Term Paper

USING GIS IN TRANSPORTATION AND ITS APPLICATIONS

For

CRP 514: Introduction to GIS

Term (101)

By

Mohammed Salem Ba-naimoon

IDNO: 200805620

Course Instructor:

Dr. Baqer M. Al-Ramadan

Contents

Abstract

In this term paper provides an overview of adaptation of the concept of transportation (GIS-T). Geographic Information systems (GIS) represent a powerful new means to efficiently manage and integrate the numerous types of information necessary for the planning, design, construction, analysis, operation, maintenance, and administration of transportation systems and facilities. GIS systems have proved to be powerful tools for the compilation, management, display of data associated with geographic space. For example, many state departments of natural resources have applied GIS to define the location of resources and the threats to these resources, to monitor changes over time, and to generate a variety of reports and displays useful to making decisions related to environmental impact. However, application of GIS to transportation has required the extension of basic functionality to include network overlays and the linking of linearly referenced information to the network. This functionality has been developed in various generic forms by firms commercially developing GIS software and hardware platforms. Thus, these GIS-T platforms now represent a highly viable alternative for information processing in transportation agencies.

1. Introduction

A Geographic Information System (GIS) is a collection of computer software, hardware, data, and personnel used to store, manipulate, analyze, and present geographically referenced information. Spatial features are stored in a coordinate system that references the Earth. Attribute data can then be associated with these spatial features. Spatial data and its associated attribute information can then be layered on top of one another for viewing and analysis. Using GIS, planners, engineers, and other professionals can efficiently view multiple items of interest about a particular geographic area.

In the transportation industry geographic analysis is the key to making better decisions. Whether monitoring rail systems and road conditions, finding the best way to deliver goods and services, tracking fleet vehicles, or maintaining transportation networks, understanding these issues from a geographic perspective is crucial to deploying or spending resources wisely.

GIS technology serves three distinct transportation needs: infrastructure management, fleet and logistics management, and transit management. Transportation professionals can use GIS to integrate mapping analysis into decision support for network planning and analysis, vehicle tracking and routing, asset management, inventory tracking, route planning and analysis, and everything in between.

2. Objectives

The main objective of this paper is to bring forth the importance of the need for data and systems integration within transportation agencies and across multiple units of government. Secondly it is intended to point out the need for Geographic Information Systems in Transportation and to explore the applications of GIS in transportation. Transportation agencies are currently faced with ever increasing demands for information to support more effective decision making throughout their organizations, from engineering at the individual project level to statewide planning and management. Additionally, the broad environmental and economic development problems that confront all of society today require data sharing and cooperation among multiple government agencies at all levels. These demands for improved information management often manifest themselves as mandates such as the **Intermodal Surface Transportation Efficiency Act** (ISTEA) of 1991 that requires systems for traffic monitoring and for management of pavement, bridge, safety, congestion, public transportation facilities and equipment, and intermodal facilities and equipment .

Furthermore, ISTEA includes consideration for the ability of these mandated systems to integrate with one another. The recent Hazardous Waste Act will force the integration of transportation-specific data with externally managing data (such as demographic data) to produce routing and emergency response plans. The recent Clean Air Act will entail the integration diverse information on transportation, population, and land use, as well as the integration of independently developed and managed forecasting systems such as urban planning and air quality models.

3. Literature Review

GIS has been successfully applied in many fields outside of the transportation industry. However, the full capabilities of GIS for transportation (GIS-T) have yet to be realized. To move forward, there is a need to identify current applications of GIS concepts and technologies in the transportation field, to identify transportation problems that cannot be addressed by current GIS concepts and technologies, to design a GIS-T that will provide comprehensive and timely information for management decision support, and to review the impacts of implementing a GIS-T on transportation agencies.

3.1 Advantages of Data Integration

Characterizing GIS as it is done so for emphasizes its technical functions. An important development has been the recognition, that introduction of GIS capabilities into a data processing environment is important not only because of the new capabilities made available but also because the fundamental concept of location that underlies GIS spatial databases, provides an efficient and practical means of integrating data of many other kinds. Benefits of data integration include data-collection cost reduction, data maintenance cost reduction, improved data reliability, and most important applications not otherwise possible.

The collection of highway-related data involves a wide variety of activities: traffic counting, accident investigation, recording of construction and maintenance projects and funding, right-of-way surveys, inventories of roadside obstacles, bridge inspection, rail-highway crossing inventories, speed monitoring, pavement condition surveys, geometric design inventories, and other data-collection and maintenance activities. In the past, these activities were often uncoordinated within highway organizations and across organizational boundaries. Collected data were typically stored in paper files or in single-purpose computer files accessible only to a few people. Because of the lack of coordination, or of a narrow concept of data use and application, data collected for one purpose were rarely usable for others. If two users needed the same data, or very similar data, the data were often collected twice.

Highway agencies have been a fertile breeding ground for independent data-collection activities and the data files that result from them. It has often been easier for organizational units to independently develop the information systems they need to operate their programs, without coordinating their efforts with data-related activity in other organizational units. In some cases, this has been the most reasonable approach to take duplication of effort has been more apparent than real. There is no question that coordination requires resources and often involves compromises with respect to data specification, editing, and maintenance. But as systems grow and the cost of data collection rises, independent data-collection and data-storage activities become expensive luxuries. Integrated systems permit broader use of collected data, which increases data value.

Integration generally makes it possible to study many relationships among two or more data elements. As an integrated system grows, the cost of providing the linkage is rapidly offset by the value of the increase in information that the system provides.

In practice, integration of data can be relatively complex. It is not always efficient or convenient, for example, for every one to use the same location reference system when collecting data. It may be best for a traffic-counting team at an intersection to identify the intersecting highways by name, whereas a survey crew recording sight-distance restrictions might use mileage from the county line. This is not a problem if the systems that are used are compatible with each other or with a third system so that location data can be translated from one system to another.

3.2 Role of GIS in Transportation

There is considerable variation across different contexts and different speakers in usage of the phrases "Geographic Information System" and "GIS." In its narrowest sense, "GIS" refers only to specialized software for the management and of spatial data and their attributes. In other contexts, the term refers to both hardware and software. Still other usages comprehend hardware, software, and data.

Perhaps the nearest to a consensus definition is the one provided by (Dueker and Kjerne, 1989). "*Geographic Information System*: A system of hardware, software, data, people, organizations, and institutional arrangements for collecting storing, analyzing, and disseminating information about areas of the earth."

According to this definition, a GIS includes not only computing capability and data, but also managers and users, the organizations within which they function, and the institutional relationships that govern their management and use of information. This broad view establishes a fundamental premise (Vonderohe et al., 1993), the premise that the technology of GIS cannot usefully be evaluated, projected and planned for in isolation from institutional setting, management framework, and staffing resources upon which success or failure of the GIS will depend. GIS system design and implementation planning are not separable processes. They must occur in conjunction with one another.

Figure 1 depicts that the GIS-T conceived as the union of an enhanced Transportation Information System (TIS) and an enhanced GIS. The necessary enhancement to existing TISs is the structuring of the attribute database to provide consistent location reference data in a form compatible with the GIS, which in turn has been enhanced to represent and process geographic data in the forms required for transportation applications.

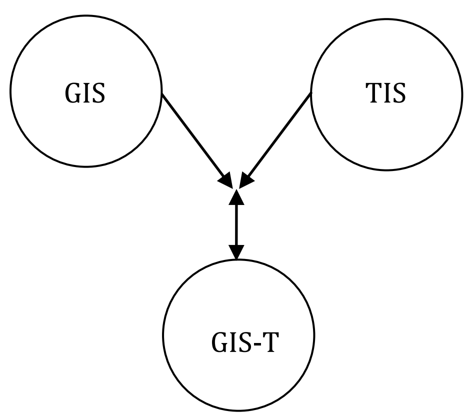

Figure 1: GIS-T as the merger of an enhanced GIS and enhanced transportation information system (TIS) (Reference: Vonderohe et al., 1993)

This does not imply that databases must be redesigned according to the constraints imposed by commercial software. In fact, one of the required enhancements to off-the-shelf GIS software is the ability to link with and utilize all or nearly the entire linearly referenced highway data collected and maintained by transportation agencies.

What it does imply is that the attribute databases use a database scheme for the concept of location translatable into the location schemas used in the GIS spatial databases (the databases containing the digital base maps) so that the content of the former can be unambiguously correlated with the content of latter, so that queries can span both kinds of databases, and so that separate attribute databases can be integrated through their use of location schemas translatable into the ones used by the GIS software. In addition to improved management of linearly referenced data, necessary enhancements to GIS software include better modeling and analysis of transportation networks.

3.3 Definition and Role of GIS-T

Geographic information systems for transportation (GIS-T) can be defined as interconnected hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and communicating particular types of information (i.e., transportation systems and geographic regions) about the Earth (Vonderohe et al. 1993).

As described by Vonderohe et al. (1993) GIS-T can be viewed as the product of the interaction between improved concepts of both geographic information system (GIS) and transportation information system (TIS). GIS-T applications are currently used broadly by transportation analysts and decision makers in different areas of transportation planning and engineering, from infrastructure planning, design and management, traffic safety analysis, transportation impact analysis, and public transit planning and operations to intelligent transportation systems (ITS) such as Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO).

4. GIS Models Used in Transportation

In general, three classes of GIS models are used in transportation, which include (Thill, 2000):

- Field models of the continuous variation of a phenomenon over space (e.g., land elevation).
- Discrete models, depending on which discrete entities (points, lines or polygons) populate space (e.g., toll barriers, urbanized areas).
- Network models to represent topologically-connected linear entities (e.g., roads, rail lines, or airlines) that are fixed in the continuous reference surface.

All of these three models are useful in transportation; however, the network model built around the concept of arc and node plays the key role in this application domain because single- and multi-modal infrastructure networks are vital in enabling and supporting passenger and freight movement. In fact, many transportation applications only require a network model to represent data. On the other hand, still it is worth noting that advanced transportation applications, particularly disaggregate travel demand modelling approaches and intelligent transportation systems, require representation of complex transportation features that are not well-supported by the node-arc data model. Goodchild (1998) recognized three meaningful extensions to overcome these kinds of deficiencies:

- Planner versus non-planner model (with different representations for topology versus cartography);
- Turn tables (for including properties of the turning movements); and
- An object-oriented view of the infrastructure to define topology between lanes (e.g., links are objects formed of traffic lanes).

5. Geographic Information Systems for Transportation (GIS-T)

Geographic Information Systems for Transportation (GIS-T) refers to the principles and applications of applying geographic information technologies to transportation problems (Miller and Shaw, 2001).

GIS-T research can be approached from two different, but complementary, directions. While some GIS-T research focuses on issues of "How can we further develop and enhance the GIS design in order to meet the needs of transportation applications?" other GIS-T research investigates the questions of "How can we use GIS to facilitate and improve transportation studies?" (Shaw, 2002)

In general, topics related to GIS-T studies can be grouped into three categories: GIS-T data representations, GIS-T analysis and modeling, and GIS-T applications.

5.1 GIS-T Data Representations

Data representation is a core research topic of GIS. Before we can use GIS to tackle real world problems, we must properly represent our data in a digital computing environment. One unique characteristic of GIS is the capabilities of integrating spatial and non spatial data in order to support both display and analysis needs. There have been various data models developed for GIS. The two basic approaches are object-based data models and field-based data models (Lo and Yeung, 2002). An object-based data model treats geographic space as populated by discrete and identifiable objects. On the other hand, a field-based data model treats geographic space as populated by real-world features that vary continuously over space. These two approaches correspond to the widely known vector GIS (i.e., features are represented as points, lines, and/or polygons) and raster GIS (i.e., features are represented as grid cells).

GIS-T studies have employed both vector and raster GIS data models to represent the relevant geographic data. Some transportation problems tend to fit better with one type of GIS data model than the other. For example, network analysis based on the graph theory typically represents a network as a set of nodes interconnected with a set of links. Vector GIS therefore are better candidates for such transportation network representations. There also exist other types of transportation data that require extensions to the general GIS data models. One well-known example is linear referencing data (e.g., highway mileposts). Transportation agencies often measure locations of features or events along transportation network links (e.g., a traffic accident occurred at the 52.3 milepost on I-75 in the State of Tennessee). Such a 1-dimensional linear referencing system (i.e., linear measurements along a highway segment with respect to a pre-specified starting point of the highway segment) cannot be properly handled by the 2-dimensional Cartesian coordinate system used in most GIS data models. Consequently, the dynamic segmentation data model was developed to address this specific need of the GIS-T community. Origin-Destination (O-D) flow data are another type of data that are frequently used in transportation studies. Such data have been traditionally represented in matrix forms (i.e., as a two-dimensional array in a digital computer) for analysis. Unfortunately, the relational data model widely adopted in most commercial GIS software does not provide an adequate support of handling matrix data. Some GIS-T software vendors therefore have developed additional functions for users to work with matrix data within an integrated GIS environment. The above examples illustrate how the conventional GIS approaches can be further extended and enhanced to meet the needs of transportation applications.

In recent years, we also have seen the development of enterprise and multidimensional GIS-T data models. Successful GIS deployments at the enterprise level (e.g., within a state department of transportation) demand additional considerations to embrace the diversity of application and data requirements. An enterprise GIS-T data model is designed to allow "each application group to meet the established needs while enabling the enterprise to integrate and share data." (Butler and Dueker, 2001). The needs of integrating 1-D, 2-D, 3-D, and time for various transportation applications also have called for an implementation of multidimensional transportation location referencing systems. The National Cooperative Highway Research Program (NCHRP) Report 460 provides guidelines for the implementation of multidimensional and multimodal location referencing systems.

In short, one critical component of GIS-T is how we can best represent transportation-related data in a GIS environment in order to facilitate and integrate the needs of various transportation applications. Existing GIS data models provide a good foundation of supporting many GIS-T applications. However, due to some unique characteristics of transportation data, we still face many challenges of developing better GIS data models that will improve rather than limit what we can do with different types of transportation studies.

5.2 GIS-T Analysis and Modeling

GIS-T applications have benefited from many of the standard GIS functions (query, geocoding, buffer, overlay, etc.) to support data management, analysis, and visualization needs. Like many other fields, transportation has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms (e.g., traveling salesman problem, vehicle routing problem), spatial interaction models (e.g., gravity model), network flow problems (e.g., user optimal equilibrium, system optimal equilibrium, dynamic equilibrium), facility location problems (e.g., p-median problem, set covering problem, maximal covering problem, p-centers problem), travel demand models (e.g., the 4-step trip generation, trip distribution, modal split, and traffic assignment models), and land use-transportation interaction models. For a review of these transportation analysis methods and models, readers can refer to a GIS-T book . While the basic transportation analysis procedures (e.g., shortest path finding) can be found in most commercial GIS software, other transportation analysis procedures and models (e.g., facility location problems) are available only selectively in some commercial software packages. Fortunately, a recent trend of moving towards component GIS design in the software industry provides a better environment for experienced GIS-T users to develop their own custom analysis procedures and models.

It is essential for both GIS-T practitioners and researchers to have a thorough understanding of transportation analysis methods and models. For GIS-T practitioners, such knowledge can help them evaluate different GIS software products and choose the one that best meets their needs. It also can help them select appropriate analysis functions available in a GIS package and properly interpret the analysis results. GIS-T researchers, on the other hand, can apply their knowledge to help improve the design and analysis capabilities of GIS-T.

5.3 GIS-T applications

GIS-T is one of the leading GIS application fields. Many GIS-T applications were implemented at various transportation agencies in the past two decades. They covered much of the broad scope of transportation, such as infrastructure planning, design and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit planning and operations, environmental impacts assessment, hazards mitigation, and intelligent transportation systems (ITS). Each of these applications tends to have its specific data and analysis requirements. For example, representing a street network as centerlines and major intersections may be sufficient for a transportation planning application. A traffic engineering application, however, may require a detailed representation of individual traffic lanes. Turn movements at intersections also could be critical to a traffic engineering study, but not to a region-wide travel demand study. These different application needs are directly relevant to the GIS-T data representation and the GIS-T analysis and modeling issues discussed above. When a need arises to represent transportation networks of a study area at different scales, what would be an appropriate GIS-T design that could support the analysis and modeling needs of various applications? In this case, it may be preferable to have a GIS-T data model that allows multiple geometric representations of the same transportation network.

With the rapid growth of the Internet and wireless communications in recent years, we also haven seen a growing number of Internet-based and wireless GIS-T applications. Such applications are especially common for ITS and for location-based services (LBS). Another trend observed in recent years is the growing number of GIS-T applications in the private sector, particularly for logistics applications. Since many businesses involve operations at geographically dispersed locations (e.g., supplier sites, distribution centers/ warehouses, retail stores, and customer sites), GIS-T can be useful tools for a variety of logistics applications. Again, many of these logistics application are based on the GIS-T analysis and modeling procedures such as the routing and the facility location problems.

GIS-T is interdisciplinary in nature and has many possible applications. Transportation geographers, who have appropriate backgrounds in both geography and transportation, are well positioned to pursue GIS-T studies. For additional information on GIS-T research, (Thill (2000)) provides a collection of articles on different GIS-T studies. Investments in Transportation assets are among the largest made by today's societies. GIS technology is used by a diverse group of people serving all major transportation modes, both public and private.

Transportation facilities, including roadways and railways, bridges and tunnels, air and sea ports, are planned and managed using GIS. Public and private fleets are being made more efficient and effective through the application of GIS. Both passengers and freight shipments arrive on schedule more often and more safely, in part due to the growing number of GIS-based information systems. Some kinds of such applications of GIS-T are presented below.

5.3.1 Aviation

Airports, airlines, and flight control managers have all profited from their use of GIS in several ways. Commercial, emergency, and defense-related airfields use GIS to

- Manage facilities, both airside and landside
- Model and monitor noise
- Facilitate environmental compliance
- Manage construction and maintenance
- Improve airside parking operations
- Capacity and traffic planning
- Track flight paths

Airlines and flight control groups use GIS to analyze routes and capacities, and to plan re-routing and contingency plans for weather-related or other emergencies. GIS provides an excellent means of visualizing flight paths, capacities, or noise contours. The Metropolitan Airports Commission Aviation Noise and Satellite Program use GIS to display and analyze aircraft noise impacts in the Minneapolis/St. Paul Metropolitan Area.

5.3.2 Highways and Streets

Transportation infrastructure represents one of the largest and most critical investments made in any nation, at any stage of development. The movement of people and goods either domestically or internationally is vital to every aspect of that economy.

GIS can be used to determine the location of an event or asset and its relationship or proximity to another event or asset, which may be the critical factor leading to a decision about design, construction, or maintenance.

5.3.3 Railroads

Railways around the world find great utility in using GIS to manage key information for rail operations, maintenance, asset management, and decision support systems. Major functions or disciplines in which GIS has been successfully deployed in railway organizations include

- Real estate management
- Facility management: track, power, and communications and signaling
- Asset tracking
- Commodity flow analysis
- Emergency response management
- Environmental and construction management
- Intermodal management
- Passenger information
- Capacity planning
- Marketing
- Supply chain management
- Site selection
- Risk management

6. GIS and Transportation Case Studies

Case Study 1: - GIS and Transportation Case study- The transportation infrastructure is one of the most important geographic features of an area. This case study is to define the best route for the buses in the school district.

Within GIS, transportation features are one of the most challenging elements to work with. Due to the inherent degree of difficulty, many GIS software producers have created specialized tools to deal with transportation issues, and these applications in GIS are now routinely given the acronym GIS-T.

An interesting feature of transportation GIS projects is that many data sets related to the areas served by the transportation infrastructure are important. The different features found in these areas, such as homes, schools, hospitals, shopping areas, etc. can also shape the transportation infrastructure. It is not only dependent on the roads, rails, air travel patterns or waterways within the project area. The potential changes in the demographics and land use elements must also be taken into account.

In this Case Study, ArcView's Network Analyst extension tool is used. With it, you will learn about the complexities of transportation data and the potential impacts on land area and how demographic information contained within the area affect the transportation infrastructure.

The Crestwood School District, mostly serving the area of northern Dearborn Heights in Wayne County, Michigan, has asked for a revised bus route and schedule to run a newly developed Summer Program. The primary focus of the Case Study is to define the best route for the buses in the school district according to predefined conditions such as demographic data, administrative considerations, and optimal bus usage.

Case Study 2: Maryland DOT Rolls Out a Highway Monitoring Application--State Highway Administration integrates five significant data sets--accidents, bridges, highways, pavements, and traffic control devices--into one GIS-based application to improve transportation planning and analysis within the agency.

In November 1998, the Maryland State Highway Administration (SHA) rolled out a new ArcView GIS-based application to improve transportation planning and analysis within the agency. SHA is responsible for building and maintaining a safe, efficient highway system for the entire State of Maryland. This includes managing more than 16,000 lane miles of interstate, primary, and secondary roads and more than 2,500 bridges. SHA employees plan, design, build, and maintain these roads and bridges to the highest safety and performance standards possible, paying close attention to sociological, environmental, ecological, and economic concerns.

To make decisions that are well informed from these and other points of view, different divisions at SHA developed their own digital data sets. Among these are five of significant content and size--those containing data on accidents, bridges, highways, pavements, and traffic control devices.

- The accident data set includes all accidents recorded during the past five years, as well as high-accident intersections and road sections identified annually for monitoring by the SHA Office of Traffic and Safety.
- The bridge database includes more than 6,000 records for bridges and other structures like noise walls and retaining walls.
- The Highway Performance Monitoring System (HPMS) is a database of important road characteristics like number of lanes, speed limits, and average traffic volume.
- The pavement database includes information about pavement construction history, friction, and ruts.

- The traffic control device database includes close to 5,000 records for devices like traffic signals, traffic sensors, and variable-message signs.

These data sets were developed and maintained in different formats by the different divisions that were responsible for them. Making data access even more difficult, SHA's employees are physically separate; the agency's headquarters are in Baltimore, another three major offices are co-located outside of Baltimore, and its seven engineering district offices are in various locations around the State. Recognizing that its employees needed fast, easy access to its digital data, in 1996 SHA contracted ESRI to build an ArcView GIS application that would allow 200 of its employees to access all of its data sets.

Case Study 3: Virginia Dept. of Transportation Maps Its Future with GIS-The Cartography Department recognized the need for a fully automated mapping program to facilitate accurate and efficient map production. By Randy Trott, Assistant GIS Manager, and Gary Morrison, GISTechnician, TIMMONS.

TIMMONS, a Richmond, Virginia, based multidiscipline engineering and GIS consulting firm, recently completed an 18-month transportation network data development project for the Commonwealth of Virginia Department of Transportation (VDOT). Prior to this project, the State County Map Series had been manually produced since 1932 by VDOT's Cartography Section. The code of Virginia requires VDOT to continue regular publication of these maps.

"The Cartography Department recognized the need for a fully automated mapping program to facilitate accurate and efficient map production," says Tim Klinker, Cartographic Services manager for VDOT. "We also recognized a unique opportunity for the entire agency to establish a base-level GIS road network for those roads included within the VDOT maintenance system in addition to fulfilling the mapping needs."

VDOT decided to develop their GIS base data using ESRI's ArcInfo software with the flexibility to support data transfer to the department's existing cartography software. This required a database design effort in which ArcInfo coverage files would be sufficiently normalized and attributed to retain a similar "look and feel" in both the ArcInfo environment and the department's CAD software. A total of 166 Mylar maps representing 98 Virginia counties required data conversion, attribution, quality control, and CAD file development. TIMMONS worked extensively with subconsultant Michael Baker's graphics section to develop a conversion mechanism that could be applied for each county coverage throughout the State.

The data compilation phase consisted of database design, data compilation, quality assurance, and final data development phases. The data model and application development were developed for ESRI's ArcInfo software running on Sun UNIX and Microsoft Windows NT platforms. Map elements were categorized and organized into seven different data layers that were implemented as coverage files. An AML-based adjustment and attribution interface was developed to assist technicians in the data standardization and coverage development necessary to create and maintain county-based files within a seamless ArcInfo LIBRARIAN tiling structure.

The data capture consisted of utilizing on-screen digitizing techniques in an ARCEDIT environment. The existing county map Mylars were scanned into raster images for on-screen digitizing. These images were registered to preliminary centerline coverages to facilitate attribute capture and annotation placement. Next, TIMMONS used TIGER data from the U.S. Census Bureau as an initial vector base, then geo-referenced and conflated this vector data using a State-wide SPOT satellite imagery catalog as the primary registration reference. TIMMONS was also able to acquire alternative data sources from existing local and regional GIS and CAD data through a cooperative effort with VDOT and 18 different state and local government agencies. These sources were projected and incorporated to enhance the overall accuracy of the spatial data set. During the conversion process, map updates were incorporated from VDOT's daily flow of road inventory changes.

After the initial data compilation and quality control process, each county data set was edge matched to produce a seamless transportation network database. The information was then incorporated into an ArcInfo LIBRARIAN tiling scheme based on jurisdictional (county and city) boundaries. The project is currently in a maintenance phase, where TIMMONS is further developing the tools and processes necessary for VDOT to maintain their GIS database into the next century.

In addition to developing GIS data files, VDOT asked TIMMONS to demonstrate GIS-T functionality between the GIS data and VDOT's legacy road tracking systems in an ArcView GIS environment. Using ESRI's ArcInfo software's dynamic segmentation model, a linear referencing system was developed in a pilot area to allow the visualization and analysis of several different databases within a GIS environment. Event themes, segment data, and inventory elements like current road conditions, accident data, traffic volume data, and other mission-critical information were incorporated into several different pilot applications to be demonstrated to the VDOT GIS steering committee.

7. Challenges for GIS-T

GIS-T applications cover much of the broad scope of transportation; however, GIS-T is still facing a lot of challenges. Thill (2000) categorized major GIS challenges brought by suffix “T” as follows:

- Legacy data management system (need for data integration, i.e., transferring disparate data into a unified data management system)
- Data interoperability (need for map matching algorithms, error models in transportation data, and data quality/exchange standards)
- Real-time GIS-T (need for quicker access data models, more powerful spatial data combination techniques, and more powerful dynamic routing algorithms)
- Large data sets (need for pioneering system designs in order to optimizing speed and accuracy of the display of information as well as the run time of algorithms, and better analytical tools of network analysis), and
- Distributed computing (need for more powerful analytical tools to fit the limited distributed computing resources, wise design of system architectures to make efficient use of local and remote computing resources, and geo-referencing of remote service users and real-time tracking of their movements)

8. Conclusions and Recommendations

The following are the conclusions and recommendations of this term paper:

- From the investigations of the potentials for GIS-T, it is concluded that data, technology, and institutions represented the three primary considerations that had to be addressed to promote the implementation of GIS-T.
- It was found that transportation agencies own numerous datasets. Often, these datasets have various origins in individual divisions, lack common location

reference schemes, and suffer from poor data definition and lineage tracking making their integration difficult.

- It also discovered that concerns over technological obsolescence, the lack of trained staff, high capital costs, and frequent changes to software made agency management reluctant to commit to GIS-T implementation.
- The DOT strategies for adaptation and exploitation of information technology should be needs driven rather than technology driven. New technology should be adopted and used because it meets specific, well-defined needs, not for its own sake and not because it is likely to serve some good, but ill-defined purpose.
- DOT GIS-T plans should address staffing and training issues. A GIS-T implementation team and core staff should be identified. Methods for training of the core staff and of users should be explicitly addressed.

References:

Butler, J.A. and Dueker, K.J. (2001) Implementing the Enterprise GIS in Transportation Database Design, URISA Journal.

Dueker, K.J. and Kjerne, D. (1989) "Multipurpose Cadastre: Terms and Definitions." Annual Convention of ACSM-ASPRS.

Goodchild, M.F. (1998) Geographic information systems and disaggregate transportation modeling.

Lo, C.P. and Yeung, A.K.W. (2002) Concepts and Techniques of Geographic Information Systems. Upper Saddle River, NJ: Prentice Hall.

Miller, Harvey J. and S. L. Shaw (2001), "Geographic Information Systems for Transportation", Oxford University Press, New York.

Shaw, S.L. (2002) Book Review: Geographic Information Systems in Transportation Research, Journal of Regional Science, 42(2), 418-421.

Thill, Jean-Claude (2000), "Geographic Information Systems for Transportation in Perspective", *Transportation Research*, Part C 8, Elsevier Science Ltd., Oxford, UK.

Thill, Jean-Claude (2000), Geographic Information Systems in Transportation Research. Oxford, UK: Elsevier Science Ltd.

Vonderohe, A. P., L. Travis, R. L. Smith and V. Tsai (1993), "Adaptation of Geographic Information Systems for Transportation", NCHRP Report 359, Transportation Research Board, Washington, D.C.

ESRI Canada & Transportation: www.esricanada.com/english/transportation

GIS in Transportation, Federal Highway Administration (FHWA): http://www.gis.fhwa.dot.gov/

GIS in Transportation Planning, U.S. Department of Transportation: tmip.fhwa.dot.gov/clearinghouse/docs/gis/

Transportation and GIS Resources: www.public.iastate.edu/~kushkows/subjects/trans.html

Applications of GIS in Transportation: http://people.hofstra.edu/geotrans/eng/ch1en/meth1en/ch1m4en.html#1

GIS and Transportation case study: http://ceita.emich.edu/wsatraining/Transportation/index.html