that is expended on this project will have been wasted if an ineffective implementation strategy is designed and implemented. Part of a successful implementation strategy for this project must include provisions for data sharing among the participating members. Along with this data sharing will come enhanced capabilities for intergovernmental cooperation for transportation planning. DVRPC has applied this basic premise to structuring and delivering implementation strategies to its member organizations. This project presents the opportunity to consider new, state-of-the-art approaches to GIS data management that may change the way DVRPC and its members do business, creating new and improved opportunities for working cooperatively towards common goals.

Goal No. 4: "Structure the region-wide GIS design so that it can be expanded and enhanced by individual partners, while maintaining its consistency and exchangeability."

The approach taken by DVRPC introduces technology tools that will significantly enhance it's own capabilities and those of its member entities for creating and maintaining a truly dynamic transportation GIS. This approach is focused on the database and not any specific proprietary software solution. This solution introduces substantial flexibility with regard to the database maintenance options that can be applied. The concept of using a database engine that supports multiple software platforms is a truly unique, yet proven, effective means for achieving this goal.

II. Needs Assessment Phase

This project has been conducted in several phases. The first of these is the Needs Assessment Phase. The purpose of the Needs Assessment Phase was to (1) Expand the use of GIS among all transportation planning partners and assist all members to improve their capacity as needed to reach a common operational level; and (2) Evaluate the transportation GIS files developed and maintained by federal and state agencies, DVRPC member governments and transit operators to determine how they can be used in an accurate and regionally consistent manner. In order to reach these goals it was necessary to extract a variety of information related to GIS for transportation planning from all of the member agencies. The information that was gathered included linework quality, attribute quality, availability and information related to the hardware and software that was currently in use. This was accomplished through a series of face-to-face interviews where the member agency representatives not only defined their current conditions relating to GIS for transportation planning, but were also allowed to express their concerns related to this topic as well.

The principle data collection technique that was employed consisted of interviews conducted with responsible representatives of each of the organizations listed in the following table.

New Jersey (State):
New Jersey Department of Transportation
New Jersey Transit Corporation
New Jersey Turnpike Authority
New Jersey (Local):
Burlington County Engineer’s Office
Burlington County Office of Information Processing
Camden City Department of Development and Planning
Camden County Division of Engineering
Camden County Division of Planning
Camden County Improvement Authority
Gloucester County Planning Division
Mercer County Planning Division
Trenton City Department of Development and Planning
Trenton City Department of Housing
Pennsylvania (State):
Pennsylvania Department of Transportation – Bureau of Planning and Research
Pennsylvania Department of Transportation – District 6 Office
Pennsylvania Turnpike Commission
Pennsylvania (Local):
Bucks County Planning Commission
Chester County Department of Computing and Information Services
Chester County Planning Commission
Delaware County Planning Department
Montgomery County Planning Commission
Philadelphia City Planning Commission
Philadelphia City Mayor’s Office of Information Services
Philadelphia City Police Department
Philadelphia City Streets Department
Regional:
Delaware River Port Authority
Delaware Valley Regional Planning Commission
Port Authority Transit Corporation
Southeastern Pennsylvania Transportation Authority

Table 1 - List of Participating Organizations

First, the interviews were scheduled and initial pre-interview surveys were sent to the member agency representatives. These pre-interview surveys served two purposes. One, they allowed the representatives to gain insight on what type of questions would be asked at the actual interview; and two, they afforded the representatives the opportunity to verify that the proper personnel would attend the interview. Although the interview had a defined agenda with specific questions, the format was informal, allowing the chance for free flowing discussions regarding transportation planning for GIS. The discussions covered information like hardware and software resources, personnel resources, linework scale and extent and basically anything else related to GIS for transportation planning. From the interviews, the level of accuracy and detail required to support GIS-based transportation planning activities on a region-wide scale became apparent. The interview results were compiled into specific needs assessments for each member agency and those results were then forwarded to the agency for review and comments. Once all of the agencies had approved their assessment, the needs assessment phase was deemed complete.

II-1 Summary of Results

Information that was collected, compiled and analyzed through the Needs Assessment process revealed a number of pertinent, interesting details regarding the use of GIS technology throughout the region. The following section outlines some of the more critical of these details. The comments that are presented are organized by the four (4) primary subject areas addressed by the process: (1.) general use of GIS and related technologies; (2.) geography files (spatial data) currently being used and maintained; (3.) database files (attribute data) currently being used and maintained; and (4.) interoperability and data sharing.

II-1.1 General Use of GIS and Related Technologies

The Needs Assessment surveys revealed the widespread use of GIS and related technologies among the participants. There are basically two levels of sophistication. Characteristics of those at the higher level include:

- Substantial hardware and software resources
- Integration with other systems
- Accurate database
- Data maintenance program

Included among this group are Chester County and the City of Philadelphia in Pennsylvania and Burlington County in New Jersey. Also included are the Pennsylvania and New Jersey Departments of Transportation, New Jersey Transit Corporation, Pennsylvania Turnpike Commission and DVRPC.

Those at the lower end are typically characterized by:

- Limited hardware and software resources
- Standalone operations
- Limited database accuracy
- Little or no data maintenance

Included among this group are Montgomery County, Pennsylvania and the City of Camden, New Jersey. Most of the remaining participants fall somewhere in between the low and high ends of the technology spectrum

II-1.1.1 GIS Applications

With regard to the applications of GIS technology, the region-wide base of applications is relatively consistent. Of the participants actively using GIS the following are the predominant applications:

- Land Information Systems (Cadastral)
- Land Use and Zoning (Planning)
- E-911 Emergency Services
- Asset Management

Among those that are most actively applying GIS in some or all of these ways are Chester County and the City of Philadelphia in Pennsylvania, and Burlington County, New Jersey.

Other, more advanced applications in evidence are:

- Integration with Other Systems (E-911, development approval)
- Routing (municipal service vehicles, transit systems)

A notable example of this is the City of Philadelphia's use of GIS technology to support the efficient routing of trash trucks. Chester County has integrated GIS technology in both its E-911 services and its development review and approval process.

Virtually no local participants reported an active use of GIS for transportation planning. Only the State and regional participants currently use GIS for transportation planning.

II-1.1.2 Organizational Entity Responsible for GIS

The Needs Assessment process also addressed some organizational issues regarding the use of GIS technology. A critical issue is the component of the organizational structure that holds responsibility for managing and maintaining the GIS. The interview process revealed that there exist a variety of types of organizational entities that are responsible for GIS. These include:

- Planning Department
- IS/IT Entity
- DPW, Engineering
- GIS Section or Group

Generally, the identity of the organizational entity that is responsible for GIS for any given participant is directly correlated to the level of sophistication of GIS usage described earlier. That is, those organizations at the high end of the spectrum typically have a dedicated GIS entity within their organizational structure. For example, DVRPC, Chester County, the City of Philadelphia and Burlington County all have formal GIS sections or departments that are responsible for managing the GIS. The City of Camden, New Jersey, at the low end of the spectrum, is using GIS, but the system is maintained on an ad hoc basis by a single individual in the Planning Department.

II-1.1.3 GIS Software

The vast majority of participants are using GIS software developed and marketed by Environmental Science Research Institute (ESRI). Exceptions include the Departments of Transportation and New Jersey Transit Corporation, who are users of Intergraph software.

Here again, the types of software that are being used are generally consistent with the level of technical sophistication. Those at the higher end are typically using the full range of GIS software products, supporting a wide range of applications from desktop mapping to the serving of maps and data across the Internet. At the low end, software that supports relatively simple desktop mapping and fundamental database queries is normally found.

II-1.1.4 Hardware Platforms

The interview process revealed that virtually all the participants are using Intel-based desktop systems and servers to support their GIS operations. There are a limited number of UNIX servers in use. The relative amount of hardware resources and the network infrastructure that is in place varies widely.

II-1.1.5 Data Management and Strategic Planning

The two final topics addressed under this category included the management of GIS data in terms of the use of formal metadata and the existence of a strategic plan for the future development of GIS. At this time, roughly 50% of the participants are using some form of metadata. In Pennsylvania, most of the metadata conforms to the Pennsylvania Spatial Data Access (PASDA) standard, while most New Jersey participants are using NJ Metalite, a system that creates and maintains metadata in a format that is a subset of the Federal Geographic Data Committee (FGDC) standard.

The majority of the participants have no strategic plan in place for GIS. Most have expressed recognition of the value of such a plan and a desire to have one. Of those plans that do exist, most have not been fully implemented or followed.

II-2 Geography Files (Spatial Data) Currently Being Used and Maintained

During the Needs Assessment process, participants were asked about the geography data files that they may currently use and maintain as part of their GIS. As with the prior category, the responses were varied. For the most part, the existence and use of a road centerline file was emphasized.

II-2.1 Road Centerline

Virtually all of the participants currently use a road centerline file of some sort or another. Considered on a region-wide basis, these centerline files are characterized by a lack of consistency in scale and map projection, data sources, level of data maintenance and types of applications. There is also variation in the extents or geographic area that is encompassed, as reflected in the following list:

- PennDOT – State routes
- NJDOT – State and county roads
- Counties – All roads within County
- Cities – All roads within City
- PA and NJ Turnpike – Turnpike only
- DVRPC – All roads in region
- NJ Transit – All roads in State
- SEPTA – All roads in service area (dated)

II-2.1.1 Scale and Map Projection

Differences in scale are normally correlated with extent of area covered. The following list shows some examples:

- State-Level → Typically 1"=2,000'
- Region-Level → Typically 1"=1,000' – 1"=2,000'
- County-Level → Typically 1"=200' – 1"=1,000'
- Municipal-Level → Typically 1"=50' – 1"=400'

Differences in map projection typically reflect the location of a given participant within one of the two states encompassing the region. Participants in Pennsylvania typically use Pennsylvania State Plane coordinates; those in New Jersey use New Jersey State Plane coordinates. For databases that include areas in both states, DVRPC uses Universal Traverse Mercator (UTM). Since the Pennsylvania State Plane grid is divided into a north and south zone, PennDOT uses a Polyconic map projection. All of the local DVRPC members fall within the Pennsylvania South Zone.

II-2.1.2 Source Data

Source data refers to the information that was originally used to create the centerline file, whether it is a paper map or some sort of computer-based data. Within the DVRPC region, road centerline source data typically falls within the following categories:

- Digitization From Paper Source Maps
- Aerial Photography/Photogrammetric Mapping
- Captured With Global Positioning Systems
- Purchased From Third Party

Of these, the latter two are the most prevalent sources of road centerlines. A number of participants have purchased centerline data from third party suppliers, with varying degrees of success.

II-2.1.3 Level of Data Maintenance

The success of any GIS hinges on the quality of its database. The quality of data is directly related to the currency and completeness of the database. High levels of currency and completeness can only be achieved through a regular program of data maintenance and updating.

As with other issues addressed through the Needs Assessment process, the existence of data maintenance programs and their relative levels vary significantly throughout the region. Some of the participants such as Chester County, City of Philadelphia, Burlington County, DVRPC, the DOTs, and New Jersey Transit Corporation, have regular data maintenance programs in place that ensure that the data being accessed by their respective end users is reliable. Furthermore, integration of the GIS data maintenance and update process with other information systems is present within the region. For example, Chester County's GIS data update process is tied closely with the County's E-911 system and with its development review and approval process. PennDOT has several business processes in place to ensure that the GIS database is updated automatically with data that is generated by other systems.

At the other end of the spectrum are those organizations with little or no GIS data maintenance plans in effect. Again, there exists a close correlation between the lack of a data maintenance process and a relatively unsophisticated level of GIS utilization. Many of the organizations that originally acquired commercial data as a means of establishing a centerline file have since abandoned that approach for the very reason that maintenance and updating of a proprietary database is often difficult due to licensing and other issues.

II-2.1.4 Types of Applications

Typical GIS applications for road centerline files include such things as:

- Location of linear and point event data though geocoding
- Vehicle locating and routing
- Asset management
- Emergency services
- Base mapping

Through the Needs Assessment, it has become apparent that examples of all of these applications exist throughout the region. The most predominant is base mapping and some degree of variation exists within this individual application area, particularly in the use of symbology to display various aspects of map features.

II-3 Database Files (Attribute Data) Currently Being Used and Maintained

The Needs Assessment process also addressed the related database files that are being used and maintained by the various participants as part of their GIS operations and as part of their enterprise-wide (city, county, etc.) information systems. This information is particularly critical, for the sharing and communication of the information being captured, managed and maintained within these databases throughout the region is the primary long-term goal of this project. Typically, these databases contain event data such as traffic accidents, traffic counts, transit stop locations, bus routes, construction project locations, etc. Information collected through the Needs Assessment covered a variety of topics.

II-3.1 Database Management Software

Database management software is the software that is used to develop, manage and maintain the data that are associated with the features in the geographic files. In a GIS operating environment, there are a number of options available for storing attribute data. The Needs Assessment process found a number of database management systems in use supporting GIS operations, including:

- INFO – This is the database management software that is bundled with ESRI software
- Microsoft Access
- DBF – This is the database management software supported by ESRI's Shapefile format
- Oracle – This is a leading enterprise database management system
- SYBASE – This is also a leading enterprise database management systems

At the enterprise level, the predominant systems included Oracle, DB2 and SYBASE. It is interesting to note that in many cases, the interviewees were unaware of the database management system that is being used by the enterprise.

The respondents were asked if there were plans to migrate the GIS attribute data to an enterprise-wide database platform. This is relevant in that it serves as an indication of the likelihood that GIS technology will become an integral part of the organization's IT infrastructure. Approximately one-half responded in the affirmative. This was particularly true in cases where an IS/IT entity has responsibility for the GIS within the organization.

II-3.2 Mainframe Usage

About one-third of the organizations reported that they use mainframe computers as part of their IT infrastructure. Most of this usage is for legacy tax assessment applications. Some public utility applications (customer billing, plant operations) also fit into this category.

II-3.3 Road Centerline Attributes

Road centerline attributes refer to those attributes that are stored directly with the geographic feature that represents the centerline in the GIS. These attributes are distinguished from external event table attributes by the fact that they are not maintained in external database tables but are stored in attribute tables that comprise a part of the internal GIS database structure. The Needs Assessment process revealed that most of the participants use and some maintain road centerline attributes, which includes the following:

- Unique identifier
- Street names
- Address ranges
- Direction of traffic
- Road or street classification

II-3.4 Placement of Event Attributes on the Centerline

With regard to the process of relating external event attributes to a specific location along a road centerline, the Needs Assessment process focused on two primary components: the attributes that are being placed along the centerlines and the methods that are employed to perform this placement. This process is typically referred to as geocoding. The result of the process is the assignment of a geographic location to the event in terms of a pair of coordinates for point events and starting and ending coordinates for linear events. For the most part, the event attributes that are being located along centerlines through GIS processes include:

- Traffic accident locations
- Traffic count locations
- Transit routes
- Asset locations (traffic signs, signals, etc.)

Approximately one-half of the participants are using GIS to locate events along centerlines. The primary practitioners are the DOTs and the transit agencies, but a number of cities and counties are doing this also. The methods by which this is being accomplished include:

- Address matching
- Capture of GPS coordinates
- Intersection location
- Street segment/offset
- Route-milepost
- Standard Route Identifier (SRI) number

This is significant because the successful implementation of a region-wide GIS transportation model will require that all participants possess the capability for locating events along centerlines and that all participants implement a database design that fully supports this process.

II.3-5 Unique Identifier and Street Address Ranges

The mapping of event data using GIS software requires elements in the database that support the various methods described above. Through this project, it has been determined that the two most critical elements are a unique identifier and street address ranges for each centerline segment. Most of the participants that were interviewed do not have a meaningful unique identifier other than a standard value that is assigned, normally automatically, by the host GIS software. The DOTs currently maintain a system of unique identifiers and several local governments, including Chester County and the City of Philadelphia, maintain street address ranges. Others use street address ranges that are included with a commercial centerline product.

II-3.6 Other GIS Data Types

One goal of the Needs Assessment process was to ascertain the extent to which other, related GIS data types are maintained and used throughout the region. The most prominent of these are:

- Mostly Cadastral (Parcels)
- Asset Locations (Traffic Signs, Signals)
- Land Use
- Zoning

II-4 Interoperability and Data Sharing

Interoperability and data sharing refers to the levels at which organizations have integrated their GIS operations with the enterprise IT operations, including other GIS applications, and the extent to which they effectively share data with other organizations. The interview process focused on these issues as a means of assessing the potential capabilities of the member organizations for participating in a future region-wide data sharing arrangement.

The primary elements for assessing current and future data sharing capabilities include:

- Integration of GIS data of various scales and from various sources
- Receipt of data from other organizations from within the region
- Level of data requests received from outside the organization
- Existence of a data distribution policy
- Transportation GIS data elements that are desired by the member organizations
- Perceived potential applications of transportation-related GIS data

Interviewees were asked to provide information for each of these elements.

II-4.1 Integration of GIS Data of Various Scales and From Various Sources

This element serves as an indication of the degree to which multi-disciplined applications of GIS exist throughout the region. Data that represents land use is typically maintained at a scale and level of accuracy that is less precise than property ownership data. Using the two data sets concurrently within a single application could introduce errors and lead to erroneous results. For the most part this is not being practiced by the DVRPC member organizations.

II-4.2 Receipt of Data From Other Organizations

This element serves as one indication of the degree to which member organizations are currently sharing GIS data amongst themselves. Nearly 100% of the respondents reported some form of sharing transportation-related GIS data. This occurs in both New Jersey and Pennsylvania. Predominantly, the "flow" of data is "top-down". That is, most of the data is provided by the DOTs, DVRPC and the transit agencies down to the local government level. There is little data flowing up from the local governments to the regional and state agencies.

II-4.3 Data Requests From Outside the Organization

This element also serves to indicate the level of data sharing that currently exists throughout the region. Most of the respondents reported some form of data requests coming in from external organizations, yet outside of special cases, the practice does not appear to be widespread or commonplace. The following list reflects some of these data requests that were identified:

- DOTs – Requests from other State agencies, DVRPC, transit, Counties, Cities
- DVRPC – Requests from Counties
- Transit Agencies – Requests from DOTs, Counties, Cities
- Counties – Requests from municipalities and consultants
- Cities – DVRPC, SEPTA

II-4.4 Data Distribution Policy

The formulation of future data sharing arrangements may require that participants put into place policies that govern the distribution and ultimate use of the data. One goal of the Needs Assessment process was to identify similar policies that exist within the region currently. About one-third of the participants currently have a data distribution policy in place. Those that do exist typically are comprised of a policy and a pricing schedule. Chester County, Burlington County and DVRPC are some of the organizations with data distribution policies.

II-4.5 Transportation GIS Data Elements Needed by Member Organizations and Potential Applications

As another means of defining the future potential for region-wide data sharing, the participants were asked to identify the GIS data elements that they would like to have in order to develop their transportation GIS databases and potential applications for which the data would be used. This information is pertinent to define future data needs and database development requirements. The most prevalent data elements identified were:

- Transit (routes and stops)
- State and local road project data

- Asset management data
- Long term road maintenance plans
- Variety of event data (accident locations, traffic count locations, etc.)

The interview process revealed a relatively high level of interest in obtaining and applying these types of data elements.

Potential applications that were identified included:

- Routing (emergency services, snow plows, school buses)
- Asset management
- Crime analysis
- Intelligent Transportation Systems
- Video log
- System usage analysis (Transit)

II-5 Needs Assessment Conclusions

As a result of the Needs Assessment process, there are a number of conclusions that can be drawn from the information that was collected. These are summarized as follows:

1. The development and implementation of a centralized, regional transportation GIS database is unlikely. The success of this project clearly depends upon the adoption and implementation, by the member organizations, of a region-wide GIS database model that supports the sharing of pertinent data elements while allowing the members to independently develop and manage their centerline files.
2. There exists a high level of interest in, and need for, transportation GIS data throughout the region.
3. Successful data sharing in the current environment hinges on three primary factors:

   - Database approach - The approach to implementing a region-wide transportation GIS data model should be focused on the database, not the linework. The database should be designed independently of linework data. The database should be designed to support linear referencing and street address geocoding. Finally, the database should be designed to support broad-based transportation planning efforts.
   - Staged process – The process of implementation needs to be staged. The process should establish the current status of each participant. A baseline needs to be established and focused implementation plans need to be developed for each member organization.
   - Prototypes - The use of prototypes would be a useful tool for validating any proposed approach. These prototypes should be used to test various scenarios for implementation at various stages. Actual data should be applied to establish a common operational framework while preserving the independence of each organization in developing their internal GIS operations and databases.

II-6 Four Stages of Centerline Development

The most practical end result of the Needs Assessment phase was the identification of four (4) stages of centerline development. In defining the characteristics of each stage, consideration was given to the most critical components of a transportation GIS as determined through the Needs Assessment interview phase and current technical standards for GIS applications for transportation planning. On the basis of this determination, the following components were identified:

- A base road centerline geometry that is topologically accurate and is updated and maintained on a regular basis
- An attribute database that is related to the graphic components of the centerline and includes a unique identification attribute (unique identifier) for each road segment
- A road centerline and related attribute database that supports a Linear Referencing System (LRS) accompanied by a GIS that applies a Linear Referencing Method (LRM) for dynamically locating events along road segments

These stages lie on a scale from Stage 1 through Stage 4, with Stage 1 being the least supportive of GIS for transportation planning and Stage 4 being the most supportive of these types of applications.

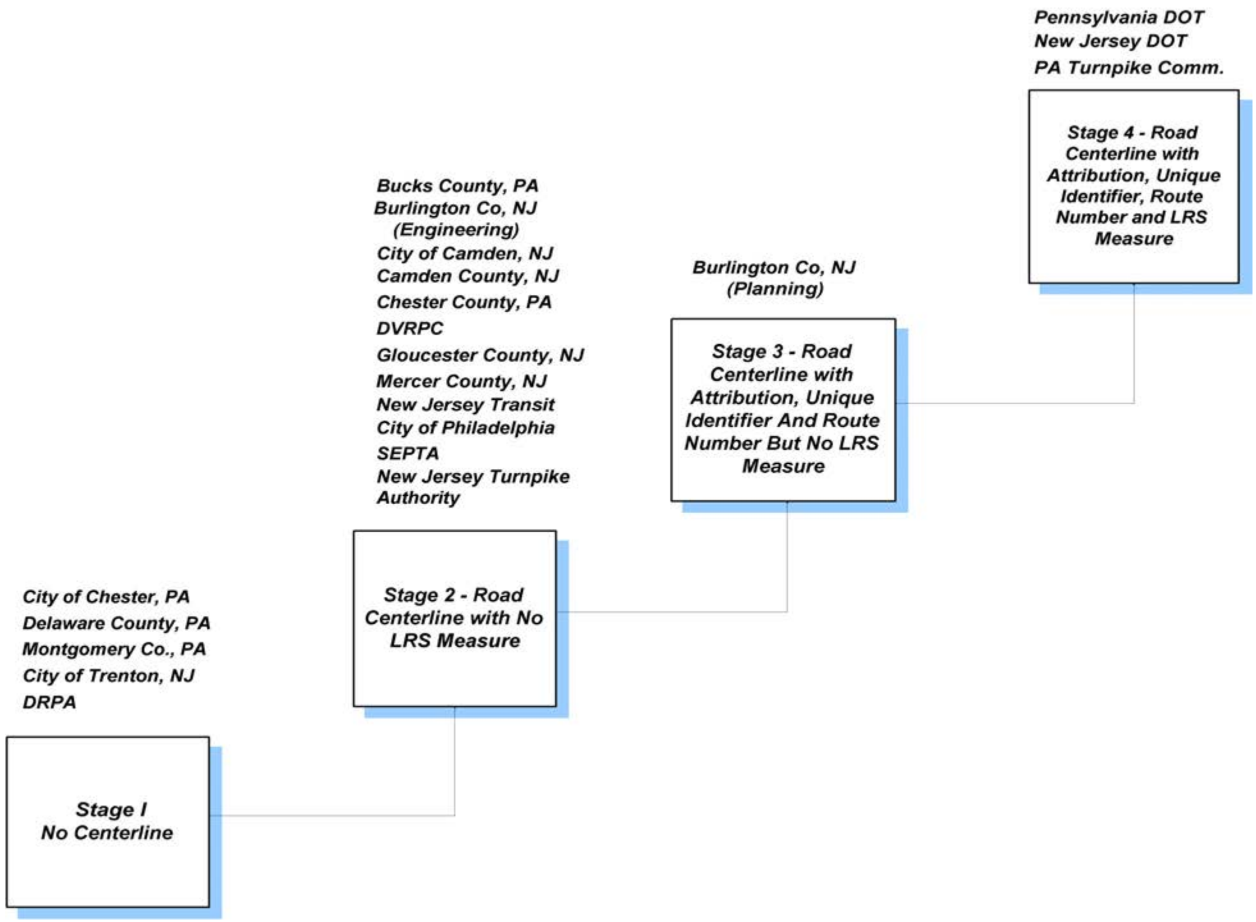

Figure 1 – Four Stages of Street Centerline Development

Figure 1 depicts the distribution of the various participants across the range of centerline development stages. It must be understood that the rating of each participant is based solely on the suitability of their centerline data for supporting transportation planning applications. This is by no means intended to reflect an overall assessment of the utility and value of the centerline data within the context of a comprehensive, multi-functional GIS.

Street centerlines support numerous GIS applications, such as E-911, vehicle routing and pavement management. The focus of this project is transportation planning.

II-6.1 Stage 1 – No Road Centerline

Agencies, which fall into this stage, have either no road centerlines or have road centerlines that were either purchased or collected but have fallen out of date with no maintenance plans in place to update them.

II-6.2 Stage 2 – Road Centerline with No LRS Measure

Agencies, which fall into this stage, have digital road centerlines that have been either purchased or collected and have an established maintenance procedure in place to maintain them at regular or periodic intervals. These files may or may not include feature attribution. In most cases, they are not being utilized for transportation planning applications of GIS. In some cases, there has been a standard unique identifier established for each road segment, but there is no route number. The Coordinate/Route model described in the Chapter III of Volume II cannot be supported in these cases. An example of this is the City of Philadelphia, which has established BD# for each street segment in the City, but no route number. Also, Chester County currently uses geocoding by street address as its means of locating event data along street centerlines. While this is useful and support of transportation planning is feasible given a supportive database design, this approach does not conform to DVRPC's concept of a Common Linear Referencing System.

II-6.3 Stage 3 – Road Centerline with Attribution and Unique Centerline ID and Route Number but no LRS Measure

Agencies, which fall into this stage, have road centerlines with various degrees of database attribution attached to the centerline but also have established a unique Centerline ID and a route number to facilitate the application of the Coordinate/Route model.

II-6.4 Stage 4 – Road Centerline with Attribution, Unique ID and LRS Measure

Agencies, which fall into this stage, have all of the information included in Stage 3 but also have incorporated an LRS that includes a route number and LRS measure, into their database design. Additionally, the agency's GIS software supports the use of an LRM to place both point and linear events along the road network.

II-7 Best Practices for Centerline Representations

In developing recommendations for designing, creating, and maintaining the topological structure of the centerline data, the research effort focused heavily on the ***National Spatial Data Infrastructure (NSDI) Framework Transportation Identification Standard (Public Review Draft)*** (FGDC-STD-999.1-2000) prepared by the Ground Transportation Subcommittee of the Federal Geographic Data Committee (FGDC) and distributed in December 2000. Each DVRPC member organization needs to coordinate the development of a road database with all appropriate stakeholders, particularly with respect to the manner in which the various types of roads are modeled in the local database. Each agency's centerline dataset should be developed or modified to conform to the recommendations offered by NSDI. This should include methods for representing road segments (single or dual-line), ramps, roads with access restrictions, frontage and service roads, and topological connectivity.

III. Research Phase

The process employed through the needs assessment phase worked towards an understanding of the basic status of GIS for transportation planning throughout the region served by DVRPC. This process has not only assessed the status, accuracy and maintenance of the centerline files but also the types of transportation data that are being collected against the centerline.

Detailed information was gathered pertaining to the methods being employed to place or reference that transportation data along the centerline. The methods of how that data is being placed along the centerline are termed a linear referencing method. Route/Milepost, Street Addressing, Offset from Intersections and Route/x,y are all examples of linear referencing methods.

III-1 Basic Questions

The research phase addressed the most basic questions faced in this project:

- How can the organizations that have been identified as being in the lower stages of GIS-T development best work their way up to the higher stages and play a more active role in the region-wide GIS-T environment?
- How can address-based data and data models that best support the geocoding of these data be effectively and consistently exploited for GIS-T applications?
- How can the different agencies that collect transportation data share that data amongst themselves and others without forcing a single, region-wide linear referencing method or a single, region-wide centerline file?
- And, by what means can such a concept be proven beyond the realm of merely writing about it?

III-2 Technology Vision and Implementation Options

In order to answer these questions and formulate the Technology Vision, several prototypes were developed. These prototypes tested various scenarios for developing centerlines, as well as various models that would facilitate data sharing throughout the region. These prototypes should provide a foundation for the Technical Recommendations and Implementation Plans and help to establish reasonable estimates of implementation costs, resource requirements and schedules.

III-2.1 Technology Ramp

The Technology Ramp (Figure 2) describes a matrix of data transformation technologies that can be used to perform data sharing between DVRPC member agencies. In general, the matrix becomes increasingly costly and complex as you move from the lower left corner to the upper right corner.

The matrix contains four rows, which contain the following transformation methods: Geometric, LRS, NSDI and NCHRP 2027, which increase in complexity as you move from the bottom to the top. The term “transformation method” refers to the process that is used to convert locational reference of a feature or event from one system to another. The Transformation Methods are described below.

III-2.1.1 Geometric Transformation Methods

Geometric Transformation Methods allow data sharing between disparate linear networks using a common geometric reference like x, y coordinate values.

III-2.1.2 Transformation Based Upon a Linear Referencing System (LRS)

LRS Transformation Methods allow data sharing between disparate linear networks using a standard linear reference and unique identifier.

III-2.1.3 Transformation Based Upon the NSDI Transportation Framework

NSDI Transformation Methods allow data sharing between disparate linear networks using a master NSDI network through equivalency tables that map the "from" network to the "to" network.

III-2.1.4 Transformation Based Upon NCHRP 20-27

NCHRP 20-27 Transformation Methods allow data sharing between disparate linear networks using a stable linear datum. A single datum would cover the entire DVRPC region. The disparate linear networks are then referenced to this datum.

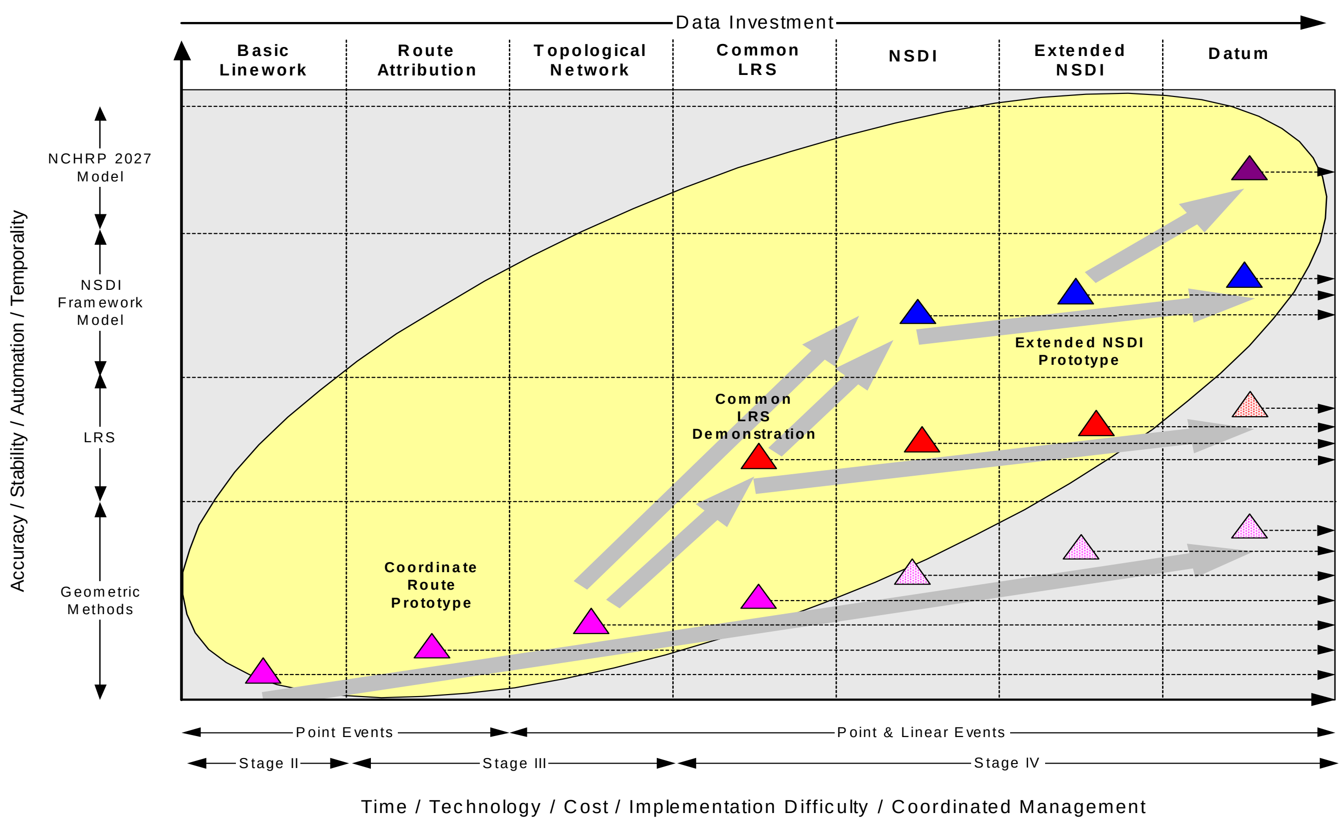

Figure 2 – Technology Ramp

The columns represent levels of investment in the data network, increasing as you move from left to right. The columns also represent stage designations and types of events that are supported. In this case as you move from left to right the stage and types of events that are supported both increase. The ellipse or "sweet-spot" of the ramp represents those combinations of technologies that offer a reasonable solution for agencies at different times and technology investment. The triangles represent points where a specific transformation method, data investment, stage designation and event type overlap and can function properly together. The gray lines between matrix elements represent migration paths. Those within the same row represent incremental migrations associated with investing more resources into the data and software. Those migration paths that occur between rows represent a change in the underlying transformation method and are more costly.

III-3 Centerline Development Options

The available options for centerline development were determined to include in-house development, contract development, centerline borrowing and purchase from data vendor. This investigation functioned to quantify available centerline and attribution solutions and evaluate the implementation cost and estimated return on investment. As part of the investigation, street centerlines for a portion of Philadelphia were developed and attributed. All solutions depend upon the availability of personnel resources to actually perform the project, oversee the contractor or facilitate data sharing. In order to accurately compare the available solutions a baseline of 25,000 segments was assumed for the investigation. The solutions were compared based on cost, accuracy, compatibility with other agency datasets, usability for transportation planning, and foreseen maintenance difficulties. Based on the investigation, it was determined that the most effective solution for developing a centerline dataset with attributes necessary for transportation planning for those agencies currently classified as Stage I or II is some combination of Agency Development, Contract Development and Data Vendor purchase. This combination depends upon the personnel resources that are available. In cases where the Agency has the resources and training available to develop and attribute the centerlines effectively, Internal Development is the best solution. The next best solution is to hire a consultant to perform the entire project or enter into an agreement with GDT through their community update program. This latter option, however, introduces limitations such as the inability to share the data with other entities because of vendor licensing restrictions.

III-4 Coordinate Route Model

The Coordinate Route technology provides member agencies with the ability to use a combination of geometric location (x,y) and a unique route identifier to transform information between multiple network representations. In order to share information using this model, all the agency needs is a regional unique route identifier on every road segment. This unique route identifier must be regionally accepted in order for each of the sharing agencies to accurately identify each road segment. The prototype for this model was performed in a portion of Burlington County, New Jersey, using Burlington County and NJDOT centerlines and event tables. Since Burlington County already contains NJDOT's unique route identifier (SRI) on the road segments, it was an obvious choice for this prototype. The benefits of this approach include:

- Each agency can collect its transportation event information as it currently does, as long as it includes the unique route identifier and coordinates.
- DOT's can collect information as they currently do.
- Local governments can collect information as street addresses or as x,y coordinates.

- Compatible with many commercial off-the-shelf (COTS) packages including ArcView and GeoMedia.

The tradeoffs for this approach are that all participants must have a common unique route identifier and linear events are not supported (i.e., pavement condition, speed limits, parking, etc.)

III-5 Common LRS Model

The Common LRS technology provides member agencies with the ability to use a common linear referencing system to transfer information using dynamic segmentation. Data is transformed using a common linear reference composed of the unique route identifier and measurement values. As with the Coordinate Route Model, the unique route identifier must be standard across the member agencies within each state. In this case, the measurement values must also be standard across the member agencies within each state. Again, since Burlington County already contains NJDOT's unique route identifier (SRI) on the road segments, it was an obvious choice for this prototype. The benefits of this approach include:

- Each agency can collect its transportation event information as it currently does, as long as it includes the unique route identifier and coordinates.
- DOT's can collect information as they currently do.
- Local governments can collect information as street addresses or as x,y coordinates.
- The ability to handle both point and linear event data.
- Compatible with higher-end COTS GIS packages.

The tradeoffs for this approach are that all participants must have a common linear referencing system including unique route identifier and measurement values, and the centerlines must have topological integrity and connectivity.

III-6 Extended NSDI Approach

Extended NSDI provides a framework based on equivalency tables that tie multiple networks together. This approach requires a master linear network that is used to map member agencies centerlines to each other. While this master network must be centrally managed and maintained, the agency datasets are locally managed and maintained by their respective agencies. In general terms, this approach is similar to the Common LRS approach in that both require common unique route identifier and measurement values. However, in this approach, the common values are stored in equivalency tables allowing member agencies to conduct business as usual with their existing unique route identifier and measurement values or address ranges. This prototype utilized Chester County and PennDOT road centerlines since both already contained the necessary network topology. The benefits of this approach include:

- NSDI provides a highly stable transformation model.
- Compatible with many COTS packages, including ArcView and GeoMedia.
- Handles non-spatial, transportation modeling networks.
- Provides a collaboration framework for external organizations (FHWA, neighboring MPO's and states.)

The tradeoffs for this approach are that a master network must be centrally managed and maintained, equivalency tables must be developed and maintained for each agency, and the centerlines must have topological integrity and connectivity.

IV. Implementation Planning

The final phase of the project consisted of the development of tactical implementation plans for DVRPC, its member organizations, and the regional operating agencies. These plans are tactical in the sense that they provide recommended tactics for each of the participants that can be used to implement the recommendations developed through this project. The characteristics of each plan are reflective of the position of the participant on the scale of the four stages of street centerline development.

These plans address four primary tactical areas: (1.) centerline linework development, (2.) database development, (3.) computer hardware and software and (4.) staffing and training. By applying these tactics, it will be feasible for the member organizations to effectively construct GIS databases that will facilitate the exchange of transportation related data to support a variety of applications at and among local, regional and State levels.

Using the recommendations put forth by the implementation plans, the member organizations will be able to define the components of a scope of work to support the development of a transportation GIS database, whether the work is done in-house or contracted out.

V. Conclusion

The overriding objective of this project has been to provide DVRPC with a solid technical foundation upon which to build a region-wide transportation GIS model. Throughout the project, emphasis has been placed on the need for sharing transportation-related data among the various State, regional and local government entities that both generate and use data of this nature. Furthermore, through the research effort, it was recognized that the most logical means for facilitating this data sharing would be through a common LRS, implemented through a standard data model that provides immediate benefits and, at the same time, supports the eventual adoption of emerging technologies as they become viable.

There virtually was immediate consensus that the idea of creating and implementing a common, region-wide centerline file that would be used by all member organizations was impractical for a number of reasons, not the least of which would be the complexities involved with ensuring that the file remains current and is properly maintained. Therefore, the recommendations put forth are rooted in a "database-centric" approach. This approach focuses on the database model as the vehicle for effectively sharing spatial and attribute data, as opposed to using a common, difficult to manage and maintain centerline file as the basis for data sharing. The approach has the added benefit of allowing the individual participants to continue to develop and maintain their own centerline data and still be able to share important data with other entities within the region. It should be noted that even with this "database-centric" approach, the greater the positional accuracy of the centerline file, the greater the accuracy of placement of features using the common LRS model.

On the basis of these factors, a proposed approach to designing, developing and implementing a region-wide transportation GIS data model that facilitates the exchange of valuable data among a variety of diverse organizations has emerged. This approach includes two primary components: (1.) a common LRS for each of the two states encompassing the geographic extent of the region and (2.) a method for including street-addressing within the database design that will facilitate sharing and application of event data that is street-address based. More specific details of these components include:

- In New Jersey, it is recommended that the Standard Route Identifier (SRI) currently employed by NJDOT be adopted as the standard format for creating route numbers for all centerline segments in that State. The SRI number coupled with starting and ending measurements constitute the common LRS to be established for participants in New Jersey.
- In Pennsylvania, PennDOT uses NLF-ID to uniquely identify routes on the State Maintained Highway System. This unique route identifier is not coded and is sequenced as new routes are added. In contrast to NJDOT, one must look at the data attributes in order to identify information about the route. This methodology for uniquely identifying routes works well for PennDOT, but it is arbitrary and offers no solution for identifying local roads. It is recommended that PennDOT adopt a numbering scheme similar to NJDOT, which will allow the local agencies to take part in the scheme and thus share data with the DOT. To fulfill this recommendation, it is proposed that the Pennsylvania participants, including PennDOT, create a unique route identifier that includes the County Code and State Route number currently used by PennDOT and a direction indicator. The inclusion of a starting and ending measure value will complete the LRS component.
- With regard to street addressing, it is recommended that participants in both states adopt a standard that closely follows the TIGER model developed by the U.S. Bureau of the Census.

More details on all of these recommendations can be found in Volume III, Technical Recommendations.

This project is just the beginning of a long-term process designed to implement a comprehensive transportation GIS model that will serve DVRPC and its members, as well as the various transportation operating agencies within the region. Some of the additional steps that need to be taken include:

- *The adoption and implementation of the tactical plans presented in Volume IV*. Before any benefits can be derived from the recommendations emerging from this project, it will be necessary for the member governments to undertake the work that will be required to put the technical components in place.
- *The development and adoption of official LRS components for each State.* The successful implementation of these recommendations can only occur after the participating agencies in each State have agreed to acceptable standards for implementing the LRS components on all roads and streets. This step is especially critical to the success of the implementation process.
- *Consideration of other transportation modes.* This project and the investigation and research efforts that supported it, focused on the road network as the primary transportation facility within the region. While this focus was warranted when considered in light of the most critical transportation planning needs of the region, it must be recognized that other modes of transportation such as railroads and transit facilities are also part of the region-wide transportation network. Their consideration in future projects cannot be ignored as the DVRPC members proceed to build a region-wide GIS framework.
- *Continued commitment.* Like all implementations of technology and technology-based standards, the implementation of a region-wide transportation GIS framework model by DVRPC will only succeed if there is continued commitment by all of the participants. Once agreement has been reached on the adoption of the basic standards, there remains considerable work to be done to ensure that all of the benefits that can be realized are, indeed, realized.

Region-wide Transportation GIS Project Design and File Architecture
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ABSTRACT
The primary purpose of this project is to assure that DVRPC, it's member city and county governments, and transportation operating agencies have a GIS and data files that can be developed and shared with each other to facilitate better transportation planning analysis and decision-making. This report, divided into five volumes, serves as the foundation to establish the operational framework for these efforts.

Volume V – Executive Summary presents the findings and recommendations of the four previous volumes, that include: Volume I – Needs Assessment Summary; Volume II – Technology Vision and Implementation Options; Volume III – Technical Recommendations; and Volume IV – Implementation Plans. It also includes additional steps that need to be taken in order to fully realize the benefits of a comprehensive transportation GIS.

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