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16. Abstract

Transportation planning requires substantial amounts of data and cooperation among transportation planning agencies. Advances in computer technology and the increasing availability of geographic information systems (GIS) are giving transportation planners the ability to develop and use data with a much higher degree of efficiency. However, as information systems advance, the need to provide effective data integration/exchange protocols and procedures to reduce redundancy and data collection costs is becoming more important. Many factors influence the effectiveness of data exchange and data integration efforts, such as data compatibility, data access, data quality, completeness, metadata, hardware, software, and staff expertise. This research resulted in a catalog of spatial data sources available to transportation planning agencies in Texas. The work included a synthesis of current transportation planning practices in Texas with a focus on spatial data integration and exchange issues, meetings with transportation planning and data stakeholders, the development of a map of data sources, the development of a preliminary logical data model of spatial data entities, and a compilation of metadata documents for a sample of data sources. Developing the catalog of categories and subcategories for transportation planning spatial data was an iterative process that involved several rounds of data entity categorization; analysis of the resulting structure for inconsistencies, gaps, and redundancies; and subsequent changes to the data entity categorization scheme. In the end, the three-level grouping structure resulted in 7 categories, 63 subcategories, and 589 spatial data entities. The research also resulted in a prototype web-based map and metadata viewer called Transportation Planning GIS (TPGIS) Data Viewer.

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ANALYSIS AND INTEGRATION OF SPATIAL DATA FOR TRANSPORTATION PLANNING

by

Cesar Quiroga, P.E.
Research Engineer
Texas Transportation Institute

Yingfeng Li
Assistant Research Scientist
Texas Transportation Institute

Nicholas Koncz
Assistant Research Scientist
Texas Transportation Institute

and

John Overman
Associate Research Scientist
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

3R	Resurfacing, Restoration, and Rehabilitation
4R	Resurfacing, Restoration, Rehabilitation, and Reconstruction
AACOG	Alamo Area Council of Governments
AADT	Average Annual Daily Traffic
ACR	Accumulative Count Recorder
ADA	Americans with Disabilities Act
ATR	Automatic Traffic Recorder
BTS	Bureau of Transportation Statistics
CAMPO	Capital Area Metropolitan Planning Organization
CMAQ	Congestion Mitigation and Air Quality
CMSA	Consolidated Metropolitan Statistical Area
CO	Carbon Monoxide
COG	Councils of Government
CRIS	Crash Records Information System
CSDGM	Content Standard for Digital Geospatial Metadata
CSEC	Commission on State Emergency Communications
DES	Design Division
DFO	Distance from Origin
DOQ	Digital Orthophoto Quadrangle
DVD	Digital Versatile Disk
ENV	Environmental Affairs Division
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FTP	File Transfer Protocol
GAIP	GIS Architecture and Infrastructure Project
GDP	Gross Domestic Product
GENII	Genesis Enterprise Information Integrator
GIS	Geographic Information System
GISST	Geographic Information System Screening and Analysis Tool
GLO	Texas General Land Office
GPS	Global Positioning System
GS	Ground Set
H-GAC	Houston-Galveston Area Council
HPMS	Highway Performance Monitoring System
HTML	Hypertext Markup Language
IBWC	International Boundary and Water Commission
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation System
LIDAR	Light Detection and Ranging
LIS	Land Information System
MAB	Metropolitan Area Boundary

MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
MST	Main Street Texas
MTP	Metropolitan Transportation Plan
NAD 83	North American Datum of 1983
NCTCOG	North Central Texas Council of Governments
NDD	Natural Diversity Database
NEPA	National Environmental Policy Act
NHD	National Hydrography Dataset
NTAD	National Transportation Atlas Database
PDF	Portable Document Format
PM_{10}	Particulate Matter
RPC	Regional Planning Commission
RTI	Research Technology and Implementation Office
RTIP	Rural Transportation Improvement Program
SA-BC MPO	San Antonio-Bexar County Metropolitan Planning Organization
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SIP	State Implementation Plan
SPOT	Satellite Pour l'Observation de la Terre
STIP	Statewide Transportation Improvement Program
STP	Statewide Transportation Plan
StratMap	Strategic Mapping Program
TAZ	Traffic Analysis Zone
TCEQ	Texas Commission on Environmental Quality
TDM	Travel Demand Model
TEA-21	Transportation Equity Act for the 21st Century
TEAP	Texas Ecological Assessment Protocol
TGIC	Texas Geographic Information Council
TIF	Tagged Image File
TIP	Transportation Improvement Program
TMA	Transportation Management Area
TMC	Traffic Management Center
TMMP	Texas Metropolitan Mobility Plan
TNRIS	Texas Natural Resources Information System
TOC	Table of Contents
TPGIS	Transportation Planning GIS
TPP	Transportation Planning and Programming Division
TPWD	Texas Parks and Wildlife Department
TSD	Technology Services Division
TSDC	Texas State Data Center
TSID	TxDOT System Interface Diagram
TSPS	Texas Society of Professional Surveyors
TUMP	Texas Urban Mobility Plan
TWC	Texas Workforce Commission
TxDOT	Texas Department of Transportation

TXT	Text
UPWP	Unified Planning Work Program
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UTP	Unified Transportation Program
VMT	Vehicle Miles Traveled
XML	Extensible Markup Language

CHAPTER 1. INTRODUCTION

Transportation planning requires substantial amounts of data and cooperation among transportation planning agencies. Advances in computer technology and the increasing availability of geographic information systems (GIS) are giving transportation planners the ability to develop and use data with a much higher degree of efficiency. However, as information systems advance, the need to provide effective data integration/exchange protocols and procedures to reduce redundancy and data collection costs is becoming more important. Many factors influence the effectiveness of data exchange and data integration efforts, such as data compatibility, data access, data quality, data completeness, metadata, hardware, software, and staff expertise.

This report describes the work completed to develop a catalog of spatial data sources available to transportation planning agencies in Texas. The work included the development of a map of data sources, a preliminary logical data model of spatial data entities, and a compilation of metadata documents for a sample of data sources. The report is organized as follows:

- Chapter 1 is this introductory chapter.
- Chapter 2 reviews transportation planning practices in Texas.
- Chapter 3 summarizes meetings with metropolitan planning organizations (MPOs) and other stakeholders.
- Chapter 4 describes a prototype logical data model for transportation planning spatial data.
- Chapter 5 includes a project summary and recommendations for implementation.

CHAPTER 2. TRANSPORTATION PLANNING PRACTICES IN TEXAS

INTRODUCTION

This chapter summarizes documentation requirements, spatial data elements, and data exchange issues associated with transportation planning practices in Texas. The objective is not to provide a comprehensive description of transportation planning processes and activities since many other documents already cover these areas extensively (see, e.g., *1*, *2*, *3*, *4*, *5*).

LEGISLATIVE FRAMEWORK

Planning has long been part of the transportation process in the United States (*1*). The long history of transportation and environmental legislation (Table 1) has been instrumental in the evolution and molding of transportation planning practices and has directly affected how data collection requirements, technologies, and practices have evolved over the years.

Table 1. Significant Federal Legislation Affecting Transportation Planning (*1*).

Year	Legislation	Comment
1934	Federal-Aid Highway Act	Authorized the use of federal funds for surveys, plans, engineering, and economic analysis. The initial purpose of the surveys was to inventory and map the highway system.
1944	Federal-Aid Highway Act	Significantly increased the funding for highway programs, which triggered or accelerated the implementation of a wide range of data collection initiatives and planning analysis techniques, most of which are still in use today.
1954	Housing Act	Authorized federal funding to state planning agencies, cities, and other municipalities with a population of less than 50,000 people.
1956	Federal-Aid Highway Act	Launched the construction of the National System of Interstate and Defense Highways, also known as the Interstate System.
1961	Housing Act	Started a small loan program for mass transit systems. Included a provision for making federal assistance available for preparing urban transportation surveys, studies, and plans.
1962	Federal-Aid Highway Act	Mandated transportation planning as a condition for receiving federal funds in urbanized areas.
1964	Civil Rights Act	Title VI is the statutory basis for environmental justice. It prohibits discrimination on the basis of race, color, creed or national origin.
1964	Urban Mass Transportation Act	Authorized federal funding for building mass transportation facilities and equipment.
1965	Housing and Urban Development Act	Amended the Housing Act of 1954 by authorizing grants to planning organizations within a metropolitan area or urban region.
1966	Demonstration Cities and Metropolitan Development Act	Required the submission of all applications for the planning and construction of facilities to an areawide planning agency (composed of local elected officials) for review and comment.
1968	Federal-Aid Highway Act	Required public hearings to address economic, social, and environmental effects of proposed projects. Established the highway beautification program. Authorized a highway relocation assistance program. Established a revolving fund for advance right of way acquisition.
1968	Intergovernmental Cooperation Act	Required the establishment of areawide planning agencies under state-enabling legislation. Required notification to state governments of the availability and amount of aid grants.
1969	National Environmental Policy Act (NEPA)	Required federal agencies to use a systematic interdisciplinary approach for planning and decision making affecting the environment. Required the preparation of an environmental document for all federal actions that would affect the environment significantly.
1970	Clean Air Act Amendments	Created the United States Environmental Protection Agency (EPA) and authorized it to establish air quality standards. EPA developed standards and proposed regulations on state implementation plans (SIPs) to meet those standards.
1970	Urban Mass Transportation Assistance Act	Provided long-term federal commitments to mass transportation projects. Required public hearings to address economic, social, and environmental impacts of proposed projects.
1970	Federal-Aid Highway Act	Established the federal-aid urban highway system with a requirement for the selection of routes by local and state agencies in a cooperative manner.
1973	Federal-Aid Highway Act	Enabled the use of funds from the Highway Trust Fund for urban mass transportation projects. Realigned federal-aid systems by functional use. Established a separate mechanism for urban transportation planning funding.

Table 1. Significant Federal Legislation Affecting Transportation Planning (*1*) (continued).

Year	Legislation	Comment
1973	Endangered Species Act	Required an assessment of which species would be considered endangered. Required a process to determine if a project would have an adverse impact on endangered species.
1974	National Mass Transportation Assistance Act	Authorized the use of federal funds for transit operating assistance.
1976	Federal-Aid Highway Act	Expanded the transferability of federal funds among different federal-aid systems. Expanded the definition of construction to include resurfacing, restoration, and rehabilitation (3R).
1977	Clean Air Act Amendments	Required state and local governments to develop revisions to SIPs for all areas where air quality standards had not been attained. Required that in nonattainment areas, priority for transportation funds was to be given to transportation control measures that contributed to reducing air pollution emissions from transportation sources.
1978	Surface Transportation Assistance Act	First act that combined highway, public transportation, and highway safety authorizations. Accelerated completion of the Interstate System.
1978	National Energy Act	Extended existing efforts to promote energy conservation through federal-aid programs.
1981	Federal-Aid Highway Act	Increased the priority for completion of the Interstate System. Created a resurfacing, restoration, rehabilitation, and reconstruction 4R category composed of resurfacing, restoration, rehabilitation, and reconstruction.
1982	Surface Transportation Assistance Act	Extended authorizations for highway, safety, and transit programs. Increased highway user charges.
1987	Surface Transportation and Uniform Relocation Assistance Act	Updated provisions for relocation compensations. Extended the Highway Trust Fund. Enabled the use of federal-aid funds on projects with tolls.
1990	Clean Air Act Amendments	Classified nonattainment areas for ozone, carbon monoxide (CO), and particulate matter according to the severity of the air pollution problem. Established attainment date goals. Set more stringent emission standards for mobile sources.
1990	Americans with Disabilities Act (ADA)	Prohibited discrimination on the basis of disability, which resulted in the requirement to provide paratransit services and the development of ADA Accessibility Guidelines.
1991	Intermodal Surface Transportation Efficiency Act (ISTEA)	Expanded the role of MPOs. Defined metropolitan area boundaries for attainment areas and nonattainment areas. Required MPOs to consider 15 planning factors. Required MPOs to prepare a transportation improvement program (TIP) in cooperation with the state and transit operators. Required the implementation of six management systems: pavement, bridges, safety, congestion, transit, and intermodal facilities.
1992	Energy Policy Act	Increased the limit on tax-exempt transit benefits and provided funding for electric motor vehicle demonstration programs.
1995	National Highway System Designation Act	Designated the National Highway System, consisting of 160,000 miles including the Interstate System. Eliminated the ISTEA requirements for six management systems, making them optional.
1998	Transportation Equity Act for the 21st Century (TEA-21)	Expanded surface transportation appropriations. Increased tax-free transit benefits. Expanded congestion mitigation and air quality (CMAQ) improvement and transportation enhancement programs.
2005	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)	Established the Safe Routes to School program. Consolidated planning factors into 8 factors. Required TIPs and statewide TIPs (STIPs) to be updated at least every 4 years. Delegated categorical exclusions to states. Delegated environmental responsibilities to five states on a pilot basis. Encouraged design-build contracting strategies.

According to SAFETEA-LU provisions (*6*), the transportation planning process should consider projects and strategies that will:

(A) support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency;
(B) increase the safety of the transportation system for motorized and nonmotorized users;
(C) increase the security of the transportation system for motorized and nonmotorized users;
(D) increase the accessibility and mobility of people and for freight;
(E) protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between transportation improvements and State and local planned growth and economic development patterns;
(F) enhance the integration and connectivity of the transportation system, across and between modes, for people and freight;

(G) promote efficient system management and operation; and
(H) emphasize the preservation of the existing transportation system.

METROPOLITAN PLANNING ORGANIZATIONS IN TEXAS

Federal law authorizes MPOs to carry out the transportation planning process for urbanized areas (i.e., areas with a population of at least 50,000, as designated by the U.S. Census Bureau) (*6*). The metropolitan planning area encompasses at least the existing urbanized area and the contiguous area expected to become urbanized within a 20-year forecasting period. The law includes provisions for inclusion of the metropolitan statistical area (MSA) or the consolidated metropolitan statistical area (CMSA), as well as provisions for handling urbanized areas in nonattainment areas for ozone or carbon monoxide. In urbanized areas with a population over 200,000, the metropolitan planning area is also designated as a Transportation Management Area (TMA). TMAs have additional analysis and reporting requirements beyond that of MPOs with less than 200,000 in population.

There are 25 MPOs in Texas, covering 30 urbanized areas (Figure 1, Table 2). Eight of the metropolitan planning areas are TMAs. There are four nonattainment areas for air quality standards in Texas (*7*):

- **Houston/Galveston/Brazoria** (eight-hour ozone). It includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties.

- **Dallas/Fort Worth** (eight-hour ozone). It includes Collin, Dallas, Denton, Tarrant, Ellis, Johnson, Kaufman, Parker, and Rockwall counties.

- **Beaumont/Port Arthur** (eight-hour ozone). It includes Hardin, Jefferson, and Orange counties.

- **El Paso** (particulate matter [PM_{10}]). It includes El Paso County.

There are also three Early Action Compact areas:

- **Austin/San Marcos** (ozone). It includes Travis, Williamson, Bastrop, Hays, and Caldwell counties.

- **San Antonio** (ozone). It includes Bexar, Comal, Guadalupe, and Wilson counties.

- **Northeast Texas** (ozone). It includes Rusk, Smith, Upshur, Gregg, and Harrison counties.

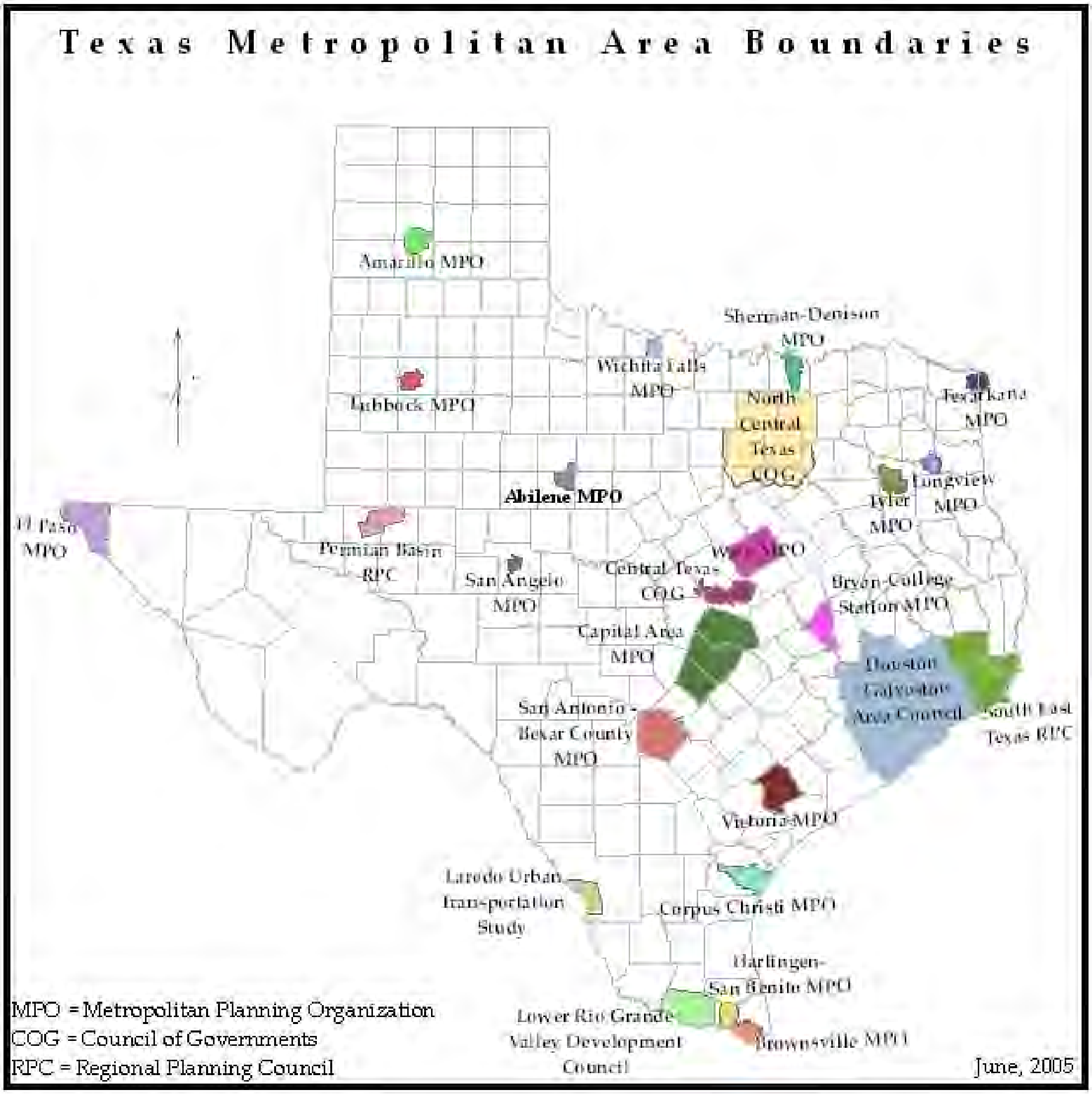


Figure 1. MPOs in Texas (*8*).

Table 2. Texas MPOs.

MPO	Transportation Management Area	Nonattainment Area	Urbanized Areas Included
Abilene MPO			Abilene
Amarillo MPO			Amarillo
Brownsville MPO			Brownsville
Bryan/College Station MPO			Bryan/College Station
CAMPO	X		Austin
Central Texas Council of Governments			Killeen, Temple
Corpus Christi MPO	X		Corpus Christi
El Paso MPO	X	PM_{10}	El Paso
Harlingen-San Benito MPO			Harlingen
H-GAC	X	Ozone	Houston, Galveston
Laredo Urban Transportation Study			Laredo
Longview MPO			Longview
Lower Rio Grande Valley Development Council	X		McAllen-Edinburg-Mission
Lubbock MPO	X		Lubbock
NCTCOG	X	Ozone	Dallas/Ft. Worth, Denton
Permian Basin Regional Planning Commission			Midland, Odessa
San Angelo MPO			San Angelo
SA-BC MPO	X		San Antonio
Sherman-Denison MPO			Sherman-Denison
SETRPC		Ozone	Beaumont, Port Arthur
Texarkana MPO			Texarkana
Tyler MPO			Tyler
Victoria MPO			Victoria
Waco MPO			Waco
Wichita Falls MPO			Wichita Falls

Some MPOs in Texas are part of councils of governments (COGs) or regional planning commissions RPCs that manage a broader range of regional issues such as workforce development and economic development. For example, H-GAC, which houses the MPO that covers the Houston and Galveston urbanized areas, also addresses other regional issues such as air quality, disaster preparedness and emergency services, community and economic development, human services, homeland security, and criminal justice planning (*9*). It is important to note that the metropolitan planning area for the MPO does not necessarily coincide with the COG or RPC boundary.

COGs and RPCs that do not house MPOs do not appear in Figure 1 or Table 2. For example, AACOG manages a wide range of services in the San Antonio area, covering 12 counties, including areas beyond the transportation planning area. AACOG is also a primary source for demographic and socioeconomic data, but does house the MPO for the region (*10*). SA-BC MPO has that responsibility.

MPOs frequently work together to support transportation planning activities. For example, travel survey data collection frequently encompasses more than one MPO jurisdictional area (e.g., Tyler and Longview MPOs in Northeast Texas and Harlingen-San Benito MPO, Brownsville MPO, and Lower Rio Grande Valley Development Council in South Texas). This data collection approach results in a much stronger understanding of both travel patterns within each individual MPO and the interaction of travel patterns among all MPOs involved, which in turn results in significant improvements in travel demand modeling capabilities for the entire region.

REQUIRED TRANSPORTATION PLANNING PRODUCTS

Federal regulations require agreements or memoranda of understanding between the state, the MPOs, and public transit service operators clearly identifying the responsibilities for transportation planning and programming (*11*). TxDOT functions as the program manager for the metropolitan transportation planning process in Texas, overseeing the allocation and use of funds by the MPOs (*12*). TxDOT also provides support and information to assist MPOs in developing plans and programs.

MPOs must prepare the following transportation planning products in accordance with federal law and regulations (*6*, *12*):

- **Metropolitan Transportation Plan (MTP)**. MTPs contain a list of projects recommended for the forecasted year and provide systematic long-range planning for transportation projects and programs in metropolitan areas. MPOs are responsible for developing MTPs in cooperation with the state and publicly owned transit operators. MTPs must address at least a 20-year planning horizon, be financially constrained, and follow an approved public involvement process. The cycle for reviewing and updating the MTP is five years (four years for nonattainment areas).

- **Metropolitan Transportation Improvement Program**. The TIP is a subset of the MTP that includes a list of priority projects expected to be funded within a four-year period and have been approved for development in the near term. The TIP is the region's spending plan for capital and operational transportation improvements to the metropolitan transportation system. The cycle for reviewing and updating the TIP is four years.

- **Unified Planning Work Program (UPWP)**. The UPWP describes short-range transportation planning activities, including responsible party, anticipated work schedule, anticipated products, proposed funding, and total amounts and sources of federal and matching funds. MPOs develop UPWPs in cooperation with the state and publicly owned transit operators. The cycle for preparing UPWPs is one year.

- **Public Participation Plan**. MPOs must develop a public participation plan to meet individual community involvement requirements, including public comment periods; information dissemination about issues and processes; consideration for the needs of traditionally underserved segments of society; and summaries, analyses, and reports.

- **Certification**. At least every four years, the state and the MPOs must certify that the metropolitan planning process is carried out in accordance with all requirements. In addition, FHWA and Federal Transit Administration (FTA) review and evaluate the transportation planning process for each TMA at least every four years.

- **Congestion Management Process**. For TMAs, the transportation planning process must include the implementation of a congestion management process that includes multimodal system performance measures and strategies that are consistent with the MTP and the TIP.

- **Annual Listing of Projects**. MPOs must prepare a listing of obligated projects, including the amount of federal funds requested in the TIP, federal funds obligated during the preceding year, and federal funds remaining and available for subsequent years.

In Texas, MPOs also need to prepare a Texas Metropolitan Mobility Plan (TMMP) or a Texas Urban Mobility Plan (TUMP). The TMMP is a state-based requirement for Texas TMAs to develop a comprehensive, locally developed plan to reduce congestion and improve mobility and air quality (*13*). The TUMP has the same goals as the TMMP, but applies in the case of smaller metropolitan areas in the state. As opposed to the MTP, the TMMP and the TUMP are financially unconstrained, focusing instead on the identification of a comprehensive set of unmet transportation needs for a region. In other words, the TMMP and TUMP reflect a region's perception about what they need, whereas the MTP reflects what realistically they could afford.

Additional documents that are necessary as part of the statewide transportation planning process in Texas include the following (*14*, *15*):

- **Transportation plans**. Each TxDOT district develops a Rural Transportation Plan. TxDOT also generates a Statewide Multimodal Transportation Plan. TPP reviews and assembles the various transportation plans, including the MTPs from the 25 MPOs, into a Statewide Transportation Plan (STP).

- **Unified transportation program**. The Unified Transportation Program (UTP) is a 10-year plan that identifies projects and the corresponding authorized level of development, links projects and programs to anticipated funding, and lists estimated letting years for project-specific programs.

- **Transportation improvement programs**. Each TxDOT district develops a Rural Transportation Improvement Program (RTIP). TPP reviews and assembles the TIPs and RTIPs into a draft Statewide Transportation Improvement Program (STIP) that needs to be sent to FHWA for review and approval.

- **Letting schedule**. Using the UTP and STIP, TPP develops a letting goal for a given fiscal year with an associated letting schedule of projects.

Preparation of the various planning documents is time-consuming and requires a substantial amount of resources and data exchange among stakeholders. This is particularly true in the case of an MTP, which can take anywhere from four to five years to complete. At any given point in time, different MPOs around the state are at different stages in the production of their MTPs.

Major steps in the MTP development process include the following:

- **Data collection and forecasts**. This step involves gathering data such as traffic counts, travel surveys, employment data, household data, and anticipated growth rates. It also includes preparing socioeconomic and land use forecasts.

- **Transportation planning network development**. This step involves developing and/or revising the transportation planning network to reflect current conditions for the base year. A "committed" transportation planning network takes the base-year network and adds proposed projects.

- **Travel demand model (TDM)**. This step involves the use of travel demand modeling tools to identify the performance of the existing system and identify needs of the future system.

- **Alternatives analysis**. This step involves using the results from the travel demand forecasting process to evaluate the impact of adding or removing projects from the transportation planning network.

- **Ultimate needs plan**. This step involves using the results of the travel demand model and the alternative analyses to create a "needs" plan. This plan identifies all metropolitan area needs if unlimited financial resources were available.

- **Financial forecast**. This step involves developing a financial plan that matches proposed projects and programs to available and projected funding.

- **Conformity determination**. MPOs in nonattainment areas must demonstrate that estimated vehicle emissions for projects included in the MTP are lower than the maximum allowed in the SIP.

TxDOT performs travel demand modeling for all urban areas under a cooperative arrangement with the MPOs (except Dallas/Fort Worth, Houston/Galveston, and El Paso, which maintain their own models). Under this cooperative arrangement, TxDOT develops and maintains the travel demand models, conducts travel surveys, and performs five-year counts in the urban areas it models. For the MPOs that maintain their own models, TxDOT provides five-year counts and works with MPOs on conducting travel surveys. TxDOT has standardized the process for developing travel demand models for the MPOs that fall under the cooperative arrangement with TxDOT. The standardized process includes a series of critical meetings, memoranda, guidelines, and a timeline diagram. At the end of this process, TxDOT provides a summary of results comparing base and forecast year conditions, which include the following (*16*):

- socioeconomic data such as population, household data, and employment data;
- volume/capacity analysis and traffic assignment;
- node-to-node turning movements for each intersection in the network;
- trip length summary by trip purpose;
- 24-hour volumes by trip purpose;
- external local and external through trips;

- vehicle miles traveled (VMT) by functional class, per capita, and per household; and
- total assigned traffic volumes within each sector and/or district.

In addition, TxDOT makes transportation planning network and 24-hour trip data available to each MPO in Caliper® TransCAD® format, including the following:

- base and forecast year transportation planning networks;
- traffic analysis zones (TAZ);
- sector layer;
- TxDOT county file;
- MPO boundary file;
- origin-destination trip matrix;
- speed/capacity table;
- area types and sector data by TAZ;
- comment for each special generator zone; and
- population, household, employment, and special generation data by TAZ.

SAMPLE TRANSPORTATION PLANNING DATASETS

It is impractical in this report to describe in detail all the datasets that may be used for transportation planning purposes. As a reference, this section describes some of the most commonly used datasets, with a focus on datasets that TxDOT produces, uses, or can make available to the MPOs: traffic counts, travel surveys, socioeconomic data, transportation network data, and environmental data.

Traffic Count Data

TxDOT collects the majority of traffic data used for transportation planning process in Texas, although MPOs sometimes collect and use additional traffic data (e.g., high occupancy vehicle lane counts) with their own resources or from other sources. Relevant traffic data that TxDOT collects and processes include the following (*16*):

- **Automatic Traffic Recorder (ATR) volume data**. Permanent ATR equipment at about 160 permanent sites collects data 24 hours a day, 365 days annually for each lane. TxDOT uses ATR data to calculate statewide VMT data, directional factors, K-factors, and seasonal variation factors.

- **Accumulative Count Recorder (ACR) traffic data**. With ACRs, TxDOT conducts 60,000-80,000 counts per year on selected Highway Performance Monitoring System (HPMS) roads and on-system roads. TxDOT reports ACR volume data aggregated at the 24-hour level for a typical weekday.

- **Five-year count data**. Five-year counts are ACR traffic counts made throughout the metropolitan areas of Texas based on the schedule of MPO, MTP, and TIP updates.

These counts, also called "saturation counts" (since an urban area is "saturated" with counts), are used for the MPO travel demand model. MPOs, with cooperation from the local TxDOT district office and TPP, identify count locations.

TxDOT uses ATR and ACR axle data to calculate average annual daily traffic (AADT) data. Count data processing includes reviewing the raw output from the counters, running a conversion routine to import the data to a mainframe computer, producing a matrix of counts and locations, and importing the resulting data into TransCAD for the production of district traffic maps (Figure 2) and five-year count maps (Figure 3). After receiving approval from FHWA, TxDOT makes the traffic maps available in paper or portable document format (PDF). TxDOT also provides MPOs with a GIS layer of traffic count locations.

Feedback from data users has identified difficulties associating traffic count data with transportation planning network segments, e.g., traffic counts not having coordinate data (e.g., ramp counts) and counts with several potential locations (e.g., frontage road, ramp, and freeway). Another issue reported by users includes not having adequate count station coverage to properly account for different functional class segments in the transportation planning network.

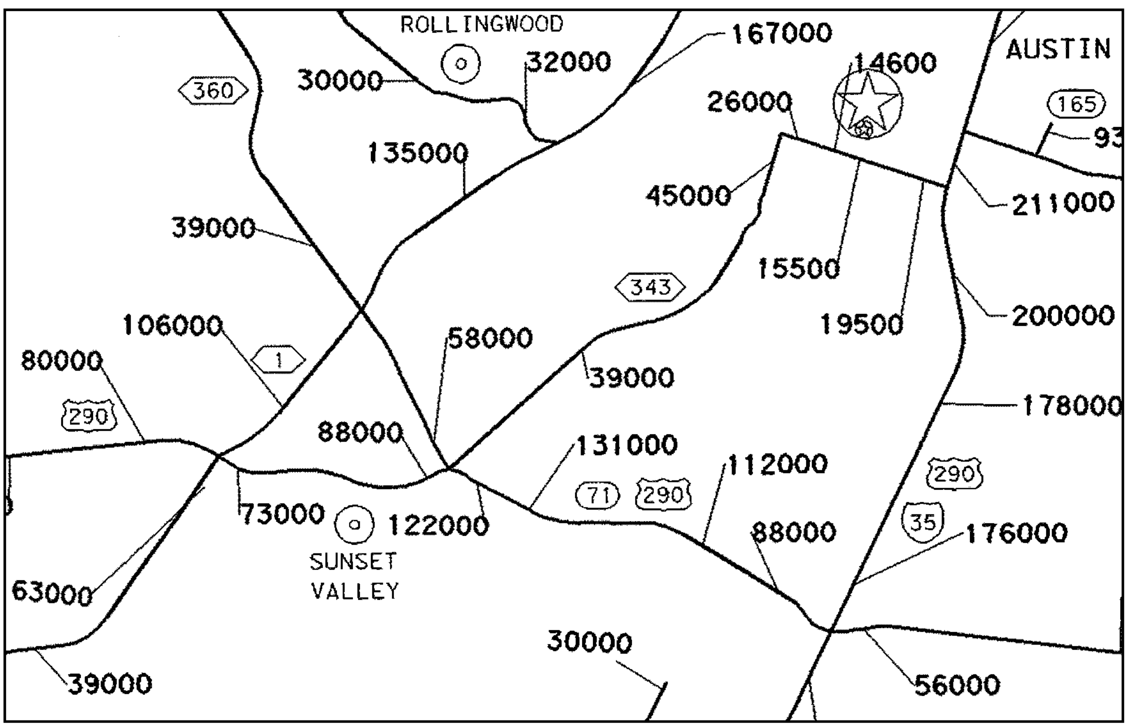


Figure 2. Sample Austin Area District Traffic Map (2002).

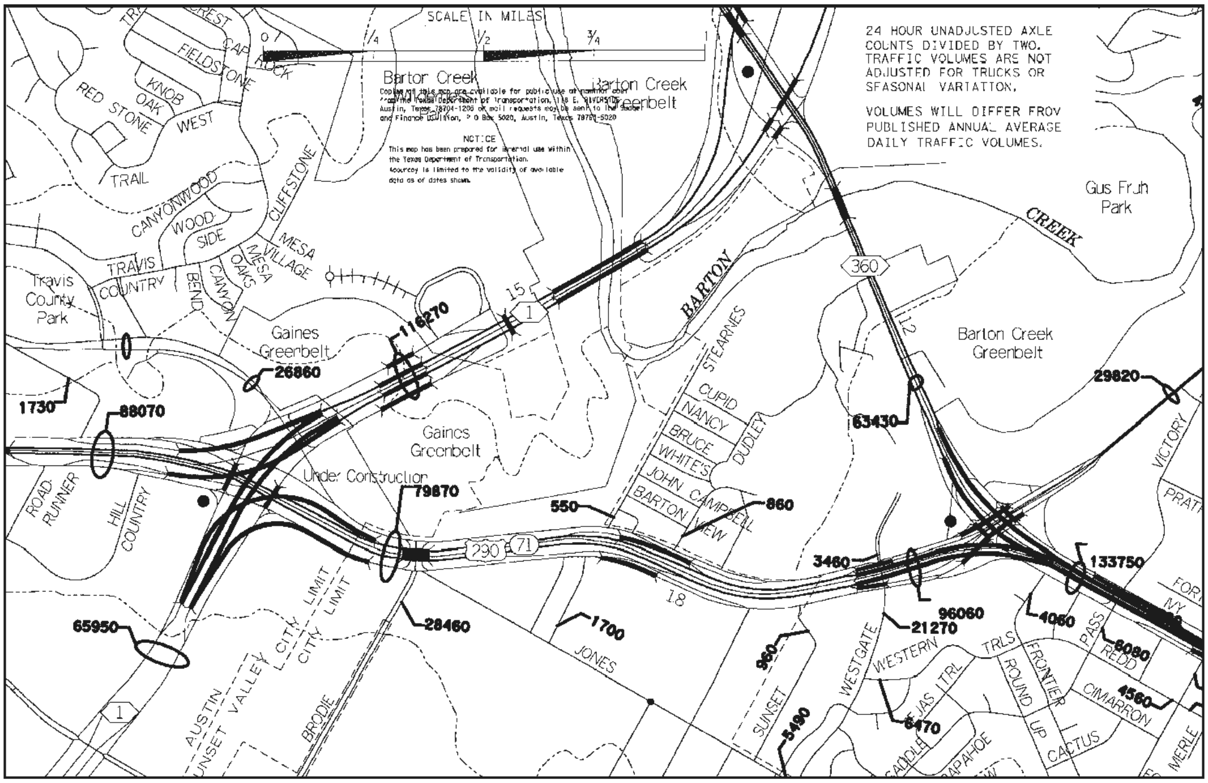


Figure 3. Sample Austin Area Five-Year Count Map (2002).

Travel Survey Data

TxDOT conducts almost all travel surveys used in the transportation planning process in Texas, typically within one year of the five-year counts. As an illustration, Table 3 summarizes typical travel surveys in Texas and commonly used data collection techniques (*16*). In addition, TxDOT districts frequently conduct project-specific corridor-level travel surveys, which MPOs often use.

Although traditional data collection techniques enable the collection of travel data such as trip purpose, origin and destination data, mode characteristics, and vehicle type, a concern with most traditional data collection techniques is how to map and validate the data collected in relation to corresponding locations on the ground such as origins, destinations, and other points of interest. Other issues include the ability to correctly map data to TAZs and/or network links.

New global positioning system (GPS)-based survey techniques enable the collection of geo-referenced data at fine spatial and temporal increments. Experience with this technique in Texas and elsewhere has produced fine resolution data that have also enabled the validation of trip data that interviewees provide (*17, 18, 19*). Currently, most of the GPS data processing is done manually, with some level of automation provided by the use of relatively simple scripts. Further automation (which is an active research area, particularly abroad) involves the development of business rules and mapping algorithms to automatically extract all the travel survey data needed to characterize trips using the GPS data and relevant data layers such as transportation network, land use data, and landmarks.

Table 3. Typical Travel Survey Data Collection Techniques in Texas.

Data Collection Technique	Survey Type						
	Household	Workplace	External Station	Commercial Vehicle	Air Quality	Transit	Special Generator
Automatic traffic recorder/accumulative count recorder					X		
Automatic vehicle classification counter		X	X		X		X
Computer assisted self interview						X	
Hand-out/hand-back/mail-back survey						X	
Hand-out/mail-back survey						X	
Intercept personal interview (computer-assisted)		X	X				X
Intercept personal interview (paper-based)		X	X				X
License plate survey			X				
Telephone interview (computer-assisted)	X	X					X
Telephone interview (paper-based)	X	X					X
Travel diary (GPS-assisted)	X						
Travel diary (paper-based)	X	X		X			X
Truck travel log				X			
Vehicle speed data collection site					X		
Weigh-in motion					X		

Socioeconomic Data

Socioeconomic data include household, employment, and special generator base and forecast year data for each TAZ (*16*). Household data include U.S. Census Bureau data for base years and Texas State Data Center (TSDC) data for estimates and forecast year projections. Employment data include U.S. Census Bureau data and Texas Workforce Commission (TWC) data. TWC data include employers, associated addresses, locations (latitude/longitude), North American Industry Classification System codes, and number of employees.

Under the cooperative agreement with TxDOT, MPOs can request assistance for processing TWC data, including geocoding the physical location of employment sites, aggregating employment sites by employment type for each TAZ, identifying employment sites that cannot be aggregated to a TAZ, and identifying employment sites that did not report any employees. Issues that users have identified with TWC data include multiple establishment employers (i.e., parent-child relationships), erroneous coordinate data, and missing employment data. TWC sometimes reports employee locations based on location of the payroll office, e.g., in the case of gas station chains or independent school districts. In this case, it is necessary to use tools such as aerial photography and land use data to check and adjust employment location points. In the case of erroneous coordinate data, TWC sends business address data to a consultant for geocoding. Sometimes, geocoded locations are wrong, e.g., locations might be depicted on the wrong sides of highways, frontage roads, or TAZs. In some other cases, the addresses reported are mailing addresses or postal office box addresses. Through the application of quality control procedures, however, it appears that the magnitude of the coordinate data problem is much smaller at present than in the past. More important is the issue of employment data that are missing from TWC datasets because TWC removes sensitive data (e.g., military employment) before releasing the datasets.

Base and Forecast Transportation Network Data

The transportation planning network is an abstraction of the actual highway and transit systems of a metropolitan area, which typically includes freeways, arterials, and collectors at a generalized level of detail (i.e., curvature may not be accurate). The network is composed of TAZs, centerline links (e.g., highway segments, transit lines, and TAZ centroid connectors), and nodes (e.g., link intersections, link vertices, and TAZ centroids). As an illustration, Figure 4 shows parts of the transportation planning network for the Waco MPO.

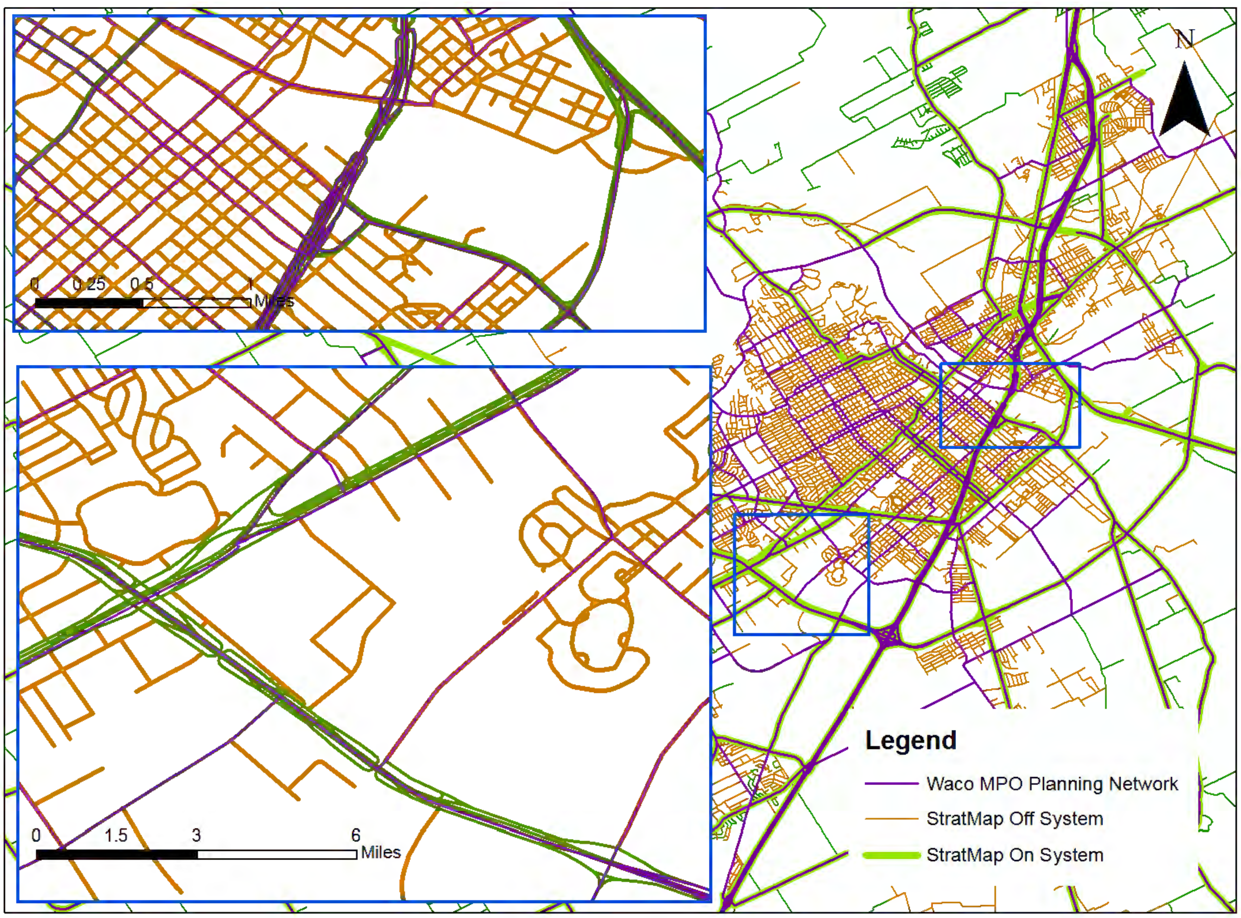


Figure 4. Waco MPO Transportation Planning Network Overlaying On-System and Off-System Roadbed Networks.

TxDOT works with 22 of the 25 state MPOs (i.e., except for NCTCOG, H-GAC, and El Paso MPO) to develop transportation planning networks for both base and forecast years. Originally, TxDOT digitized transportation planning networks in Bentley Systems® MicroStation™ format using U.S. Geological Survey (USGS) topographic maps and imported the network data into Urban Analysis Group TRANPLAN software. Subsequent upgrades involved extracting network data from the Strategic Mapping Program (StratMap) version 1.0 datasets (available through TNRIS) and importing the network data into TransCAD.

For each MTP update cycle, developing the base-year transportation planning network involves the MPO providing additions or changes to the paper or digital plot of the TxDOT-provided preliminary base-year transportation network. For new roads that have become operational since the last update cycle, TxDOT digitizes those roads using aerial photography (or TxDOT's on-system or off-system segments if available). TxDOT also reviews link attribute edits that the MPOs have made to the TransCAD link layer. Upon review and approval by the MPO, the updated network becomes the base-year transportation planning network for the current cycle.

Developing the forecast-year transportation planning network involves the MPO identifying committed projects to be completed up to the forecast year and updating the transportation planning network. Using this information, TxDOT updates the base-year transportation planning network. Upon review and approval by the MPO, the updated network becomes the forecast-year transportation planning network for the current cycle.

Updating TAZ boundaries follows a somewhat similar process as that for the base-year and forecast-year transportation planning network. In general, MPOs provide changes to TAZ boundaries from the previous update cycle on the paper or digital plot of the TxDOT-provided preliminary base-year transportation network, making sure the updated TAZ boundaries are compatible with the network (e.g., by splitting TAZs to avoid roadways crossing TAZ boundaries). With the data provided by the MPOs, TxDOT edits TAZ boundaries and uses a TransCAD conflation tool to conflate TAZ boundaries to the updated transportation planning network.

It may be worth noting that TxDOT maintains a separate "measured" version of the (state) on-system and off-system transportation network for use with TxDOT's linear referencing systems. The measured transportation dataset follows its own development and maintenance schedule and protocols. For MTP update cycles, TxDOT does not start with the latest measured transportation dataset. Instead, TxDOT uses the transportation planning network from the previous MTP update cycle and updates links and nodes using (mostly) aerial photography.

For updating the measured transportation dataset, TxDOT uses a number of tools, including aerial photography and GPS data. TxDOT uses sub-meter positional accuracy GPS equipment with real-time differential correction to inventory new on-system routes and off-system county roads. **Note**: TxDOT has also experimented using as-built plans to assist in the process of building transportation network datasets. However, results have been mixed because those plans sometimes do not reflect true as-built conditions. In addition, in the current practice, TxDOT only archives plan sheets in two formats: tagged image file (TIF) and PDF (*20*). If properly updated, as-built plans can provide more accurate, comprehensive information than either sub-meter GPS equipment or meter-level aerial photography. In fact, as-built plans can provide a wealth of ready-to-use spatial data within the right of way, including actual roadbeds and their corresponding roadbed centerlines, roadside features, and right of way lines, particularly when using the original georeferenced MicroStation files used for the production of the plan sheets (*21*, *22*).

Through the 9-1-1 program, RPCs and local jurisdictions in Texas also develop and maintain transportation networks. In an effort to standardize the production of 9-1-1 GIS products across the state, the Commission on State Emergency Communications (CSEC) developed a guideline that includes minimum levels of accuracy and mapping standards (*23*). The guideline includes recommendations on 10 areas or modules that cover topics such as metadata and documentation, data format, map projections, mapping datum, positional accuracy, map base layers and data fields, database, maintenance procedure, wireless services, and map product disclaimer. It may be worth noting that the guideline suggests a minimum positional accuracy for 9-1-1 GIS products of 82 feet (25 meters), but recommends 33 feet (10 meters).

Environmental Data

Access to environmental data in the transportation planning process is increasingly important. It is also increasingly recognized that the outcome of the transportation planning process can support the NEPA process, e.g., by providing information needed for the purpose and need statement, conducting a preliminary screening of alternatives, providing a basic description of the environmental setting, or conducting a preliminary identification of environmental impacts (*11*).

There are several GIS-based resources and systems for environmental analysis, some of which are relevant to this research. This section discusses the following tools:

- Geographic Information System Screening and Analysis Tool (GISST),
- Texas Ecological Assessment Protocol (TEAP),
- NEPAssist,
- Texas Natural Diversity Database (NDD), and
- Texas Historic Sites Atlas.

Geographic Information System Screening and Analysis Tool

GISST is an Environmental Systems Research Institute (ESRI)® ArcGIS™ application developed by the United States Environmental Protection Agency to evaluate environmental vulnerability and impact (*24*). Using a grid shape file that provides common geographic area units for the analysis, GISST calculates criteria values for each geographic area unit (e.g., surface water use, flood plain area percentage, wetland area percentage, population change, and percent agricultural land), rates the potential impact associated with each criterion, and combines the results into one total cumulative impact number. GISST uses over 100 different environmental weighted criteria. GISST stores criteria and total cumulative impact values as attributes associated with each geographic area unit in the shape file (Figure 5). For rating potential impacts, GISST imposes a scoring structure of 1 to 5 on each criterion so that a "1" represents a condition of low concern/vulnerability and a "5" represents high vulnerability.

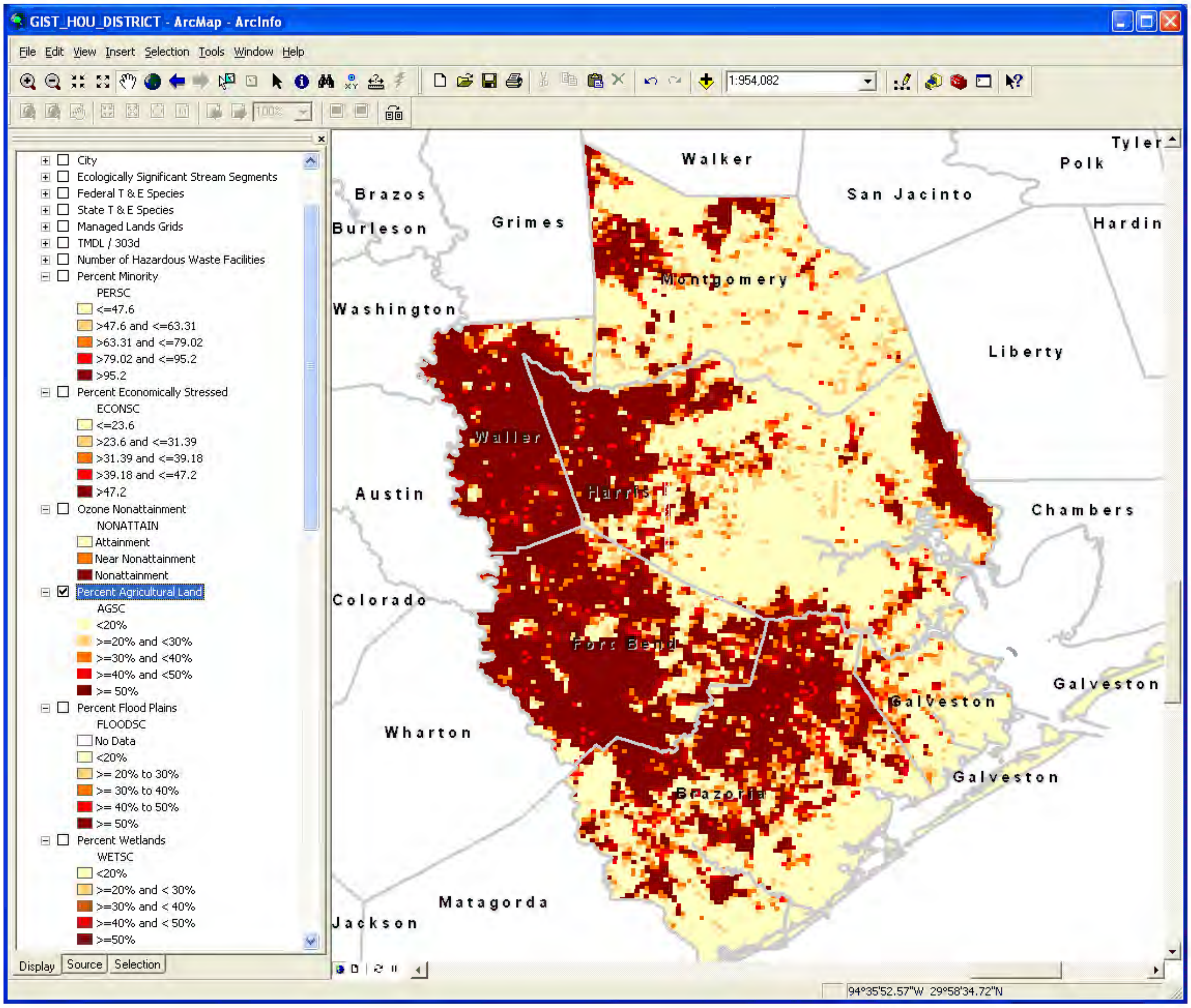


Figure 5. GISST Weighted Criteria Values (Map Shows Percentage of Agricultural Land in the Houston District Area – 1 Kilometer Grid Size).

Overlaying a proposed project alignment on the spatial data layers enables planners to determine cumulative potential impacts associated with that project. GISST uses a 1 km grid size for the environmental rating analysis. A 1 km grid size is usually adequate for large projects where potential realignments can span several 1 km cells. For relatively small, localized projects, a 1 km grid size is usually inappropriate because of the inability to evaluate impacts at finer spatial aggregation levels. TxDOT, several Texas MPOs, and other interested stakeholders use GISST. Through an agreement with EPA's Region 6, ENV has the complete version of GISST, including base data layers, scoring tables, and a custom-built GISST toolbar.

Texas Ecological Assessment Protocol

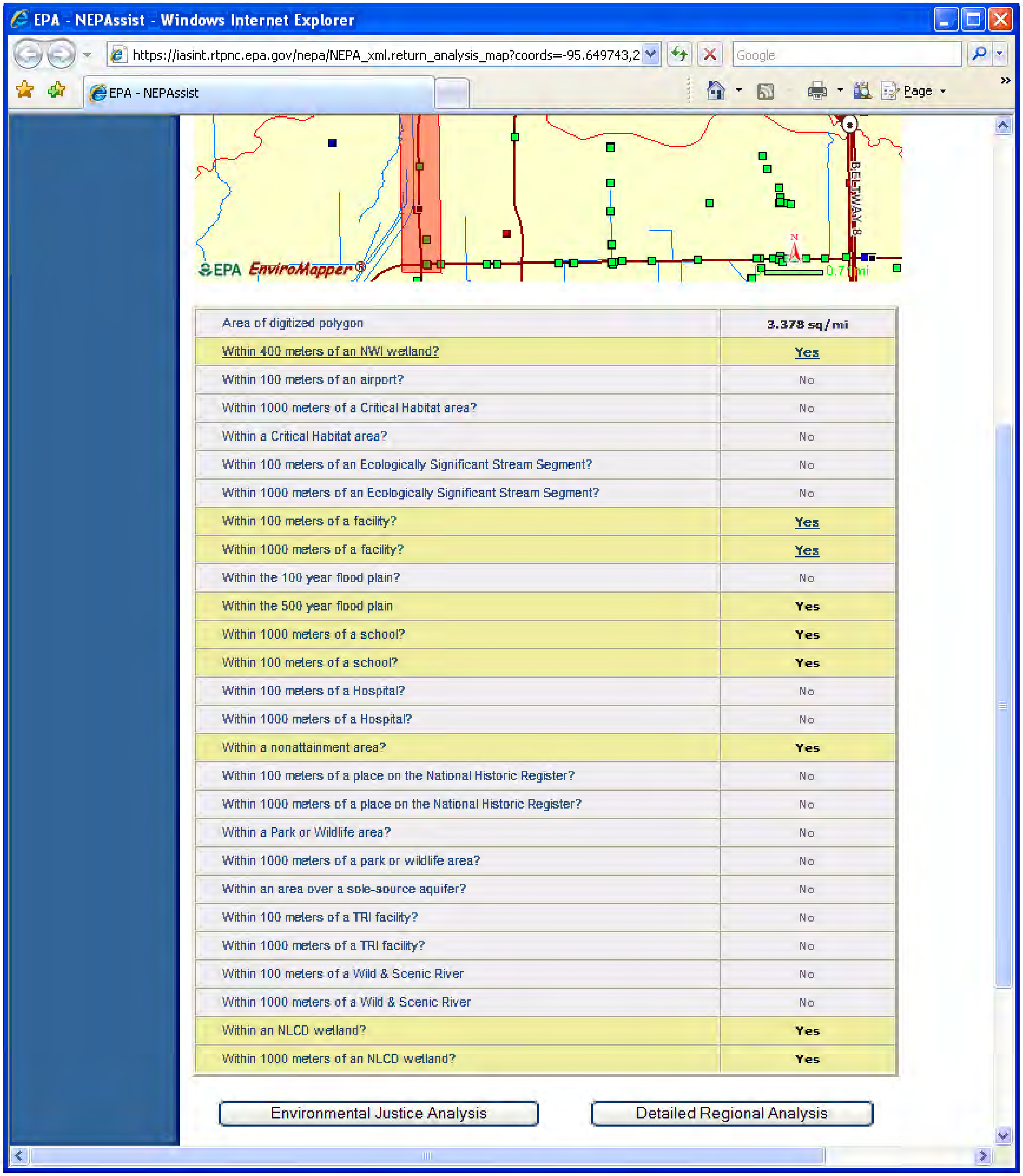
TEAP (*25*) is a GISST "spin-off" designed to identify "ecologically important" locations. TEAP includes three separate 1 km grid layers that provide measures for ecological diversity, rarity, and sustainability, as well as a composite layer that shows the location of "ecologically important" areas in Texas. Similar to GISST, users perform a buffer analysis with a project boundary and TEAP layers. The results of the analysis indicate potential ecological impacts for the project. TEAP layers are attributes in the GISST grid shape file. As such, stakeholders who use GISST also use TEAP.

NEPAssist

NEPAssist is a web-based GIS application that EPA developed to assist with the environmental review process. NEPAssist started as a pilot application in EPA Region 2 in the early 2000s, and it is currently expanding nationwide (*26, 27, 28*). NEPAssist enables users to display close to 40 data layers (Table 4). Using the map viewer, the user identifies a project location by point, line, or polygon, which NEPAssist uses to perform a buffer analysis on applicable GIS databases. The result of this analysis is a table that indicates presence or absence of wetlands, airports, critical species habitat, floodplain, Historic Register locations, wildlife areas, and aquifers in the project area (Figure 6). NEPAssist also performs an environmental justice screening using U.S. Census Bureau demographic data (Figure 7).

Table 4. NEPAssist Map Features.

Category	Layer
Regulated Sites	Multi-activities
	Superfund
	Toxic releases
	Water dischargers
	Air emissions
	Hazardous waste
Places	Cities
	Schools
	Churches
	Hospitals
Transportation	Airport points
	Railroads
	Highways
	Streets
	Airport polygons
Nonattainment Area	Ozone boundary (1999)
	PM25 boundary (1999)
Water Features	Impaired water bodies
	Impaired streams
	Water bodies
	Streams
	Watersheds
Political Boundaries	ZIP codes
	Congressional district boundaries
	City boundaries
	State boundaries
	Counties
Water Monitors	USGS water monitors
	EPA water monitors
Remote Images	TerraServer® photography
	TerraServer topography
	GlobeXplorer® Imagery
	National Land Cover Data (1992)
Federal Emergency Management Agency (FEMA) Flood	Special flood hazard area
	Moderate flood hazard area
Other	USGS National Elevation Dataset
	National Wetlands Inventory Wetlands



Area of digitized polygon	3.378 sq/mi
Within 400 meters of an NWI wetland?	Yes
Within 100 meters of an airport?	No
Within 1000 meters of a Critical Habitat area?	No
Within a Critical Habitat area?	No
Within 100 meters of an Ecologically Significant Stream Segment?	No
Within 1000 meters of an Ecologically Significant Stream Segment?	No
Within 100 meters of a facility?	Yes
Within 1000 meters of a facility?	Yes
Within the 100 year flood plain?	No
Within the 500 year flood plain	Yes
Within 1000 meters of a school?	Yes
Within 100 meters of a school?	Yes
Within 100 meters of a Hospital?	No
Within 1000 meters of a Hospital?	No
Within a nonattainment area?	Yes
Within 100 meters of a place on the National Historic Register?	No
Within 1000 meters of a place on the National Historic Register?	No
Within a Park or Wildlife area?	No
Within 1000 meters of a park or wildlife area?	No
Within an area over a sole-source aquifer?	No
Within 100 meters of a TRI facility?	No
Within 1000 meters of a TRI facility?	No
Within 100 meters of a Wild & Scenic River	No
Within 1000 meters of a Wild & Scenic River	No
Within an NLCD wetland?	Yes
Within 1000 meters of an NLCD wetland?	Yes

Figure 6. NEPAssist Study Area NEPA Analysis Results.

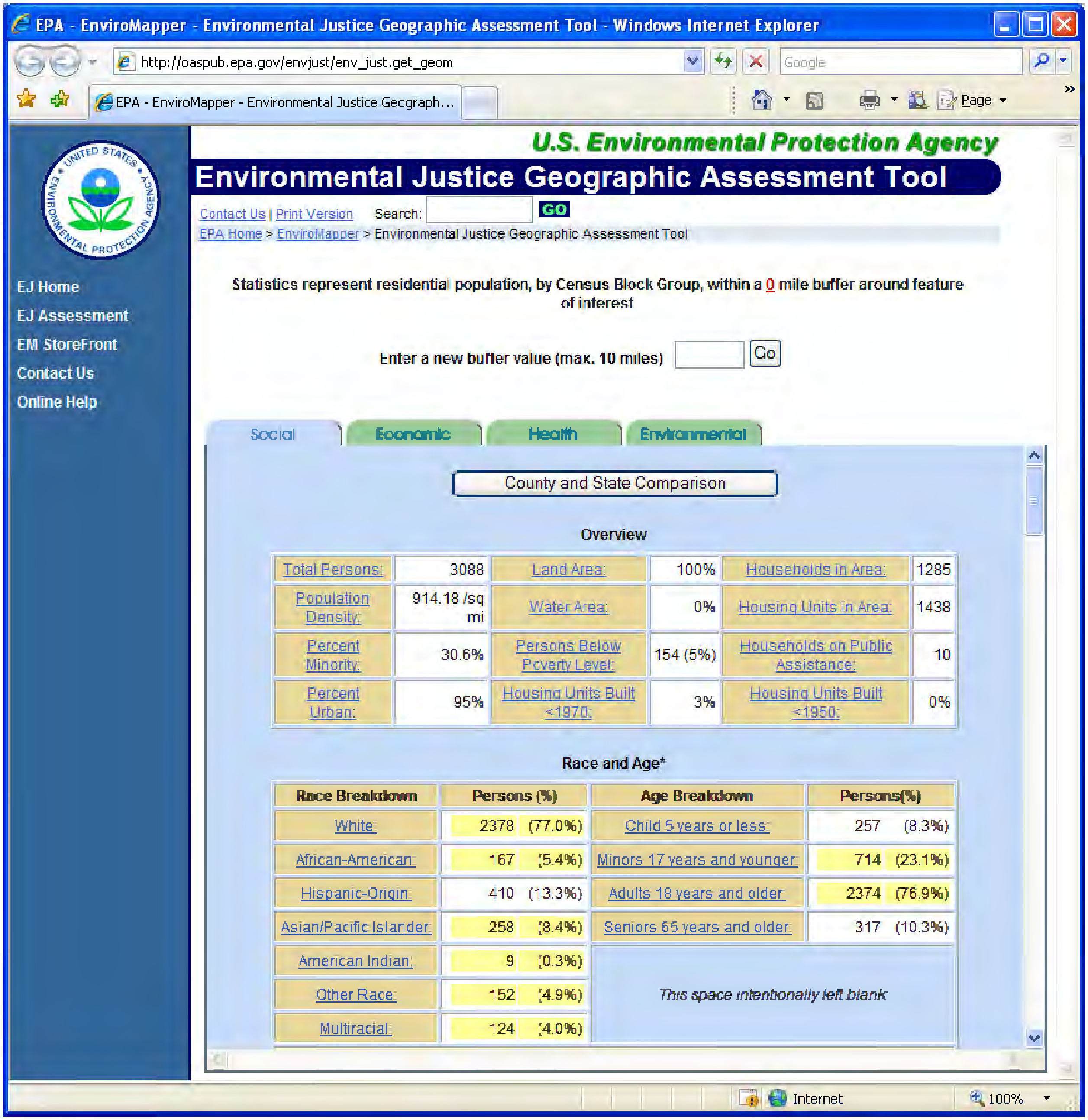


Figure 7. NEPAssist Study Area Environmental Justice Analysis Results.

Texas Natural Diversity Database

NDD is maintained by the Texas Parks and Wildlife Department (TPWD) and NatureServe (*29*). NDD stores data on non-game species and habitat in an Oracle® database (using ESRI ArcSDE™) that represents observations and habitats as points, lines, or polygons (Figure 8). The tool enables users to generate buffers around proposed project locations and create listings of element occurrences within the project boundaries. NDD contains historical data that can date back several decades. As such, the data are only valid to identify potential “red flags,” which require further investigation.

The Environmental Affairs Division has a memorandum of understanding with TPWD, which allows the division to use but not distribute NDD. In the current practice, the Environmental Affairs Division uses NDD at the project level after projects are selected to identify potential project impacts to endangered species. TxDOT then verifies every NDD observation in the field.

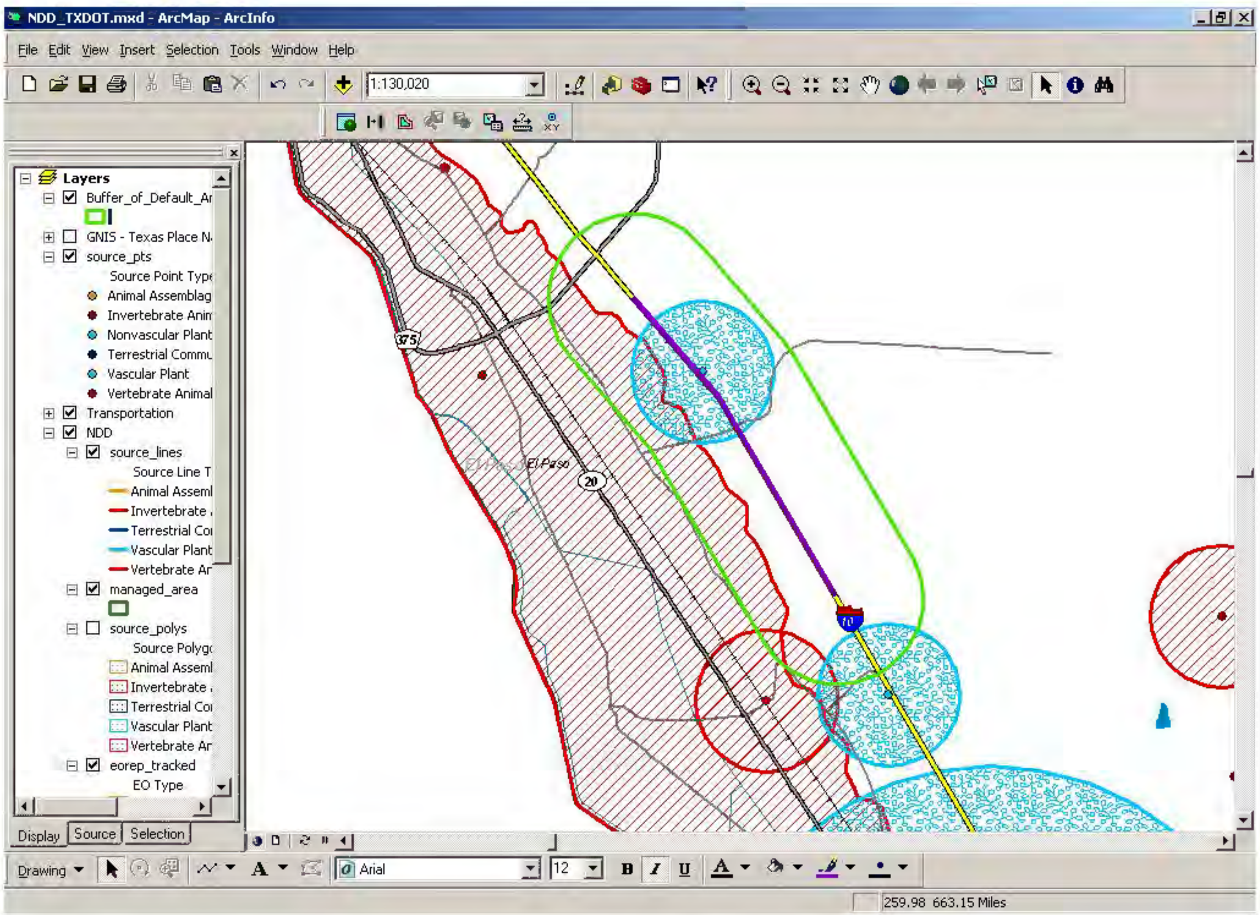


Figure 8. TPWD NDD with a Proposed Project Region.

Texas Historic Sites Atlas

The Texas Historic Sites Atlas is a web-based application that the Texas Historical Commission developed to provide information on the location and condition of Texas’ cultural resources (*30*). This application allows users to search and access detailed text descriptions, historical photographs, and interactive maps. The Atlas is a database of almost 300,000 historic and archeological records on over 150,000 sites in over 30 separate databases. The application provides two types of access levels: public and restricted. Public data access includes official Texas historical markers, historic places and districts, museums, cemeteries, county courthouses, East Texas sawmills, and military sites. Restricted data access applies to archeological site data (to help protect archeological sites from destruction and vandalism).

Users can search datasets by keyword, county, map address, designation, or site name. The result of a query is an interactive map and a list of records that contains hyperlinks to tables and maps (Figure 9). The Atlas also enables users to download tabular data at a county level as comma separated text files or map data in ESRI shape file format. In the current practice, TxDOT uses the Atlas at the project level after projects are selected.

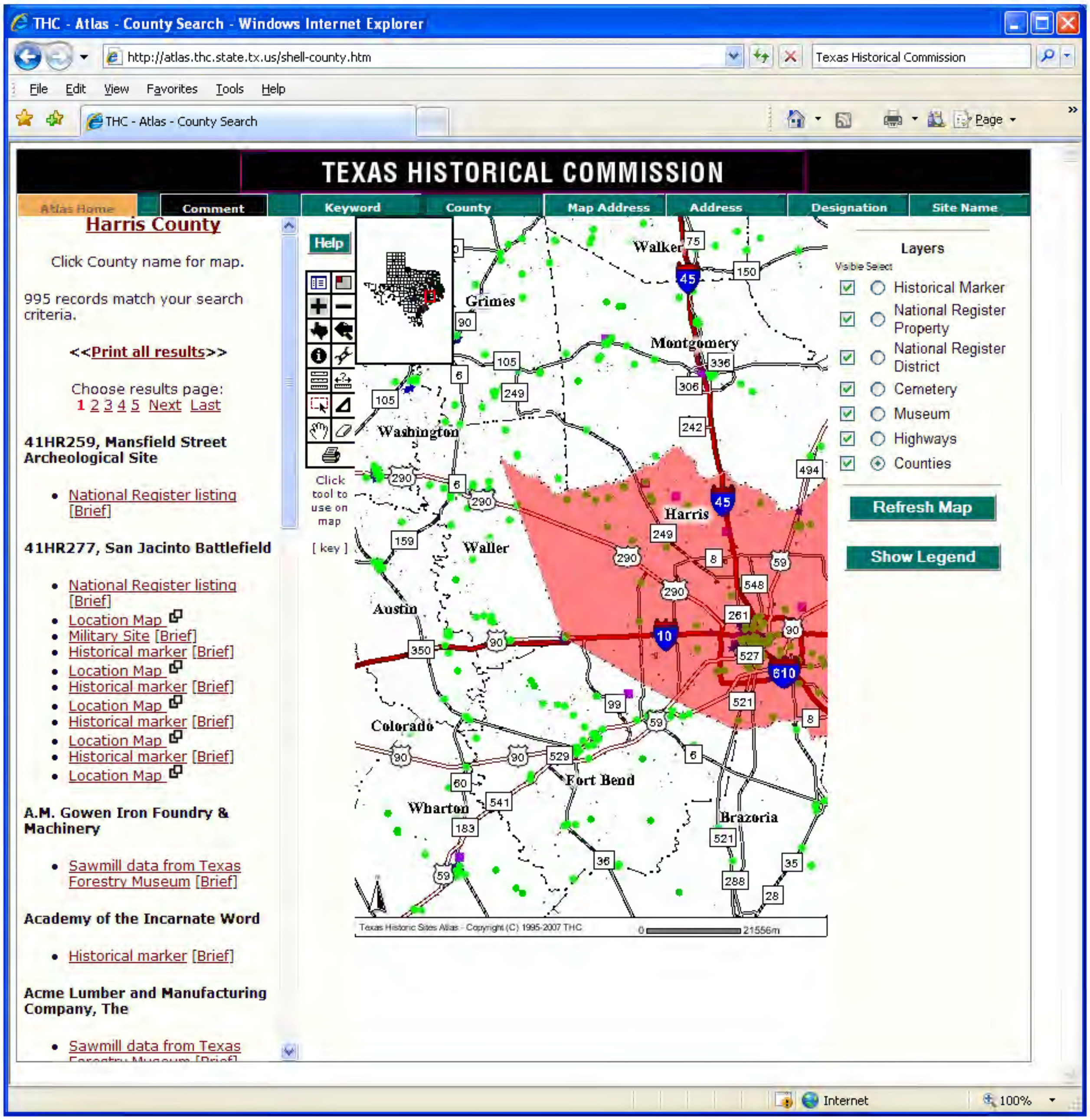


Figure 9. Texas Historic Sites Atlas Web Interface (*30*).

GIS DATA MANAGEMENT-RELATED PRACTICES AT TXDOT

GIS Practices and Plans

TxDOT primarily uses GIS technology to support programming, planning, and maintenance activities—although the use of GIS to support design, construction, and operations is growing. TxDOT is also involved in several multiagency GIS initiatives (*31*, *32*). For example, through StratMap, TxDOT has contributed state and county road GIS data to the Texas Base Map Plan transportation dataset. Other contributors to the transportation dataset include municipal, county, and regional agencies. The transportation dataset is available through TNRIS (*33*). Table 5 provides a summary of production GIS datasets at TxDOT, with an indication of the source (TxDOT or other agency).

Table 5. Production GIS Datasets at TxDOT (*34*).

GIS Data Subject	Number of GIS Feature Classes According to Data Source	
	TxDOT	Other Agencies
Air		2
Aviation	2	6
Facility	1	
Geopolitical	8	5
Land	1	13
Public Land	3	4
Railroad	1	
Structures	3	
TxDOT Route	14	
Water	3	17

TxDOT's GIS infrastructure relies on the traditional linear distance-based geo-referencing method. This method uses route features and route event tables to generate points or segments that represent the geographic extent of those features (also called dynamic segmentation). A route event table includes attributes such as Route Name, From Distance from Origin (DFO), To DFO, Length, and other attributes as needed to characterize the features of interest. As an illustration, Table 6 shows sample records in a route event table that could be used to generate reference marker points. Notice the same basic structure could be used to generate linear segments (in this case, the To DFO attribute would not be blank).

Table 6. Route Event Table to Generate Reference Marker Features.

Route Name	Reference Marker	From DFO	To DFO	Length	Year	Comment
FM 1516	492	0.020			2002	
FM 1516	492	0.046			2006	

In effect, the From DFO and To DFO attributes, in conjunction with the Route Name attribute, define "homogeneous" segments (or points) that share the same attribute values. In general, as the number of attributes in the table increases, the geographic extent of the homogeneous segments tends to decrease and the number of homogeneous segments increases. For example, the TxDOT centerline dataset, which includes approximately 5500 route records, describes basic state route characteristics, e.g., name, class, prefix, suffix, and length. By comparison, the RHiNo file covers 137 attributes that represent a wide range of items including highway status and type, functional class, maintenance responsibility, AADT for the previous 10 years, truck percentage, urban/rural status, shoulder width, median width, right of way width, roadbed width, posted speed limit, surface type and characteristics, and load limits. The RHiNo file includes some 96,000 state highway records. This level of segmentation can make the analysis of information as well as the production of queries and reports quite challenging.

A limitation of the traditional linear distance-based geo-referencing approach is that *both* the underlying highway map and the cumulative distances measured along the routes govern the positional accuracy of the resulting features. To address this limitation, transportation agencies are increasingly relying on absolute location approaches that provide independence from the highway network (e.g., through GPS technology and fine-resolution aerial photography). Another limitation of traditional databases is their inability to handle temporal events efficiently.

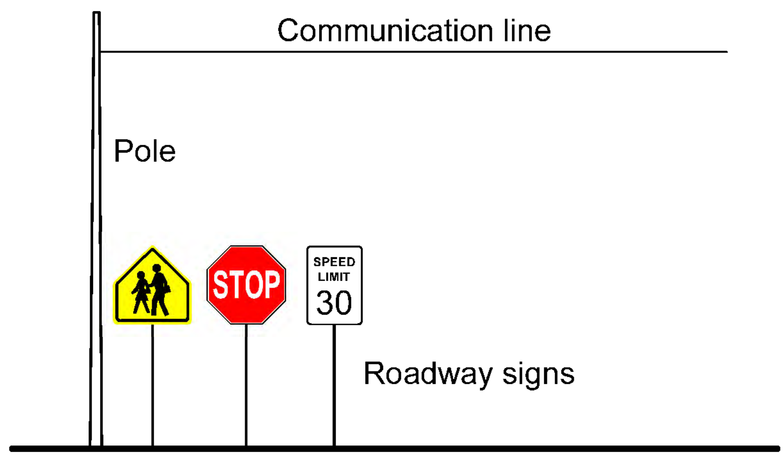
Through the GIS Architecture and Infrastructure Project (GAIP) (*35*), TxDOT developed a framework to reduce the department's dependency on the traditional linear referencing method (*36*). In GAIP, each data element of interest can be managed through a separate table that contains both spatial and non-spatial attribute values that characterize each record spatially and temporally, making the use of event tables as the primary data storage mechanism unnecessary. GAIP also facilitates the use of more accurate location techniques such as GPS or fine-resolution aerial photography to develop GIS-based data inventories. As an illustration, Table 7 shows the structure of a GAIP-compatible interpretation of the reference marker points in Table 6. Notice that, strictly speaking, it is not necessary to include attributes to describe the route and the corresponding location of the reference markers along the route, as GIS functions would enable the calculation of those attribute values "on the fly" by applying spatial intersect joins that overlay the reference marker dataset to the centerline dataset. In practice, business processes might require the inclusion of additional referencing attributes to optimize the production of queries and reports.

Table 7. GAIP-Compatible Reference Marker Feature Table.

Object ID	Shape	Reference Marker ID	From Date	To Date	Comment
189832	Point	492	01/01/2000	12/31/2005	Marker moved
454333	Point	492	01/01/2006		

In the GAIP architecture, a feature can be any managed object. Examples include roadbeds, pavement markings, pavement condition, highway signs, drainage features, right of way, and geopolitical boundaries. As an illustration, Figure 10 shows five roadside features: a pole, an aerial communication line, and three roadway signs. Figure 10 also shows how GAIP would handle feature changes over time. When there is a feature change (either spatially or non-spatially), the old feature is "retired" by populating a time stamp field indicating the completion of the life cycle for that feature and, as needed, a new feature with new attribute values is created.

Notice that Figure 10 shows both retired and new records in the same feature table. This structure is appropriate at the logical level and in situations where records do not change frequently. In practice, particularly when feature tables have a large number of records and/or many of the records tend to change frequently, it may be necessary to divide the table into smaller tables to optimize the production of queries and reports. Examples of table partition strategies that *do not* result in redundant database records include assigning records to tables according to geographic location, feature type, or start date. It is also possible to develop "versions" of feature tables to represent different status conditions (e.g., a different version for each year). While fairly simple to conceptualize, in practice this strategy can result in considerable database redundancy.



Pole Table

Object ID	Shape	Start Date	End Date	(several attributes)		Comment
100100	Point	04/15/1990	08/27/2003	…	…	Object "retired"
127203	Point	08/28/2003		…	…	Replaced pole

Communication Line Table

Object ID	Shape	Start Date	End Date	(several attributes)		Comment
100312	Polyline	05/01/1990		…	…	Existing line
				…	…	

Roadway Sign Table

Object ID	Shape	Start Date	End Date	Sign Type	(several attributes)		Comment
99156	Point	03/15/1989	01/04/2004	Stop	…	…	Object "retired"
530189	Point	01/05/2004		Stop	…	…	Replaced stop sign
367544	Point	08/12/1996		School crosswalk	…	…	
345678	Point	06/01/1995		Speed limit	…	…	

Figure 10. Conceptual Representation of Roadside Features in GAIP.

A key element of the GAIP architecture is the TxDOT network ground set (GS), which is composed of centerlines and roadbeds (*35*). As a reference, the TxDOT Glossary defines centerlines and roadbeds as follows (*37*):

> The centerline is a line dividing the roadway from opposite moving traffic. It is a survey line with continuous stationing for the length of the project. Construction plans and right of way maps refer to this line. Horizontal alignment is the center of the roadbed.

A roadbed is the graded portion of a highway between top and side slopes, prepared as a foundation for the pavement structure and shoulder.

In general, the GS consists of links and nodes, where nodes are the link endpoints. TxDOT's preference for construction of the GS is "heads-up" digitizing over a digital orthophoto rectified to a scale of 1:12,000 (1 inch = 1000 feet) or better (*35*). The current standard is for each GS segment to be within ±10 percent of the actual roadbed centerline. Notice that this standard is vague because a percentage by itself does not provide a measure of actual allowable lateral displacements. In addition, even though the TxDOT Glossary provides a survey context to the definition of a centerline (*37*), the standard does not conform to established survey standards. As a reference, the *TxDOT Survey Manual* (*38*) and the Texas Society of Professional Surveyors (TSPS) *Manual of Practice for Land Surveying in the State of Texas* (*39*) include requirements for different types of surveys. In addition, the TSPS manual of practice includes a section on GIS/Land Information System (LIS) surveys, which include survey-grade applications and non-survey-grade applications.

TxDOT classifies GS components according to jurisdiction and engineering function, resulting in the following GS subtypes: on-system ramp, on-system connector, on-system turn-around, on-system single roadbed, on-system multi-roadbed, on-system multi-centerline, on-system centerline artificial terminals, county road, local road, and private road. TxDOT used these GS subtypes to formalize four GAIP-compliant linear referencing systems: Distance from Origin, Control Section, Reference Marker, and Texas Linear Measurement System. Table 8 shows the attributes associated with the GS and the four linear referencing systems, along with the corresponding GS subtypes TxDOT used to generate features.

Table 8. Ground Set and Linear Referencing System Attributes (Adapted from [*35*, *40*]).

ENTITY	ATTRIBUTES		GS SUBTYPE
TXDOT GROUND SET LINE	OBJECTID SHAPE TXDOT UNIQUE ID TXDOT ROUTE PREFIX CODE TXDOT ROUTE NUMBER TXDOT ROUTE SUFFIX CODE STRATMAP ID ROADBED TYPE CODE NETWORK TYPE CODE LIFE CYCLE STATUS CODE ACCURACY SIGMA MEASUREMENT CREATION METHOD CODE PRIMARY SOURCE CODE	SECONDARY SOURCE CODE PRIMARY SOURCE ID SECONDARY SOURCE ID TGS FROM DATE TGS TO DATE CREATE USER NAME CREATE DATE EDIT USER NAME EDIT DATE GEOMETRY ERROR CODE REVIEW FLAG REMARKS COMMENT	On-System Ramp On-System Connector On-System Turn-Around On-System Single Roadbed On-System Multi-Roadbed On-System Multi-Centerline On-System Centerline Artificial Terminals County Road Local Road Private Road
DISTANCE FROM ORIGIN LINE	OBJECTID SHAPE TXDOT UNIQUE ID STRATMAP ID TXDOT ROUTE NAME TXDOT ROUTE PREFIX CODE TXDOT ROUTE NUMBER TXDOT ROUTE SUFFIX CODE TXDOT ROUTE NUMBER SUFFIX NAME	DFO FROM DATE DFO TO DATE CREATE USER NAME CREATE DATE EDIT USER NAME EDIT DATE GEOMETRY ERROR CODE REVIEW FLAG REMARKS COMMENT	On-System Multi-Centerline On-System Centerline Artificial Terminals

Table 8. Ground Set and Linear Referencing System Attributes (Adapted from [*35*, *40*]) (continued).

ENTITY	ATTRIBUTES		GS SUBTYPE
CONTROL SECTION LINE	OBJECTID SHAPE TXDOT UNIQUE ID TXDOT CONTROL SECTION NUMBER TXDOT ROUTE NAME TXDOT ROUTE PREFIX CODE TXDOT ROUTE NUMBER TXDOT ROUTE SUFFIX CODE TXDOT ROUTE NUMBER SUFFIX NAME BEGINNING MILEPOINT MEASUREMENT	ENDING MILEPOINT MEASUREMENT CONTROL SECTION FROM DATE CONTROL SECTION TO DATE CREATE USER NAME CREATE DATE EDIT USER NAME EDIT DATE GEOMETRY ERROR CODE REVIEW FLAG REMARKS COMMENT	On-System Single Roadbed On-System Multi-Centerline On-System Centerline Artificial Terminals
TEXAS REFERENCE MARKER LINE	OBJECTID SHAPE TXDOT UNIQUE ID TXDOT ROUTE NAME TXDOT ROUTE PREFIX CODE TXDOT ROUTE NUMBER TXDOT ROUTE SUFFIX CODE TXDOT ROUTE NUMBER SUFFIX NAME REFERENCE MARKER NAME MARKER DISTANCE FROM ORIGIN MEASUREMENT	TXDOT ROUTE MARKER NAME TRM FROM DATE TRM TO DATE CREATE USER NAME CREATE DATE EDIT USER NAME EDIT DATE GEOMETRY ERROR CODE REVIEW FLAG REMARKS COMMENT	On-System Single Roadbed On-System Multi-Roadbed
TEXAS LINEAR MEASUREMENT SYSTEM LINE	OBJECTID SHAPE TXDOT UNIQUE ID STRATMAP ID TXDOT ROUTE NAME TXDOT ROUTE PREFIX CODE TXDOT ROUTE NUMBER TXDOT ROUTE SUFFIX CODE TXDOT ROUTE NUMBER SUFFIX NAME TXDOT ROUTE ROADBED CODE	TLMS FROM DATE TLMS TO DATE CREATE USER NAME CREATE DATE EDIT USER NAME EDIT DATE GEOMETRY ERROR CODE REVIEW FLAG REMARKS COMMENT	On-System Ramp On-System Connector On-System Turn-Around On-System Single Roadbed On-System Multi-Roadbed

GIS-Based Information Systems

There are several GIS-based information systems in production or in development at TxDOT. Of particular interest to this research are Main Street Texas (MST) and the Statewide Planning Map. MST is a web-based information system TxDOT is using to implement GAIP (*41*, *42*). MST runs on a Genesis Enterprise Information Integrator (GENII™) platform (*43*), which is a web-based portal that enables spatial intersect and relational queries for the production of tabular and mapping reports. TxDOT has incorporated a number of GIS-based datasets into MST, including bridges, roadbeds, right of way maps, recycled material facilities, and primary survey control points. MST runs on an Oracle database platform, both for spatial data (using ESRI's ArcSDE) and non-spatial data.

The Statewide Planning Map is a web-based map viewer that shows planning, administrative, and infrastructure feature sets (Figure 11). This application also provides traffic values and color-coded flowbands for the Texas Trunk highway network. In addition to measurement and search tools, this application has a tool for the production of on-system reports (which include attributes as population, VMT, and lane miles) VMT, truck VMT, centerline miles, and lane miles for cities, counties, TxDOT districts, highways, and statewide. The map viewer uses a tile-based approach for the rendering of maps at different zoom levels (similar to commercial applications such as Google Maps™). The application enables viewing of spatial data but not downloading.

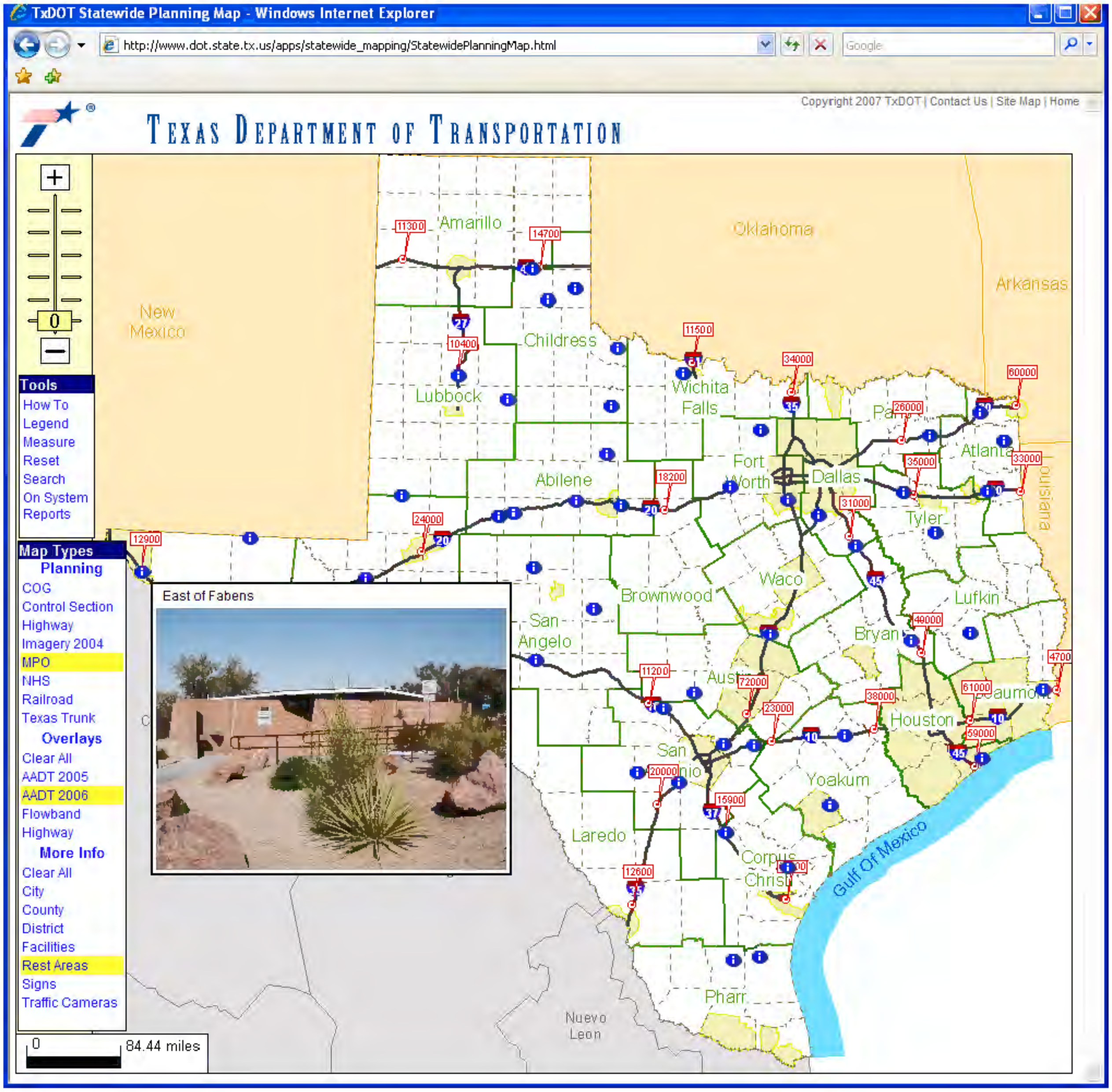


Figure 11. Statewide Planning Map Web Interface.

CHAPTER 3. MEETINGS WITH METROPOLITAN PLANNING ORGANIZATIONS

INTRODUCTION

This chapter summarizes meetings the researchers had with a wide range of transportation planning stakeholders in Texas, primarily MPOs. The original intent was to meet with representatives from all 25 MPOs. However, after consultation with the project advisors, it was decided to focus instead on a reduced number of MPOs (Table 9), while, at the same time, making every effort possible to ensure that information collected from the various MPOs could be considered representative of the wider transportation planning community in Texas.

Table 9. Selected MPOs.

MPO	Transportation Management Area	Nonattainment Area	Urbanized Areas Included
Amarillo MPO			Amarillo
Brownsville MPO			Brownsville
CAMPO	X		Austin
Corpus Christi MPO	X		Corpus Christi
El Paso MPO	X	PM_{10}	El Paso
Harlingen-San Benito MPO			Harlingen
H-GAC	X	Ozone	Houston, Galveston
Lower Rio Grande Valley Development Council	X		McAllen-Edinburg-Mission
NCTCOG	X	Ozone	Dallas/Ft. Worth, Denton
SA-BC MPO	X		San Antonio
SETRPC		Ozone	Beaumont, Port Arthur

This chapter also summarizes the results of a workshop conducted to present the results of the research to the transportation planning community in Texas. As described below, the targeted audience included all the 25 MPOs in Texas as well as other local, regional, and state agencies.

MPO SURVEY INSTRUMENT

To gather preliminary information from the MPOs, the researchers developed and sent a survey instrument to the 11 MPOs selected (Figure 12). The survey contained a number of questions designed to capture practices related to the collection, development, use, access, exchange, storage, and archive of transportation planning data. The survey also gave MPOs the opportunity to express data needs, concerns, and recommendations for improvements. In total, 10 MPOs completed the questionnaire.

TxDOT Research Project 0-5696 – Developing a Statewide, Integrated GIS/GPS Data Model

MPO Background Information

The Texas Transportation Institute (TTI) is conducting a research study for the Texas Department of Transportation (TxDOT) to identify spatial data characteristics and data needs for transportation planning functions at Texas MPOs. The results of this research are a conceptual map of GIS data sources used for metropolitan transportation planning purposes and a comprehensive set of strategies and recommendations to assist MPOs and TxDOT in exchanging transportation planning GIS data.

The purpose of the questions below is to help us obtain relevant background information prior to on-site meetings. It would be beneficial if you could email, fax, or mail the completed form to

Cesar Quiroga (c-quiroga@tamu.edu, 210-731-9938, fax: 210-731-8904)
Texas Transportation Institute, The Texas A&M University System
3500 NW Loop 410, Suite 315, San Antonio, TX 78229

For additional information, you can also contact Nick Koncz (210-731-9938, n-koncz@tamu.edu) or Khaled Hamad (210-731-9938, k-hamad@tamu.edu).

	MPO		Phone	URL
Person completing form	Title	Name	Phone	Email
Contact Person	Title	Name	Phone	Email

Spatial Technologies

What spatial technologies is the MPO currently using?

- ☐ GIS
- ☐ GPS
- ☐ Aerial Photography
- ☐ Remote Sensing
- ☐ Other, specify ________

What GIS/GPS/Imaging software do you use? ________

What applications are you using spatial technologies for (functions, tasks)? ________

What transportation modeling software do you use? ________

What applications are you using for travel demand modeling? ________

What improvements are necessary for better spatial/ technology operations? Please explain.

- ☐ Hardware ________
- ☐ Software ________
- ☐ Data Access ________
- ☐ Training ________
- ☐ Interagency communications ________
- ☐ Other, specify ________

Data

Do you have a list of data sets at the MPO? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

Does a data dictionary exist? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

Figure 12. Survey Instrument.

Do formal data models (logical/physical) exist? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

Are metadata available for each data set? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

For each data set, is there a list of fields or attributes? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

For each data set, have you identified key attributes? ☐ Yes ☐ No ☐ Partial Is a copy available? ☐

What is your primary spatial reference for data (i.e., datum, projection, etc.)?

____

Are there any known data concerns? If yes, explain.

- ☐ Data access ______________________________
- ☐ Data export/exchange ______________________________
- ☐ Data storage/archiving ______________________________
- ☐ Data quality ______________________________
- ☐ Data completeness ______________________________
- ☐ Data liability/security ______________________________
- ☐ Other, specify ______________________________

Data Processes

On a scale from 1 to 5, with 5 being most frequent, indicate how you access/distribute data?

_____Internet (HTTP) _____File Transfer Protocol (FTP) _____Local Area Network (LAN)

_____Intranet _____CD-ROM Other, specify

What is your Internet bandwidth? ______________________________

Do you have existing agreements with other data providers (e.g., TNRIS, NavTech)? ☐ Yes ☐ No

What are the primary external sources for your data (e.g., Census, TNRIS, FEMA, E-911, NavTech, etc.)?

____

Are your data copyrighted or do you have copyright issues? ☐ Yes ☐ No

Generally, how often do you update data? ______________________________

Do you have an update process for data? ☐ Yes ☐ No Is there documentation? ☐ Yes ☐ No

Do you have a process for data collection? ☐ Yes ☐ No Is there documentation? ☐ Yes ☐ No

Do you use QA/QC? ☐ Yes ☐ No Is there documentation? ☐ Yes ☐ No

What standards or protocols do you use for data, collection, processing, etc?

____

People

How many people work at the MPO? ______________________________

Does GIS/GPS have its own department? ☐ Yes ☐ No **If no, where is it in the organization chart?**

____

What is the breakdown, in numbers, of spatial technology users?

______Administrators _____Power Users _____New Users

______Programmers _____Technicians _____Other, specify ______________

Do you use data owners/stewards? ☐ Yes ☐ No

Figure 12. Survey Instrument (continued).

MPO MEETINGS

Using the survey instrument described in the prior section and a preliminary data map of available sources (see next section), the researchers met with each of the 11 selected MPOs. The purpose of these meetings was to gather and process information and compile results, request feedback regarding spatial data sources, and highlight different trends regarding GIS data and their use to support the transportation planning process.

MPO Meeting Structure

For each meeting, the researchers prepared a meeting agenda that included the following discussion items, derived from a sample of MPO federal certification review documents:

- land use, economic development, and smart growth;
- travel demand forecasting;
- freight movement and port planning;
- transit planning;
- system management and operations;
- safety and security;
- bicycle and pedestrian planning;
- congestion management, mobility, and transportation management;
- asset management;
- air quality and conformity;
- public involvement;
- Title VI and environmental justice; and
- NEPA process, environmental concerns, and ecological approaches.

The meetings typically included MPO officials and representatives from other agencies that interact with the MPO (e.g., TxDOT district liaisons, COGs, city, and transit agencies). The meetings ranged in duration from a few hours for small MPOs to more than a day for large TMA MPOs.

OTHER MEETINGS

In addition to the on-site meetings with MPO representatives and other stakeholders, the researchers met with representatives of other agencies that provide data to and/or have worked with the MPOs in order to gather additional information about concerns and data needs. More specifically, the researchers met with representatives of TSDC, TNRIS, and TGIC.

MEETING RESULTS

General trends and issues observed from the survey responses and the meetings with the stakeholders include the following:

- **Spatial technologies**. All the MPOs used GIS and aerial photography. Examples of GIS applications mentioned include ESRI ArcGIS Desktop, ArcIMS™, and ArcGIS Server; LizardTech™ MrSID®, Aerial Express, Caliper Maptitude®, and Trimble® GPS Pathfinder™/TerraSync™. MPOs typically used North American Datum of 1983 (NAD 83) state plane coordinates or latitude-longitude coordinates for GIS applications. One MPO reported using satellite imagery and Light Detection and Ranging (LIDAR) data, while two MPOs indicated they used GPS technology. The low reported use of GPS technology maybe misleading given the increasing availability of this technology for a wide range of activities including travel surveys, travel time runs, and inventories.

  Several MPOs either are using or implementing spatial technologies to develop spatial data stores. For example, NCTCOG has a web site with spatial information that was accessed for map creation and analysis over one million times last year. H-GAC is in the process of implementing a regional data clearinghouse. Several MPOs are also developing online interactive map viewers.

  MPOs use spatial technologies for a wide range of activities, including travel demand modeling, data collection, demographic forecasting, subdivision screening, bicycle and pedestrian analysis, public involvement, facility inventories, corridor studies, thoroughfare planning, congestion analysis, economic development, environmental modeling, environmental justice, emergency preparation, public safety, accident analysis, transit, and MTP project mapping.

- **Data documentation and standards**. Most MPOs reported having at least partial documentation about the datasets they use. This documentation included lists of datasets and attributes, formal data models, dataset metadata, and key attributes for each dataset. Most MPOs do not use metadata standards. In some cases, they rely on the cities and counties for directions regarding standards, including metadata.

  Some MPOs reported having processes for data update, data collection, and quality control. However, only a few MPOs have documentation on the process. In general, MPOs update datasets on an as-needed basis or when data become available. Few MPOs expressed that they had data owners or stewards responsible for data quality.

- **Data access**. MPOs reported a variety of mechanisms to access and/or distribute data. From the standpoint of technological resources, MPOs could use mechanisms such as file transfer protocol (FTP), compact disks, and/or the Internet. Most MPOs have access to T-1/DS1 lines with a bandwidth of 1.5 Mbps (**Note**: NCTCOG is currently using a T-3/DS3 line with a bandwidth of 44.7 Mbps, but is considering doubling the bandwidth under a new initiative). MPOs use data from a variety of sources, including appraisal districts, the U.S. Census Bureau, cities, COGs, counties, Emergency 911, FEMA, TNRIS, TWC, and utilities. Some MPOs, e.g., NCTCOG and H-GAC, have developed data warehouses that enable agencies within their jurisdiction (and in some cases the general public) access to a wide range of datasets.

Despite the availability of mechanisms to access and/or distribute data, MPOs identified a number of issues and challenges in this area including TxDOT and other agencies not always being forthcoming with requests for needed datasets, e.g., transportation datasets, and difficulty to find high quality data with proper attributes. MPOs also commented that they often have to use networking and barter to obtain data and often do not have agreements in place to access data. MPOs also noted that TxDOT and local governments frequently do not notify them about changes in the operational status of highway facilities, e.g., roadway openings and closings. This situation makes more difficult for MPO staff to update the travel demand models.

To address these issues, stakeholders recommended a series of strategies, including the following:

- Facilitate access to data, e.g., by developing web-based applications to store and share data with all local agencies, improving and/or establishing interagency agreements, increasing bandwidth capabilities for large dataset downloads, and establishing data connections with interagency networks
- Make orthophotography uniformly accessible to all MPOs.
- Develop local and regional visions for spatial data and improve practices regarding data storage and archiving, data quality, and data completeness.
- Provide more training opportunities to agencies on topics such as data development, maintenance, exchange, conversion, and standardization, as well as courses on transportation modeling and software.
- Improve hardware and software capabilities to better support the use of GIS software and datasets.
- Develop an automated mechanism to allow TxDOT and local governments to send a notification to the MPO whenever a new facility opens or the characteristics of an existing facility changes.
- Provide easier-to-use mechanisms for serving spatial data to the public.
- Provide more information and training on the use of Crash Records Information System (CRIS) data (available through TxDOT).

Specific feedback related to the 13 subject areas discussed at the stakeholder meetings includes the following:

- **Land use, economic development, and smart growth**. MPOs often supplement socioeconomic data from the U.S. Census Bureau, TSDC, and TWC with business databases, phone books, telephone interviews, travel surveys, and data from the U.S. Department of Defense, as well as city and county planning agencies.

  MPOs track land use developments through a variety of sources such as COGs, chambers of commerce, economic development boards, utilities, aerial photography, newspaper announcements, council meetings, planning boards, zoning, annexations, city master development plans, and land use maps from county appraisal districts, cities, and counties. Most large MPOs use GIS for land use. Several MPOs use modeling software for land use planning.

- **Travel demand forecasting**. Most MPOs use TransCAD for transportation modeling. H-GAC has transitioned from INRO EMME/2® to CitiLabs® Cube Base™ software for transportation modeling. Other software identified by MPOs included TDModel, Planung Transport Verkehr VISUM™/VISSIM™, and Trafficware® Synchro®. MPOs use transportation modeling software for MTP updates, air quality analyses, and to assess existing, new, and future on- and off-system roads for volume and capacity. Some MPOs adapt their travel demand modeling environment to fit local conditions and needs. For example, El Paso MPO uses three travel demand models to address local and regional needs: a model for El Paso, a model for Ciudad Juarez (Mexico), and an international transborder travel demand model. Other MPOs have developed multiyear models. In addition to travel demand forecasting, H-GAC uses Citilabs Cube Voyager™ for meso-scale modeling. One MPO is anticipating using software to simulate and visualize the effects of proposed changes of the transportation network and impacts of changing land-use and travel demand.

  MPOs frequently have access to computerized versions of the transportation network in their jurisdiction, which are often more comprehensive and accurate than the transportation planning networks that TxDOT provides. Cities, counties, and other agencies or services such as Emergency 911 typically have the responsibility for the maintenance of the local transportation networks. The issue of accuracy and completeness is one, which MPOs raised frequently.

- **Air quality and conformity**. MPOs are starting to use GIS for functions other than displaying air quality nonattainment areas. These functions include generating air quality contour maps; point, corridor, and area emission distribution maps; and roadway link fuel efficiency maps.

- **Freight movement and port planning**. Some MPOs are beginning to develop the capability to track freight facilities and data and to conduct freight-related simulations. For example, H-GAC has intermodal freight facilities in GIS format and Citilabs Cube Cargo™ for freight modeling. Likewise, MPOs along the Texas/Mexico border are beginning to include border freight traffic in their models. For example, El Paso MPO models new and existing ports of entry, uses a microsimulation package to evaluate delays at border crossings, and is beginning to use planning tools for port layout, design, and location. In general, travel demand models produced or modified by MPOs with freight components do not include commodity flow data or tracking.

- **Transit planning**. Most MPOs have transit routes and stops in GIS format, either obtained by transit agencies or produced by the MPO. Regional transit agencies in metropolitan areas often produce their own transit travel demand network and synchronize their models with MPO models.

- **Bicycle and pedestrian planning**. Bicycle and pedestrian planning requires a number of datasets such as existing and planned bicycle and pedestrian facilities, facility use (e.g., ridership), condition (e.g., accessibility, pavement condition), connectivity between facilities (e.g., barriers), connectivity with other modes, and adjacent facilities (e.g., parcels, geometrics, utilities, land use, traffic counts). Most MPOs have access to bicycle and pedestrian data through cities, counties, transit agencies, COGs, and TxDOT districts. However, the number of feature classes, their completeness, and the attributes for each feature class varies. Depending on the MPO, certain datasets (e.g., barriers) are handled at the project level.

- **Congestion management, mobility, and transportation demand management**. Sources of traffic data for congestion management analyses include MPOs, cities, counties, TxDOT, and, increasingly, traffic management centers (TMCs). Typical data collected in the field include mid-block counts, turning movement counts, travel time runs, and video logs. With the implementation of TMCs around the state, an increasing number of MPOs are beginning to consider using TMC-generated data such as speed, volume, and occupancy data. The use of system performance measures varies across MPOs. Examples of performance measures include volume/capacity ratio, level of service, congestion index, travel delay, and travel time. MPOs are increasing relying on GIS-based tools to produce map-based and tabular reports to document congestion and mobility issues.

- **Safety and security**. MPOs obtain incident data from a variety of sources, which often do not match, including accident reports from police departments, city agencies, county agencies, the Texas Department of Public Safety, the TxDOT Houston District Regional Incident Management System, and the National Highway Traffic Safety Administration Fatal Accident Reporting System. MPOs are also beginning to use newly available tools such as CRIS. Some of the crash-related data are in GIS format. In most cases, the data are in paper format, requiring MPOs to digitize or geocode incident data. In addition to identifying accident hot spots, MPOs use safety data to identify truck routes, truck detours, and safe routes to schools. One MPO has an incident management program and another MPO is developing an accident prediction model.

  MPOs understand the relationship between safety issues and planning requirements. However, there is considerable confusion and lack of consensus on how to address security concerns within the planning environment. For example, some MPOs consider emergency operations such as hurricane evacuation planning as a security issue. Other MPOs consider critical infrastructure such as bridges, ports, and emergency facilities as security-related infrastructure. However, the MPOs frequently have very little (if any) access to data from those facilities, even though some of those facilities clearly have transportation planning ramifications (e.g., in the case of ports or large military installations). In some cases, MPOs have data in GIS format, including flood evacuation routes, spill locations, and environmentally sensitive areas. Some MPOs have paper maps of the TxDOT evacuation route plans.

- **Asset management**. MPOs rely on asset and facility inventories from sources such as local jurisdictions and, in some cases, TxDOT districts. Other MPOs use data from systems such as pavement management systems to identify the need for projects. Some MPOs have identified the need to conduct data inventories, such as traffic signals, which need regular updates and are central to certain transportation planning functions. However, in general, the use of formal asset management principles is not part of the current transportation planning practice at the MPOs.

- **System management and operations**. MPOs are aware of the existence of intelligent transportation system (ITS) infrastructure in their jurisdiction. Most MPOs have ITS facility locations in GIS format. However, in general, the use of ITS data to support the planning process is still in its infancy and is typically limited to the use of isolated samples of archived volume data. MPOs use ITS data for corridor studies, congestion management, access management, and validation of data, but not for travel demand forecasting.

  It may be interesting to note that NCTCOG is a regional data repository in the north central Texas region. In this capacity, NCTCOG is receiving and archiving live ITS data received through a Center-to-Center plug in application (*44*).

- **Public involvement**. MPOs use GIS and aerial photography for presentation materials at public participation meetings and MPO websites. Several MPOs use, or are considering using, GIS and land use tools (e.g., map viewers, the Orton Family Foundation CommunityViz®, Google Earth™, and Google Maps) for interactive public participation in areas such as bicycle and pedestrian planning, air quality, and congestion. A few MPOs use GIS techniques to identify or screen public involvement locations. Several of these MPOs ask for meeting attendee addresses and then geocode the addresses to determine the overall effectiveness of the meeting in terms of overall targeted audience locations versus actual meeting attendee locations.

- **Title VI and environmental justice**. MPOs use variations of U.S. Census Bureau and Texas Workforce Commission data to identify environmental justice areas. Some MPOs use unadjusted Census tract, block group, or block data, while other MPOs use demographics from the travel demand model. Some MPOs supplement the datasets using aerial photography (e.g., locations of colonias). Comparing environmental justice regions with proposed projects to identify impacts requires data such as travel patterns, locations of existing and planned modal systems, and related facilities.

- **NEPA, environmental concerns, and ecological approaches**. MPOs use GIS datasets (e.g., cemeteries, historical designated areas, monuments, wildlife refuges, and wetlands), and TxDOT district constraint maps (containing schools, parks, cemeteries, fluvial channels, endangered species, and flooding areas) for high-level preliminary environmental analyses of major projects.

  In general, MPOs view tools such as GISST, TEAP, and NEPAssist positively. Some MPOs are using (or plan to use) these tools for preliminary environmental review, identification of fatal flaws, and for public participation. At the same time, MPOs have concerns about the depth of the environmental analysis required during the planning phase, the proper use of GIS-based tools, and the mechanism to transfer the results of the analysis to project sponsors. Many MPOs have heard about ecological approaches to transportation planning, but do not see those approaches used in the near future. However, it may be worth noting that CAMPO, H-GAC, and NCTCOG have received funding from FHWA to develop integrated ecosystem-based strategies into the transportation planning process (*45*).

DATA MAP OF AVAILABLE DATA SOURCES

From the meetings with the various MPOs and by evaluating a variety of data sources, the researchers developed a catalog of spatial data layers and elements MPOs use for transportation planning. Developing that catalog was critical because it provided the foundation for the definition of a formal data model for spatial transportation planning data in Texas. Examples of data sources the researchers used included the following:

- MPO websites, which provided MPO documents, downloadable data, maps, and map viewers;
- MPO certification review documents, which summarize recent MPO activities and documents;
- applications and/or datasets identified through meetings with TxDOT division officials (primarily TPP and ENV);
- state agency websites, including the Texas Historical Commission, the Texas Parks and Wildlife Department, the Texas Commission on Environmental Quality (TCEQ), the Texas Water Development Board, TNRIS, and TSDC;
- federal agency websites, including the U.S. Census Bureau, the Bureau of Transportation Statistics (BTS), EPA, USGS, the U.S. Fish and Wildlife Service, and U.S. Department of the Interior National Park Service;
- data from other TxDOT research projects that resulted in data catalogs; and
- online searches.

The review of existing documentation at the MPOs and the applications and/or datasets at TxDOT produced a list of about 13,000 spatial data instances, where a spatial data layer or element was either displayed or there was a reference for it in the document. To facilitate the analysis, understanding, and potential use of these spatial data entities, the researchers developed a three-level grouping structure composed of categories (mostly by subject matter), subcategories, and spatial data entities. To assist in this process, the researchers conducted a literature review to determine how agencies that produce and serve spatial data organize data, either at the logical level or at the physical level.

Review of Approaches to Spatial Data Cataloging

Examples that describe the current practice at some major national and statewide data repositories follow.

- **U.S. Census Bureau 2007 TIGER/Line® Shapefiles (*46*)**. The U.S. Census Bureau developed a web-based application that enables users to download TIGER/Line data files in shape format. The application organizes data using the following categories based on geographic regions:

    - National Shapefiles (14 datasets),
    - State Shapefiles (number of datasets for each state varies),
    - County files (available under each state; number of datasets for each county varies), and
    - American Indian Area Shapefiles (Current American Indian Tribal Subdivision and Census 2000 American Indian Tribal Subdivision for 22 areas).

- **BTS National Transportation Atlas Database (NTAD) 2008 (*47*).** NTAD contains a set of transportation facility geographic files, organized into categories by data format. In addition, datasets that are larger than 20 megabytes are divided into smaller files based on U.S. Department of Transportation region (**Note**: The country is divided into 10 regions, with each region including three to eight states). The categories of NTAD are:

    - points (10 datasets),
    - polylines (7 datasets), and
    - polygons (10 datasets).

- **nationalatlas.gov™ (*48*)**. nationalatlas.gov is a web-based portal that provides access to datasets organized by broad subject categories (with no subcategories) according to chapters in the national atlas. The subject categories are as follows:

    - Agriculture (contains the 2002 Agriculture Census data layer),
    - Biology (69 datasets),
    - Boundaries (17 datasets),
    - Climate (7 datasets),
    - Environment (5 datasets),
    - Geology (65 datasets),
    - History (3 datasets),
    - Map reference (3 datasets),
    - People (30 datasets),
    - Transportation (7 datasets), and
    - Water (16 datasets).

- **USGS National Map Viewer (*49*)**. The USGS National Map Viewer provides access to an extensive collection of GIS data organized into categories and subcategories, most of which are by data subject (Table 10). Each subcategory includes one or more datasets that are accessible to users on the map viewer based on scale thresholds. In the table of contents, the map viewer displays information of the visible layers including data contents and data sources. For example, the Roads subcategory in the Transportation category includes a variety of roadway datasets and associated label layers, such as "US

Major Roads (USGS)," "Texas Roads (BTS)," and "US Highway Labels (USGS)." Likewise, the County subcategory in the Boundaries category, as listed in the table of contents, includes layers such as "US County Boundaries (National Atlas)" and "County Names (USGS)."

Table 10. USGS National Map Viewer Categories and Subcategories.

Category	Subcategory
Biology	Animal Studies; Invasive Species
Boundaries	Administrative; County; EPA Regions; FEMA Regions; Incorporated Place/Locale; Minor Civil Division; Native American Area; State/Territory; United States Coast Guard Districts; United States Forest Service Boundaries; United States Fish and Wildlife Service Regions
Climatology/ Climate Change	Climatology; Ecoregions; Emission Inventory; Frozen Ground; Glaciers; National Climatic Data Center; Paleoclimatology; Sea Ice; Snow Extent; Snow Water Equivalent
Coastal Studies	Great Lakes Bathymetry; Gulf Coast Ecosystem / Habitat Impact Data; Gulf Coast Ecosystem / Human Impact Data; Gulf Coast Ecosystem / Physical Data; Tsunami Inundation Gridding Project; U.S. Atlantic East Coast Program; U.S. Coastal Zones / Coastal Relief; U.S. Gulf Coast Program; U.S. Pacific West Coast Program
Digital Atlases	Science Studies Index; National Legislative Atlas; U.S. – Mexico Border Initiative
Elevation	Contours; Index / Status (Elevation); LIDAR (or Equivalent); Shaded Relief; Satellite Pour l'Observation de la Terre (SPOT) elevations; Shuttle Radar Topography Mission
Environmental Monitoring / Assessment	Bottom Dissolved Oxygen Contours
Geographic Names	Names; Native Names
Geography	Geography
Geology	Bedrock; Earth Science; Geologic Maps; Gravity / Magnetic; Hazards; Soils; Surficial
Gulf Coast Risk Assessment	Gulf Coast Risk Index; Alabama Vulnerability Assessment; Florida Vulnerability Assessment; Georgia Vulnerability Assessment; Louisiana Vulnerability Assessment; Mississippi Vulnerability Assessment; Texas Vulnerability Assessment
Hydrography	Dams; Index / Status (Hydrography); National Hydrography Dataset (NHD) High Resolution; NHD Local Resolution; NHD Medium Resolution; Stream Names; Stream Network; Streams; Water Resources / Quality; Waterbodies; Waterbody Names; Wetlands
Imagery	Coastal Area Imagery; Coastal Area Index; Digital Orthophoto Quadrangle (DOQ) Black/White Index; DOQ Color Index; DOQ Imagery; Other Imagery / Indexes; Satellite; Scanned Maps; State and County Imagery; State and County Index; Urban Area Imagery; Urban Area Index
Land Use / Land Cover	Index / Status (Land Cover); Land Cover
National Grid	100 Meter Grid; 1000 Meter Grid; 10,000 Meter Grid; 100,000 Meter Grid; Universal Transverse Mercator (UTM) Grid / 6 x 8 Degrees
Natural Hazards / Weather	Climate; Fire; Hurricane; Tornado
Public Land Records	Index / Status (other); Land Survey; Parcels
Structures	Government Data; Index / Status (Structures); Structures; Volunteer Data
Topographic Maps	Index / Status (Topographic Maps); USGS Quadrangles
Transportation	Index / Status (Transportation); Miscellaneous Transportation; Railroads; Roads

- **International Boundary and Water Commission (IBWC) Map Viewer (*50*)**. The IBWC map viewer is a web-based interface that enables viewing and downloading GIS datasets depicting water-related data in the U.S./Mexico border region. The viewer organizes data primarily by subject area into the following categories, with each category displaying a variable number of datasets according to scale threshold:

- Water Quality Monitoring,
- Real-Time and Other Monitoring,
- Hydrography,
- Places (names),
- Anthropogenic,
- Transportation,
- Biology,
- Geology,
- Census,
- Boundaries,
- Orthoimagery,
- Land Cover, and
- Elevation.

- **TxDOT Production GIS Data (*34*).** TxDOT maintains a collection of production GIS datasets organized into 10 categories (with no subcategories) according to data subject:

    - Air (2 datasets),
    - Aviation (6 datasets),
    - Facility (1 dataset),
    - Geopolitical (13 datasets),
    - Land (14 datasets),
    - Public Land (7 datasets),
    - Railroad (1 datasets),
    - Structures (3 datasets),
    - TxDOT Route (14 datasets), and
    - Water (20 datasets).

- **TNRIS GIS Data (*51*)**. TNRIS maintains a repository of data that includes a number of state-level and county-level datasets, some of which contain several feature classes or raster datasets:

    - Bathymetry,
    - Eight-Digit Hydrologic Unit Codes,
    - StratMap Boundaries,
    - Railroads,
    - Natural Regions,
    - Airports,
    - Texas Gazetteer,
    - LandSAT,
    - Precipitation,
    - USGS / Satellite Indices,
    - Original Texas Land Survey,
    - FEMA Q3,
    - Census,

- TxDOT On-/Off- System, and
    - TxDOT Urban File.

- **Texas General Land Office (GLO) GIS Data (*52*)**. GLO maintains a collection of statewide and coastal GIS datasets, which are organized into categories based on data subjects, purpose, and data scope. The major data categories include the following:

    - Base Map Data (14 datasets),
    - Statewide Data (9 datasets),
    - Energy Resource Data (3 datasets),
    - Professional Services Data (3 datasets),
    - Oil Spill / Coastal Response Data (30 datasets), and
    - Coastal Management Program Data (13 datasets).

Transportation Planning Dataset Catalog

An analysis of the various practices for cataloguing spatial data revealed a variety of approaches for cataloguing spatial data. In general, agencies organize data by subject, geographic region, and/or data format. When an agency needs to manage a large number of datasets, it is common to organize the data into categories and subcategories. The largest data repository the researchers reviewed was the USGS National Map Viewer (Table 10) (*49*). That catalog includes a large number of categories and subcategories, with a varying number of datasets per subcategory. The researchers considered using the USGS National Map Viewer catalog structure for managing transportation planning spatial data. However, a review of the categories used by the USGS National Map Viewer revealed that only a small number of categories in the viewer were directly related to transportation, much less transportation planning. Nonetheless, it was clear that the catalog of spatial data for transportation planning developed in this research would need to follow a similar structure.

Developing the catalog of categories and subcategories for transportation planning spatial data was an iterative process that involved several rounds of data entity categorization; analysis of the resulting structure for inconsistencies, gaps, and redundancies; and subsequent changes to the data entity categorization scheme. In the end, the three-level grouping structure resulted in 7 categories, 63 subcategories, and 589 spatial data entities. Table 11 lists all the categories and Table 12 lists all the subcategories developed as part of this research. The appendix shows the list of categories, subcategories, and spatial data entities.

Table 11. Transportation Planning Spatial Data Categories.

Category	Total Subcategories	Total Spatial Data Entities
Administrative Feature	11	65
Environmental Feature	6	61
Imagery and Digital Elevation	4	18
Infrastructure Feature	23	282
Natural Feature	3	42
System Monitoring Feature	7	34
Transportation Planning Feature	9	87
Total	**63**	**589**

Table 12. Transportation Planning Spatial Data Subcategories.

Category	Subcategory	Total Spatial Data Entities
Administrative Feature	Economic Feature	5
	Federal Feature	14
	Judicial Feature	1
	Legislative Feature	6
	Other District Feature	9
	Other Feature	1
	Planning Feature	7
	Political Subdivision Feature	9
	Property Feature	7
	School Feature	4
	TxDOT Administrative Feature	2
Environmental Feature	Air Quality Feature	10
	Biological Resource Feature	21
	Disposal Facility Feature	5
	Environmental Impact Feature	11
	Hazardous Material Feature	9
	Water Quality Feature	5
Imagery and Digital Elevation	Aerial Image	4
	Digital Elevation Feature	5
	Satellite Image	3
	Topographic Feature	6

Table 12. Transportation Planning Spatial Data Subcategories (continued).

Category	Subcategory	Total Spatial Data Entities
Infrastructure Feature	Aviation Feature	4
	Bicycle or Pedestrian Feature	8
	Communication Feature	13
	Educational or Cultural Feature	6
	Electric Feature	13
	General Feature	32
	Industrial Feature	13
	ITS Infrastructure Feature	22
	Multiple Purpose Feature	5
	Oil or Gas Feature	6
	Other Sewer Feature	1
	Parks and Wildlife Feature	16
	Port Feature	3
	Rail Feature	7
	Road Feature	43
	Roadway Feature	23
	Route Feature	15
	Sanitary Sewer Feature	4
	Steam Feature	2
	Storm Sewer Feature	8
	Transit Feature	26
	Water Infrastructure Feature	7
	Water Utility Feature	5
Natural Feature	Geologic Feature	6
	Soil Feature	7
	Water Feature	29
System Monitoring Feature	Count Station Feature	5
	Environmental Quality Feature	4
	Infrastructure Monitoring Feature	2
	Roadway Operation Feature	4
	Transit Operation Feature	5
	Travel Data Feature	6
	Weather Feature	8
Transportation Planning Feature	Demographic Feature	9
	Improvement Need Feature	6
	Land Cover Feature	3
	Land Use Feature	15
	Performance Measure Feature	17
	Project Feature	6
	Public Participation Feature	12
	Study Area Feature	3
	Travel Demand Forecast Feature	16

STAKEHOLDER WORKSHOP

The researchers conducted a workshop with stakeholders to discuss the results of the research and to obtain feedback regarding the data sources and data model (see Chapter 4). Originally, the researchers planned to schedule the workshop in conjunction with the 2008 Transportation Planning Conference to maximize TxDOT and MPO attendance and participation and, therefore, the effectiveness of the workshop. However, space was limited for that venue and, after discussing several alternative options with the project advisors, the researchers decided to conduct a web-based version of the workshop. A webinar approach offered several advantages, including minimizing the impact on stakeholder schedules and travel budgets and encouraging the participation of a wide range of transportation stakeholders, since the basic requirements for participation was a high-speed Internet connection and a telephone.

For flexibility, the webinar structure included opening and topic sessions on separate dates and times (Figure 13). The goal of the opening session was to introduce and provide an overview of the research project and its deliverables. The goals of the topic sessions were to discuss findings and issues in specific areas in more detail. The researchers sent webinar announcements to officials at all 25 Texas MPOs, TxDOT, TNRIS, TGIC, and TSDC. There was an additional announcement at the Association of Texas Metropolitan Planning Organizations meeting at the 2008 Transportation Planning Conference. In addition, the San Antonio-Bexar County MPO distributed the announcement to local government agencies in the region.

Over 80 individuals expressed an interest in participating. The exact number of attendees is unknown because in several cases participants met in a common room to join the webinar using a single login. In total, 35 different locations participated in the opening session and 36 locations participated in the first topic session. Unfortunately, the second and third topic sessions (to be held on the second day of the webinar) were canceled because of illness by the research supervisor. Although incomplete, the event was productive because of the feedback that several attendees provided on the first day of the webinar. A summary of major comments and suggestions follows:

- Make current and past traffic count data easily available and in GIS format for MPOs. Efforts are under way at TxDOT to convert all traffic count data to GIS format. Although some MPOs have received 2005 and 2006 on- and off-system traffic count data in GIS format through TxDOT districts, other MPOs were unaware of these GIS datasets and the process for obtaining them.

- Include stable employer unique identifiers in the TWC employment datasets. The TWC employer identification numbers are not consistent across employment datasets (i.e., when corrections are made to IDs of a TWC employment dataset, the corrections are not present in the subsequent dataset). This recommendation is a focal point in a new TxDOT research project (0-6325 “Integrating TWC Employment Data into TxDOT Modeling”).

- Develop reliable income projection methodology and data. It is challenging for MPOs to accurately predict local income trends. Some MPOs have adopted national projections for their local planning areas, which causes bias to the transportation modeling process. MPOs also identified the potential for TWC to provide income projections.

- Archive GPS data used for travel surveys. Some MPOs indicated that archived GPS data could serve as a valuable future reference for analysis and verification purposes beyond current planning needs. For example, the GPS data collected for travel surveys could be used to augment or even reduce the need for special-purpose travel time and speed data collection programs. For corridor analysis, the GPS data could also be used to assist in the evaluation of bottlenecks and potential traffic signal system adjustments or improvements.

- Provide training and workshops on transportation planning practices such as multiyear planning networks, microsimulation, and integration of GIS and GPS data.

- Clarify distinctions in MPO related boundaries. The MPO boundary is the same as the Metropolitan Area Boundary (MAB), which is different from the MSA. However, some boundaries (e.g., Urban Area Boundary) have two versions: detailed and smoothed. Smoothed boundaries can connect separate urban regions in a MPO, especially along a major thoroughfare.

Texas Transportation Institute

Texas Department of Transportation

GIS Data Resources for Long-Range Transportation Planning Webinar

Opening Session: **Wednesday, June 11, 2008, 9:00 am-10:00 am**
Topic Sessions: **Transportation Modeling, Wed., June 11, 2008, 10:15 am–11:45 am**
Transportation Planning, Thurs., June 12, 2008, 8:30 am–10:00 am
Environmental Planning, Thurs., June 12, 2008, 10:30 am–12:00 pm

Background

Long-range transportation planning requires substantial amounts of data, which requires cooperation, including data exchange, among transportation planning agencies. Advances in computer technology and the increasing availability of geographic information systems (GIS) are giving planners the ability to develop and use data with a much higher degree of efficiency. However, with these tools, effective data integration/exchange protocols and procedures to reduce redundancy and data collection costs is critical. Many factors influence the effectiveness of data exchange and data integration efforts, such as data compatibility, data access, data quality, completeness, metadata, hardware, software, and staff expertise. Incorporating these factors into the long-range transportation planning process is becoming more important as planning agencies respond to federal legislation (e.g., Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)).
The Texas Transportation Institute is conducting research (Project 0-5696) for the Texas Department of Transportation (TxDOT) to review spatial/GIS data characteristics and data needs at Texas metropolitan planning organizations (MPOs). So far, the review has identified 7 major data categories, 63 data subcategories, and about 560 different GIS feature classes or layers that play a role in long-range transportation planning.

Webinar Purpose and Objectives

The purpose of this webinar is to discuss research results and request feedback. Objectives are to:

- discuss GIS data sources MPOs are using (or could use) for long-range transportation planning,
- discuss recommendations and strategies of transportation planning GIS data exchange among MPOs, TxDOT, and other stakeholders, and
- provide a forum for MPOs and TxDOT to discuss spatial data issues that affect long-range transportation planning.

Who Should Attend

This webinar will benefit those in long-range transportation planning, as highway, transit, and environmental planners and engineers; demographers; geographers; and information technology and GIS professionals. Targeted agencies include MPOs, councils of government, cities, transit agencies, state, and federal agencies.

Contact and Additional Information

Cesar Quiroga, Ph.D., P.E.
Texas Transportation Institute / Texas A&M University System
3500 NW Loop 410, Suite 315, San Antonio, TX 78229
Phone: (210) 731-9938 Fax: (210) 731-8904 Email: c-quiroga@tamu.edu

Figure 13. Workshop Announcement.

Requirements

The webinar requires a high-speed internet connection for video and a phone line for audio.

Timeline and Agenda

June 9, 2008 1:30 pm – 2:30 pm
System check, instructions, and tutorial for web-conferencing software (optional but highly recommended)

June 11, 2008 9:00 am-10:00 am Opening Session

- Welcome and self-introductions
- Project overview, webinar objectives, agenda, and follow-up activities
- *Presentation:* Analysis and Integration of Spatial Data for Long-Range Transportation Planning
- General Questions & Answers

June 11, 2008 10:15 am-11:45 am Topic Session I: Transportation Modeling GIS Data Resources

- Welcome and self-introductions
- Session objectives and brief project overview
- Presentation of findings and issues, with updates from participants
- Review of GIS data layers and metadata with participants
- Concluding comments, next steps, and follow-up activities

Focal areas*: Land Use, Economic Development, and Smart Growth; Travel Demand Forecasting; Truck and Freight Rail Movement Planning; Transit Planning*

June 12, 2008 8:30 am-10:00 am Topic Session II: Transportation Planning GIS Data Resources

- Welcome and self-introductions
- Session objectives and brief project overview
- Presentation of findings and issues, with updates from participants
- Review of GIS data layers and metadata with participants
- Concluding comments, next steps, and follow-up activities

Focal areas: *System Management and Operations, Safety and Security, Bicycle and Pedestrian Planning, Congestion Management, Mobility and Transportation Demand Management, Asset Management*

June 12, 2008 10:30 am-12:00 pm Topic Session III: Environmental Planning GIS Data Resources

- Welcome and self-introductions
- Session objectives and brief project overview
- Presentation of findings and issues, with updates from participants
- Review of GIS data layers and metadata with participants
- Concluding comments, next steps, and follow-up activities

Focal areas: *Air Quality and Conformity, Public Involvement, Title VI and Environmental Justice, NEPA Process, Environmental Concerns, and Ecological Approaches*

Figure 13. Workshop Announcement (continued).

CHAPTER 4. PROTOTYPE LOGICAL DATA MODEL FOR TRANSPORTATION PLANNING SPATIAL DATA

INTRODUCTION

This chapter summarizes a prototype logical data model for transportation planning spatial data the researchers developed using the catalog of spatial data entities described in Chapter 3. It includes a summary of data architecture practices and standards at TxDOT, a description of the logical data model in CA® ERwin® Data Modeler format, a discussion of the process to develop metadata documentation, and a description of a prototype web-based application to display metadata and sample datasets. A companion digital versatile disk (DVD) includes all the data model documentation and sample datasets and metadata files. The prototype web-based application source code and related files are included in a second DVD that the researchers submitted to TxDOT separately.

DATA ARCHITECTURE AND DATA MODELING PRACTICES

The TxDOT *Data Architecture* document includes standards for data modeling, special standards for GIS data, and a process for integrating commercial-off-the-shelf software with TxDOT data (*53*). According to the manual, the data design process includes the following components:

- **Project glossary**. The project glossary includes definitions of terms to facilitate communication exchange and avoid confusion during implementation of the project. A project glossary is recommended but not mandatory.

- **Conceptual data model**. A conceptual data model identifies data from a business point of view. It defines entities (e.g., persons, places, things, concepts, and events) about which it is necessary to keep data and identifies high-level associations among those entities. This type of model is recommended but not mandatory. Notice a conceptual data model that characterizes entities at a high level of aggregation is not the same as a business process model, which TxDOT currently does not require.

- **Logical data model**. A logical data model represents the data/information needs associated with entities and the relationships among those entities. A logical model is a database-independent model. This type of model is mandatory.

- **Physical data model**. A physical data model represents the mapping of a logical data model to a database platform (e.g., Oracle, Microsoft® Structured Query Language [SQL] Server™, or Sybase®). It translates entities, attributes, and relationships into tables, fields, and constraints. This type of model is mandatory.

- **Data dictionary**. A data dictionary is a compilation of entity and attribute definitions (for logical data models) or table and field definitions (for physical data models).

- **TxDOT system interface diagram (TSID)**. A TSID is a diagram that documents the relationships between computer applications and data. TSD creates and maintains TSIDs.

LOGICAL DATA MODEL DEVELOPMENT

Using ERwin, the researchers developed a logical data model of spatial data entities following the data catalog structure described in Chapter 3. Figure 14 shows the highest level of abstraction (categories). These categories contain subcategories, which, in turn, contain data entities. Because the model contains a large number of entities, the researchers created a separate subject area for each category to improve its organization and readability. In addition, the researchers also created a Main Categories subject area that contains only the seven major data categories, and an Overall subject area that contains a hierarchy of all categories and subcategories showing the data organizational structure.

The following sections provide additional information about each category and their associated subcategories and data entities.

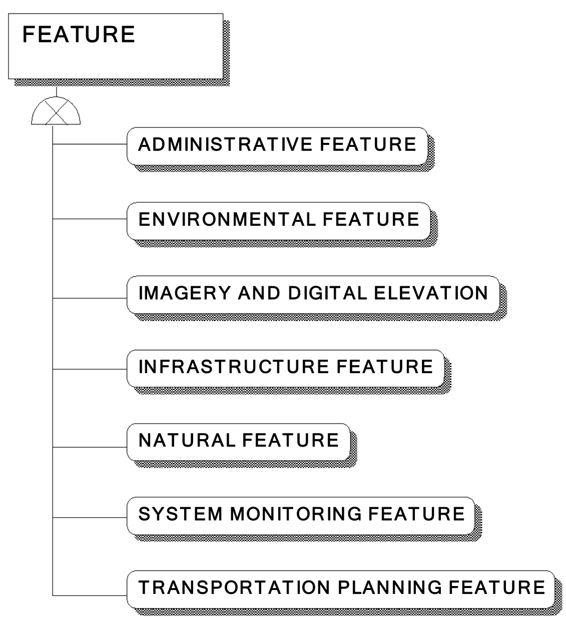


Figure 14. Transportation Planning Spatial Data Categories.

Administrative Feature Category

An Administrative Feature is an area or location where, in general, a government agency or governing body has determined the purpose of use for that area or location. The Administrative Feature category includes 11 subcategories and 65 identified data entities that describe administrative levels of information (Figure 15). Table 13 provides detailed descriptions for each subcategory.

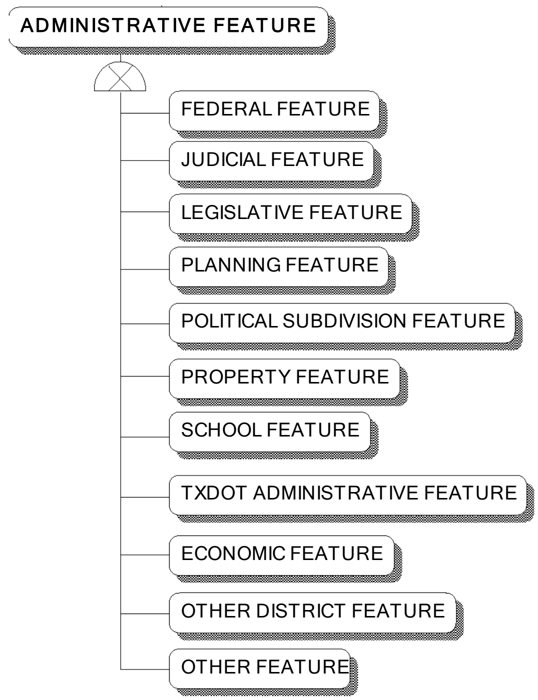


Figure 15. Administrative Feature Subcategories.

Table 13. Administrative Feature Subcategory Descriptions.

Subcategory	Description
Federal Feature	Definition: A FEDERAL FEATURE is a region or location that has been designated by a government agency at the federal level. Example: Census Tract, Urban Area, ZIP Code Area Five Digit
Judicial Feature	Definition: A JUDICIAL FEATURE is a region of jurisdiction assigned to a judge, or group of judges. Example: Justice of the Peace District
Legislative Feature	Definition: A LEGISLATIVE FEATURE is a region determined by a government agency and is represented by an elected or appointed official. Example: City Council District, Precinct Commissioner, US House District
Planning Feature	Definition: A PLANNING FEATURE is a region or location determined by a government agency for planning purposes. Example: COG Boundary, MPO Boundary, Neighborhood
Political Subdivision Feature	Definition: A POLITICAL SUBDIVISION FEATURE is a region with designated boundaries represented by a governing body. Example: City Limit, County, State
Property Feature	Definition: A PROPERTY FEATURE is an area with designated boundaries or a segment that contains information related to property rights. Example: Easement, Parcel Plat, Right of Way Line
School Feature	Definition: A SCHOOL FEATURE is a region or segment that designates areas of influence of an educational facility. Example: School District, Community College District, Education Service Center Region
TxDOT Administrative Feature	Definition: A TXDOT ADMINISTRATIVE FEATURE is a region TxDOT uses to manage activities under its jurisdiction. Example: TxDOT District Boundary, TxDOT Vehicle Title and Registration Region

Table 13. Administrative Feature Subcategory Descriptions (continued).

Subcategory	Description
Economic Feature	Definition: An ECONOMIC FEATURE is a region or location that indicates a generic or special economic purpose. Example: Community Development Block Grant Area, Enterprise Zone, Foreign Trade Zone
Other District Feature	Definition: An OTHER DISTRICT FEATURE is any district not already represented by another subcategory. Example: Police District, Special Purpose District, Subsidence District Boundary
Other Feature	Definition: An OTHER FEATURE is a generic subcategory for entities that do not fit into other subcategories. Example: GNIS Domestic Name Location

Environmental Feature Category

An Environmental Feature is an area or location describing how the environment is being used or affected. The Environmental Feature category includes six subcategories and 61 identified data entities that describe environmental levels of information (Figure 16). Table 14 provides detailed descriptions for each subcategory.

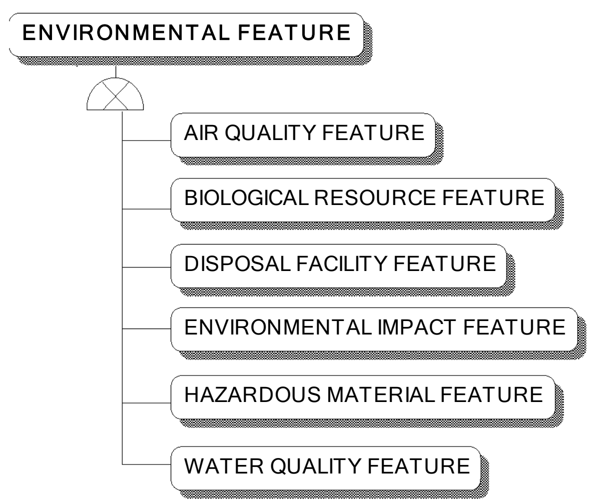


Figure 16. Environmental Feature Subcategories.

Table 14. Environmental Feature Subcategory Descriptions.

Subcategory	Definition
Air Quality Feature	Definition: An AIR QUALITY FEATURE is the location or area affected by a pollutant. Example: CO Nonattainment Area, Mobile Source Air Toxic Boundary, Point Source Air Emissions Site
Biological Resource Feature	Definition: A BIOLOGICAL RESOURCE FEATURE is a region or area that describes animal or plant life. Example: Audubon Sanctuary, Flora Condition Location, Natural Ecoregion
Disposal Facility Feature	Definition: A DISPOSAL FACILITY FEATURE is a location of a repository intended for permanent containment or destruction of waste materials. Example: Composting Facility, Municipal Solid Waste Facility Boundary, Used Oil Collection Center Source: Modified from Environmental Protection Agency http://www.epa.gov/OCEPAterms/dterms.html Accessed July 22, 2008
Environmental Impact Feature	Definition: An ENVIRONMENTAL IMPACT FEATURE is a region or location that contains information about how an object or process affects the environment. Example: Mitigation Bank, TEAP Diversity Grid, GISST Texas Grid
Hazardous Material Feature	Definition: A HAZARDOUS MATERIAL FEATURE is a location or area of storage affected by a spill or leak of hazardous waste. Example: Hazardous Material Release Area, Hazardous Material Site, Superfund Site Source: Texas Department of Transportation TxDOT Glossary 2006-02 Accessed July 23, 2008
Water Quality Feature	Definition: A WATER QUALITY FEATURE is a location or area that contains information about water or wastewater facilities. Example: Water Discharge Outfall, Wastewater Service Area, Water Quality Contour Map

Imagery and Digital Elevation

Imagery and Digital Elevation is a discreet, pixel, or vector representation of natural and/or constructed features. The Imagery and Digital Elevation category includes four subcategories and 18 identified data entities that describe a wide range of raster datasets such as aerial photography or satellite imagery (Figure 17). Table 15 provides detailed descriptions for each subcategory.

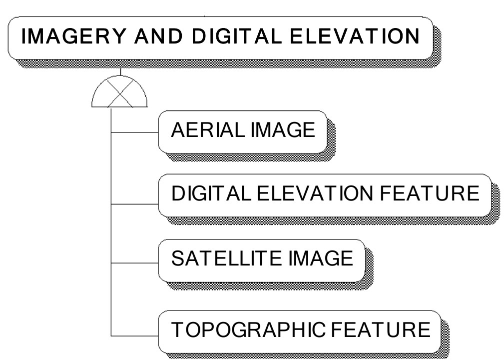


Figure 17. Imagery and Digital Elevation Subcategories.

Table 15. Imagery and Digital Elevation Subcategory Descriptions.

Subcategory	Description
Aerial Image	Definition: An AERIAL IMAGE is an image of earth features taken from an airborne device. Example: Mexico Aerial Photography, National Agriculture Imagery Program Image, Texas Orthographic Program Image
Digital Elevation Feature	Definition: A DIGITAL ELEVATION FEATURE is a representation of terrain relief using point height values and/or surfaces. Example: Digital Elevation Model, LIDAR, Grid, National Elevation Dataset
Satellite Image	Definition: A SATELLITE IMAGE is an image of earth features taken from a space borne device. Example: LandSAT 5, LandSAT 7, SPOT Image
Topographic Feature	Definition: A TOPOGRAPHIC FEATURE is an object or feature on the surface of the earth that includes a characterization of its relative position and elevation. Example: Sea Floor Survey Index Boundary, Shoreline Topographic Line, USGS DRG Topo Map

Infrastructure Feature Category

An Infrastructure Feature is a location, segment, or area that represents an object created by human intervention. The Infrastructure Feature category includes 23 subcategories and 282 identified data entities that describe infrastructure-related information (Figure 18). Table 16 provides detailed descriptions for each subcategory.

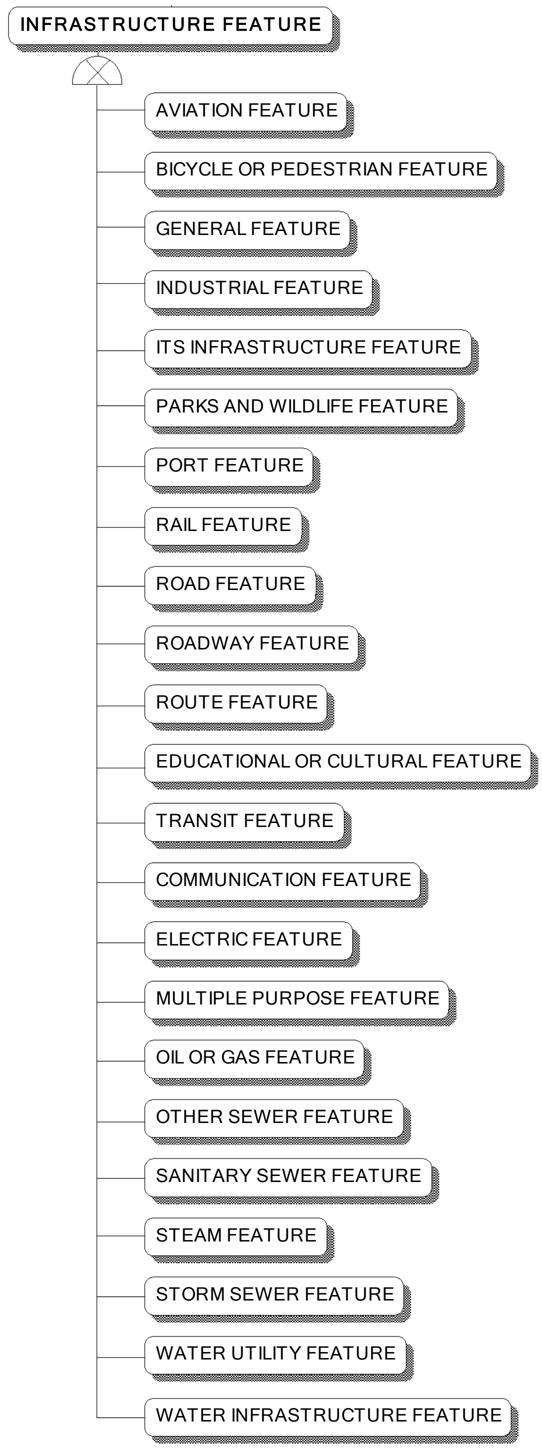


Figure 18. Infrastructure Feature Subcategories.

Table 16. Infrastructure Feature Subject Area Subcategory Descriptions.

Subcategory	Description
Aviation Feature	Definition: An AVIATION FEATURE is a location or area needed for storage or operation of aircraft. Example: Airport Location, Flight Path, Runway
Bicycle or Pedestrian Feature	Definition: A BICYCLE OR PEDESTRIAN FEATURE is a facility used by pedestrians and/or bicyclists. Example: Bicycle Lane Shoulder, Bicycle Pedestrian Trail, Bicycle Route
General Feature	Definition: A GENERAL FEATURE is the location or area of a building, structure, event, or other facility or amenity that could be used as a landmark or reference point. Example: Health Care Facility Boundary, Military Facility Point, Fence
Industrial Feature	Definition: An INDUSTRIAL FEATURE is a location or area where commercial goods are manufactured, stored, moved, or transferred. Example: Bulk Commodity Transfer Facility, Manufacturing Facility, Warehouse
ITS Infrastructure Feature	Definition: An ITS INFRASTRUCTURE FEATURE is a hardware component needed for the operation of an intelligent transportation system. Example: Dynamic Message Sign, Railroad Crossing Sensor, Ramp Meter
Parks and Wildlife Feature	Definition: A PARKS AND WILDLIFE FEATURE is a location or area of land preserved in its natural state contained within designated boundaries and governed by a local, state, or federal government agency. Example: Federal Park Boundary, State Park Point, Wildlife Management Area
Port Feature	Definition: A PORT FEATURE is a location where individuals and/or goods enter a country and clear customs. Example: Border Crossing, Port of Entry, Water Intermodal Port Source: Automated Systems for Customs Data (ASYCUDA) http://www.asycuda.org/cuglossa.asp?firstlet=P&submit1=Browse Accessed July 30, 2008
Rail Feature	Definition: A RAIL FEATURE is an area or location of a railroad or any facility needed for the operation of a freight train. Example: Rail Crossing, Railroad, Rail Yard Location
Roadway Feature	Definition: A ROADWAY FEATURE is a linear facility used by vehicles including automobiles, motorcycles, buses, semi tractor-trailers, and bicycles. Example: Thoroughfare Route, Toll Road, TxDOT Control Section Line
Road Feature	Definition: A ROAD FEATURE is a localized structure or element that can be located and/or defined along a roadway. Example: Crosswalk, Rest Area, Sign, Toll Plaza.
Route Feature	Definition: A ROUTE FEATURE is a designated path through a transportation network. Example: Evacuation Route, Hazardous Material Route, School Route
Educational or Cultural Feature	Definition: An EDUCATIONAL OR CULTURAL FEATURE is the location or area of a structure or building having an educational or cultural purpose. Example: School, College/University Point, Cultural Facility Point
Transit Feature	Definition: A TRANSIT FEATURE is a facility used for the operation of a transit system. Example: Amtrak Rail Station, Transit Bus Route, Transit Rail Station.
Communication Feature	Definition: A COMMUNICATION FEATURE is a line, facility, or system for producing, transmitting, or distributing communications. Example: Communication Duct Bank, Communication Line, Communication Pole
Electric Feature	Definition: An ELECTRIC FEATURE is a line, facility, or system for producing, transmitting, or distributing electricity. Example: Electric Duct Bank, Electric Junction Box, Electric Transformer

Table 16. Infrastructure Feature Subject Area Subcategory Descriptions (continued).

Subcategory	Description
Oil or Gas Feature	Definition: An OIL OR GAS FEATURE is a line, facility, or system for producing, transmitting, or distributing oil or gas. Example: Oil Line, Oil Valve, Gas Line
Multiple Purpose Feature	Definition: A MULTIPLE PURPOSE FEATURE is a line, facility, or system for producing, transmitting, or distributing one or many different utilities at any given time. Example: Miscellaneous Line, Utility Tunnel, Utility Easement
Other Sewer Feature	Definition: An OTHER SEWER FEATURE is a line, facility, or system for transporting and/or distributing the combination of sanitary sewer contents and storm water. Example: Combined Sewer Line
Sanitary Sewer Feature	Definition: A SANITARY SEWER FEATURE is a line, facility, or system for transporting and distributing sanitary sewer contents. Example: Sanitary Sewer Line, Sanitary Sewer Valve, Sanitary Sewer Cleanout
Steam Feature	Definition: A STEAM FEATURE is a line, facility, or system for producing, transmitting, or distributing steam. Example: Steam Line, Steam Valve
Communication Feature	Definition: A COMMUNICATION FEATURE is a line, facility, or system for producing, transmitting, or distributing communications. Example: Communication Duct Bank, Communication Line, Communication Pole
Electric Feature	Definition: An ELECTRIC FEATURE is a line, facility, or system for producing, transmitting, or distributing electricity. Example: Electric Duct Bank, Electric Junction Box, Electric Transformer
Storm Sewer Feature	Definition: A STORM SEWER FEATURE is a line, facility, or system for transmitting or distributing storm sewer water. Example: Storm Sewer Culvert, Storm Sewer Inlet, Storm Sewer Line
Water Utility Feature	Definition: A WATER UTILITY FEATURE is a line, facility, or system for transmitting or distributing water. Example: Water Hydrant, Water Line, Water Valve
Water Infrastructure Feature	Definition: A WATER INFRASTRUCTURE FEATURE is a relevant ancillary facility within the environment of a given body of water that may interact with that body of water, or a given body of water in itself. Example: Ferry Terminal, Marina Location, Waterway Source: Modified from Texas Department of Transportation TxDOT Glossary 2006-02 Accessed July 28, 2008

Natural Feature Category

A Natural Feature is a location or area that represents an object or phenomenon that occurs in nature without human intervention. The Natural Feature category includes three subcategories and 42 identified data entities that describe information related to geologic, soil, and water features (Figure 19). Table 17 provides detailed descriptions for each subcategory.

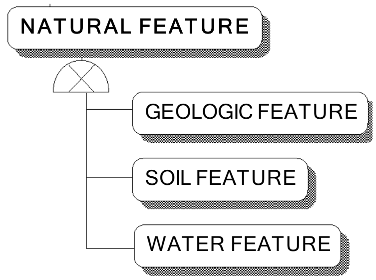


Figure 19. Natural Feature Subcategories.

Table 17. Natural Feature Subject Area Subcategory Descriptions.

Subcategory	Description
Geologic Feature	Definition: A GEOLOGIC FEATURE is an area or location that contains information about the earth, the materials it is made of, the processes that act on those materials, the products formed, and the history of the planet and its life forms since its origin. Example: Geologic Atlas of Texas Area, Texas STATEMAP Geologic Map Grid Source: U.S. Geological Survey http://earthquake.usgs.gov/learning/glossary.php?term=geology Accessed August 4, 2008
Soil Feature	Definition: A SOIL FEATURE is an area or location that describes unconsolidated mineral or organic matter on the surface of the earth, which resulted from the effect of climate and living organisms on parent material over a period of time. Example: Detailed Soil Type Boundary, Soil Boring Location, Soil Type Boundary Source: U.S. Department of Agriculture http://soils.usda.gov/education/facts/soil.html Accessed August 1, 2008
Water Feature	Definition: A WATER FEATURE is a location, segment, or area that represents the presence of water. Example: Coastal Zone Boundary, Floodplain 100 Year Area, Wetland Boundary

System Monitoring Feature Category

A System Monitoring Feature is a device, structure, or location where there is collection of data about events, incidents, people, weather, and other systems. The System Monitoring Feature category includes seven subcategories and 34 identified data entities that describe information reflecting transportation system performance characteristics (Figure 20). Table 18 provides detailed descriptions for each subcategory.

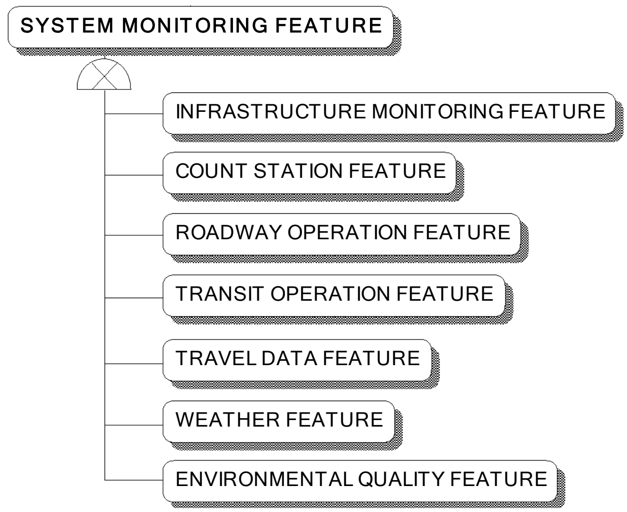


Figure 20. System Monitoring Feature Subcategories.

Table 18. System Monitoring Feature Subject Area Subcategory Descriptions.

Subcategory	Description
Infrastructure Monitoring Feature	Definition: An INFRASTRUCTURE MONITORING FEATURE is a location that contains information about one or more infrastructure features. Example: Roadway Photo Log Location
Count Station Feature	Definition: A COUNT STATION FEATURE is a location where vehicles are counted. Example: Automatic Traffic Recorder Location, Midblock Count Station Location, Turning Movement Count Station Location
Roadway Operation Feature	Definition: A ROADWAY OPERATION FEATURE is a location that contains information about a roadway including normal operation, events, and incidents. Example: Crash Point, Incident Point, Construction Zone
Transit Operation Feature	Definition: A TRANSIT OPERATION FEATURE is a location that contains information about a transit system including normal operation, events, and incidents. Example: Bus AVL Point, Transit Incident Boundary, Transit Service Request Location
Travel Data Feature	Definition: A TRAVEL DATA FEATURE is a location in conjunction with a study to determine travel characteristics of individuals and/or populations. Example: GPS Travel Point, Transit Trip Point, Travel Time Run Segment
Weather Feature	Definition: A WEATHER FEATURE is a location or area at which weather related phenomena are measured. Example: Average Rainfall Site, Precipitation Accumulation Area, Rainfall Intensity Site
Environmental Quality Feature	Definition: An ENVIRONMENTAL QUALITY FEATURE is a location where environmental data are collected. Example: Air Quality Monitoring Station, Vehicle Emission Inspection Location, Water Quality Monitoring Station

Transportation Planning Feature Category

A Transportation Planning Feature is an area or location containing relevant information for use in the transportation planning process. The Transportation Planning Feature category includes nine subcategories and 87 identified data entities that describe information related to transportation planning activities (Figure 21). Table 19 provides detailed descriptions for each subcategory.

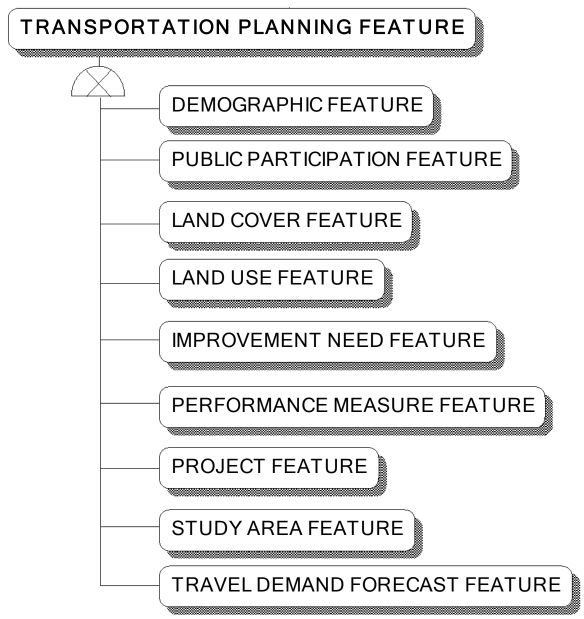


Figure 21. Transportation Planning Feature Subcategories.

Table 19. Transportation Planning Feature Subject Area Subcategory Descriptions.

Subcategory	Description
Demographic Feature	Definition: A DEMOGRAPHIC FEATURE is a location or area that contains representative data about human population. Example: Gross Domestic Product (GDP) Metropolitan Area, Employment Density, Population Density Census Block
Public Participation Feature	Definition: A PUBLIC PARTICIPATION FEATURE is a location or area that contains information needed to satisfy public involvement requirements. Example: Environmental Justice Boundary, Safety Concern Survey Location, Public Meeting Location
Land Cover Feature	Definition: A LAND COVER FEATURE is an area that describes the classification of land according to the vegetation or material that covers most of its surface. Example: National Land Cover Dataset, Texas Land Classification System Land Cover Area, Vegetation Land Cover Source: ESRI http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.search&searchTerm=land%20cover Accessed July 28, 2008
Land Use Feature	Definition: A LAND USE FEATURE is an area or location that describes the classification of land according to what human activities take place. Example: Agricultural Land Use, Impervious Surface Land Use, Zoning Area
Improvement Need Feature	Definition: An IMPROVEMENT NEED FEATURE is an area or location where a deficiency, or improvement to address that deficiency, has been identified. Example: Improvement Need Line, TAZ Bicycle Need Index, TAZ Pedestrian Need Index
Performance Measure Feature	Definition: A PERFORMANCE MEASURE FEATURE is an area, segment, or point associated with the systematic collection, analysis, and reporting of data to measure system performance. Example: Bicycle Compatibility Index Line, Economically Stressed Area, Travel Demand Management Area Source: I-95 Corridor Coalition http://www.i95coalition.org Accessed July 24, 2008
Project Feature	Definition: A PROJECT FEATURE is the location or area of a specific plan, task, or scheme undertaken by a person or group of persons, usually for the purpose of problem identification and/or resolution, within a given timeframe. Example: Regional Transportation Project Area, Regional Transportation Project Area High Priority, Regional Transportation Project Point Source: ESRI http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.search&searchTerm=project Accessed July 28, 2008
Study Area Feature	Definition: A STUDY AREA FEATURE is a region or area that defines the boundary of a study. Example: Study Area, Study Corridor, Study Point
Travel Demand Forecast Feature	Definition: A TRAVEL DEMAND FORECAST FEATURE is a location or area of an analysis and/or process used to predict travel behavior and resulting demand for a specific future period based on assumptions dealing with land use, the number and character of trip makers, and the nature of the transportation system. Example: External Station, Traffic Analysis Zone, Travel Demand Model Boundary Source: Connecticut Department of Transportation http://ct.gov/dot/cwp/view.asp?a=1383&q=259806 Accessed July 24, 2008

METADATA DEVELOPMENT

TxDOT's requirements for the development of data dictionaries include definitions (for entities) and definition, purpose, example, valid values, and format (for attributes) (*53*). While these requirements could apply in the case of geospatial data, there is a national standard that is more appropriate for geospatial metadata: the Content Standard for Digital Geospatial Metadata (CSDGM), first released in 1994 by the Federal Geographic Data Committee (FGDC) (*54*). This standard includes a large number of metadata elements grouped into seven categories, including identification, data quality, spatial data organization, spatial reference, entity and attribute information, distribution, and metadata reference. The standard includes mandatory metadata elements and optional metadata elements, as well as metadata elements that can be repeated as needed. The most recent version of the standard is GSDGM version 2, which FGDC released in 1998 (*54*).

While the use of CSDGM is mandatory for federal geospatial datasets, many states, including Texas, have adopted the standard (*55*). Part of the research effort, therefore, involved generating CSDGM-compliant metadata documents. In practice, it was not feasible during the research phase to develop comprehensive metadata documents for all the 589 spatial data entities. In agreement with the project advisors, the researchers selected a sample of entities to compile (and/or develop as needed) associated metadata documentation. The effort also included developing sample geodatabases and a web-based viewer to enable stakeholders to view both sample map and metadata documents online.

To prioritize which entities to include in the metadata and sample geodatabase effort, the researchers took into consideration factors such as ready availability of sample data and feedback from stakeholders. Stakeholder feedback was primarily in the form of an indication from individual MPOs about entities that were a priority to them. The researchers received feedback information from 11 MPOs. For each entity, the researchers added the total number of MPOs that considered that entity to be a priority and then converted the total number to a normalized score from 0–10, where "10" meant that 100 percent of the MPOs consulted considered the entity to be a priority. For simplicity, the researchers focused on sample data that were already available, e.g., through TNRIS, TCEQ, the U.S. Census Bureau, and USGS.

Sample Geodatabases

For developing the sample geodatabases, the researchers used ESRI ArcEditor™. As mentioned previously, the logical data model follows a three-level grouping structure: category, subcategory, and entity. At the logical level, this grouping structure did not make a distinction between vector data and raster data. However, for implementation purposes, such a distinction is important. One of the reasons is that ArcGIS only supports a two-level grouping structure within geodatabases. More explicitly, for *vector* data, ArcGIS supports feature classes and feature datasets (which can contain multiple feature classes but not nested feature datasets). Likewise, for *raster* data, ArcGIS supports raster datasets and raster catalogs (which can contain multiple raster datasets but not nested raster catalogs). Furthermore, a single geodatabase can contain multiple feature datasets, feature classes, raster catalogs, and raster datasets. However, feature datasets cannot contain raster data and raster catalogs cannot contain feature classes. In addition, when stored within a raster catalog, individual raster datasets cannot have their own metadata documents, i.e., a single metadata document applies to all the raster datasets within the raster catalog.

The researchers solved the two-level grouping structure limitation in the ArcGIS model by creating separate geodatabases for individual categories (Figure 22) and by creating feature datasets for individual subcategories (Figure 23). For simplicity and for portability during the research phase, the researchers used personal geodatabases (which store all the data in single Microsoft Access™ [.mdb] files). However, a similar structure may be possible when using file geodatabases (in this case, different folders would replicate the category grouping) or geodatabases (in this case, different table spaces would replicate the category grouping).

Because feature datasets cannot store raster data, the researchers created separate raster catalogs within the geodatabases to represent data entities that were in raster format (even if the entities belonged to the same subcategory at the logical level). In addition, because raster datasets within raster catalogs cannot have their own individual metadata documents, each raster catalog only stored one raster data entity whose metadata were linked to the catalog. As an illustration, Figure 23 shows a raster catalog called Geologic_Geologic_Atlas_of_Texas within the Natural Feature personal geodatabase to represent raster data that belonged to the Geologic Feature subcategory. For convenience, the name of all raster catalogs always started with the name of the corresponding subcategory, e.g., "Geologic" to indicate the raster catalog belonged to the Geologic Feature subcategory.

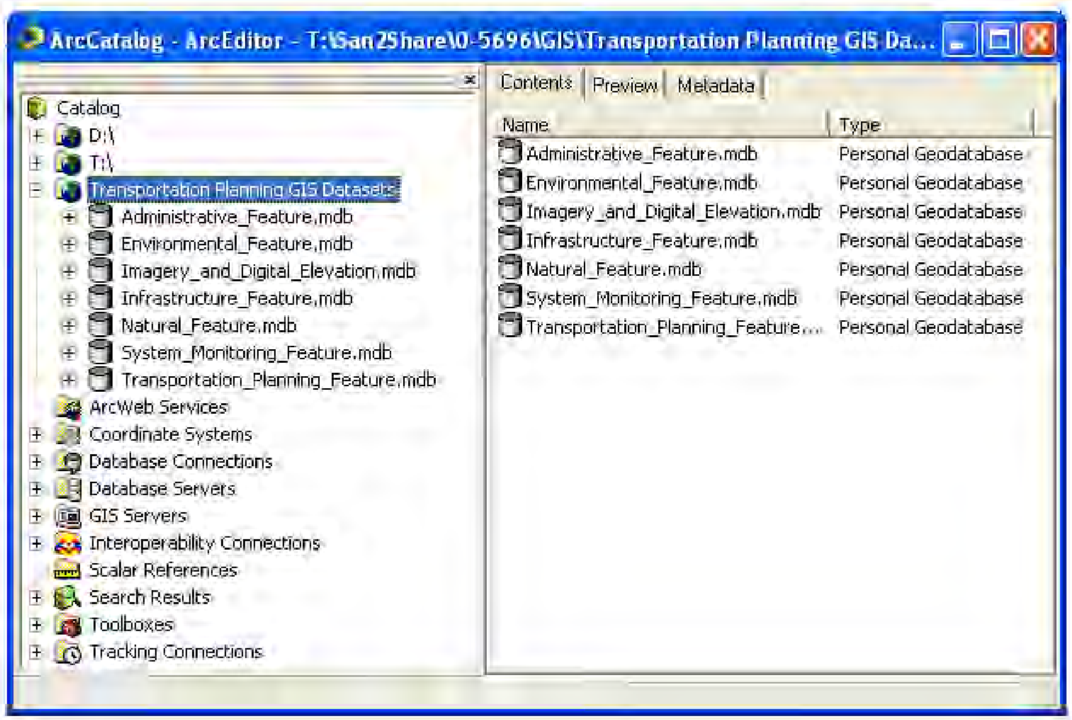


Figure 22. Transportation Planning Geodatabases.

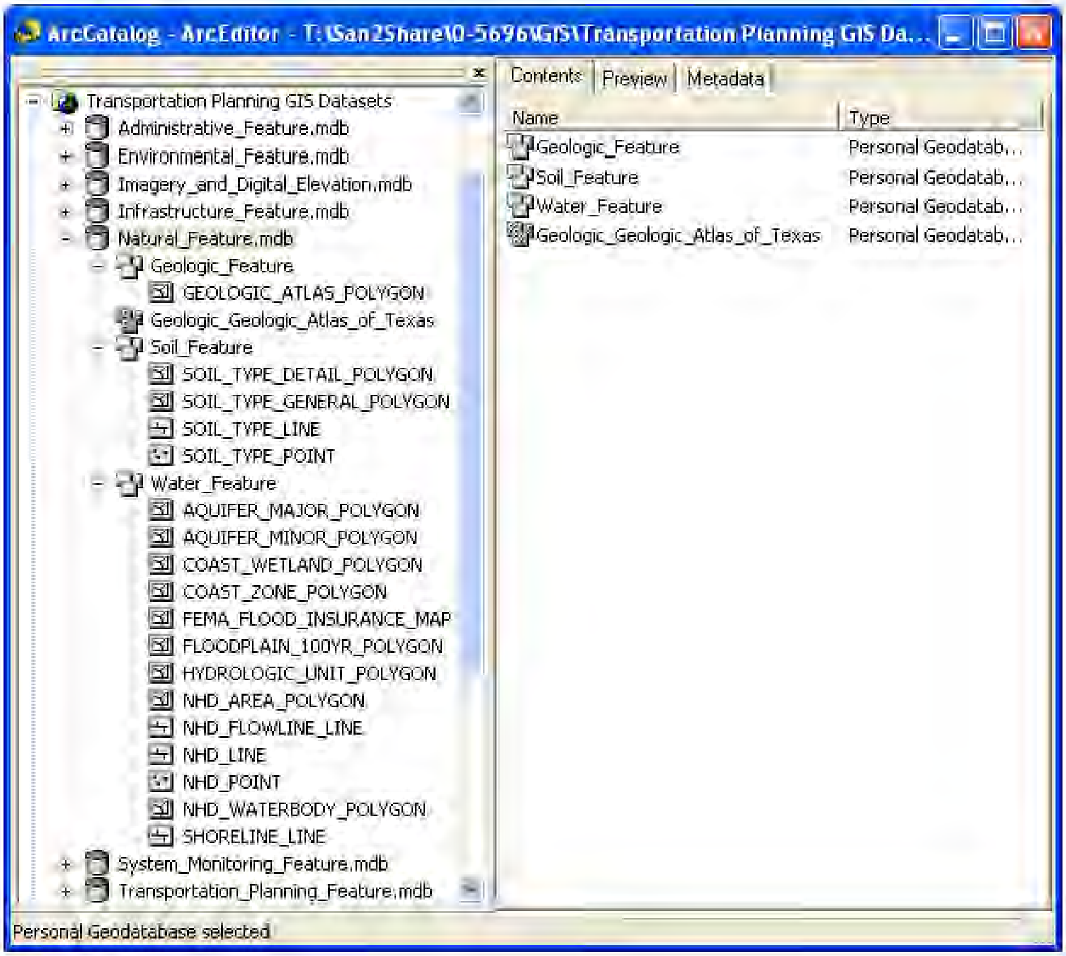


Figure 23. Natural Feature Category.

The researchers collected sample data from both online and offline sources. Major online sources included federal and statewide data providers, such as USGS, EPA, and TNRIS, while offline data sources included TxDOT and local MPOs. The researchers focused first on data sources that were available within the state and then, as needed, looked for data at the national level. In general, it was necessary to post-process the sample data in order to meet the needs of the research. For example, the researchers renamed each original feature class (or raster dataset) following TxDOT's data architecture naming conventions (*53*). For simplicity, the researchers converted the coordinate system of all sample data to GCS_WGS_1984 to ensure the data would overlay correctly on the prototype web-based map and metadata viewer. For convenience, the researchers clipped features outside the state of Texas to make the datasets more compact and to address online map viewer data rendering issues. Finally, to enable portability of the metadata documentation at the end of the research phase, the researchers developed two parallel sets of files with metadata: one set of files with spatial data and a second set of files with no spatial data.

There were differences between the names assigned to sample feature classes in the geodatabases and the corresponding names in the logical data model (or the corresponding names in the metadata documentation, as described in the following section). Typical cases were as follows:

- **Sample data were at a different level of aggregation than the logical data model entity**. For example, the logical model included a data entity called US Postal Service Facility (Administrative Feature, Federal Feature subcategory) to represent different types of facilities related to the U.S. Postal Service. In this case, an attribute in the data entity enables the distinction among different types of facilities. However, the researchers were only able to locate a sample feature class depicting post offices. For simplicity, the researchers called the sample feature class POST_OFFICE_POINT to better reflect the content of the sample data.

- **Multiple sample data files were available for the same logical data model entity**. For some data entities, the researchers found multiple sample datasets from different sources. For example, the researchers found two sample feature classes for the Railroad data entity (Infrastructure Feature, Rail Feature subcategory). One sample file originated at TxDOT covering Texas only and the other one originated at the Federal Railroad Administration covering the entire country. For illustration purposes, the researchers kept both datasets and called them RAILROAD_LINE and RAILROAD_NATIONAL_LINE, respectively.

- **Sample feature class names used underscores instead of spaces**. ArcGIS does not handle spaces in table names well. As a result, the researchers replaced spaces with underscores while translating names from the logical data model to the geodatabases (Figure 22, Figure 23). Notice that geodatabase table names did not use TxDOT abbreviations. The reason is that the potential audience of the research results includes many different agencies other than TxDOT. For those agencies, plain English names and descriptions would be more useful than abbreviated ones. During implementation, TxDOT could decide whether to use abbreviations for physical tables in the database, particularly in the case of external tables, which represent the majority of data entities in the model.

Metadata Development Process

The researchers collected, modified, or created metadata for each of the data entities that had sample data. The researchers made every effort possible to develop metadata in accordance with CSDGM (*53*). In practice, the level of metadata completeness for individual entities depended largely on the amount and characteristics of the information that was already available. For developing metadata documents, the researchers used ESRI ArcCatalog™, which includes a CSDGM-compliant editor that allows users to export metadata in a variety of formats, including text (TXT), hypertext markup language (HTML), and extensible markup language (XML).

The researchers found a wide range of metadata completeness practices in the sample data collected. In general, data collected from federal data sources were more likely to be CSDGM compliant than other data sources. Typical challenges found during the metadata collection process included the following:

- **Sample data without metadata**. In this case, the researchers tried to generate as much metadata content as possible, frequently based on limited documentation. The process was time consuming, which significantly slowed the metadata development progress.

- **Sample data with incomplete metadata**. Some sample data files contained limited metadata such as definitions, valid values, and accuracy assessment. In these cases, the availability of at least some metadata enabled the researchers to save valuable time, which resulted in a higher metadata production rate.

- **Sample data with metadata in 1994 metadata standard format**. The current version of CSDGM (completed in 1998) introduced several changes to the 1994 version of the standard. Several sample data files (even in cases where the spatial data were up-to-date) had metadata in the 1994 format. These metadata were usually available as separate TXT or HTML files, which made it necessary to input the metadata in ArcCatalog manually.

In the process of modifying sample metadata, the researchers maintained the original content, including the *Citation* > *Citation Title* tag content, as long as the content was up to date and properly related the associated sample data. This practice resulted in occasional name discrepancies between the logical data model and the Citation Titles in the metadata documents. The researchers realize this limitation would need to be addressed during implementation to avoid user confusion.

In order to provide as much clarifying information in the metadata as possible, the researchers updated the *Identification Information* tags and *Entity and Attribute Definition* metadata tags. For completeness, the researchers added text in the *Identification Information* > *Supplemental Information* tag to document the metadata development process and to provide information about the research project. For example, the researchers added the following content in the Census Block Group metadata:

> The Texas Transportation Institute (TTI) created/modified the metadata for this feature class as part of TxDOT research project 0-5696 (Developing a Statewide, Integrated GIS/GPS Data Model). For more information, contact Cesar Quiroga at 210-731-9938 or c-quiroga@tamu.edu.
>
> **Metadata modification date:** 2008
> **Sample data source:** U.S. Census Bureau (http://www.census.gov/geo/www/tiger/index.html).
> **Original feature class name:** grp00
> **Modified feature class name:** CENSUS_BLOCK_GROUP_POLYGON
> **Original coordinate system:** None
> **Modified coordinate system:** GCS_WGS_1984
> **Original metadata source:** Obtained with the original sample data.
> **Metadata development process:** The researchers modified the Identification Information tags and completed the Entity and Attribution Definition tags.

The final product was a spatial dataset that included seven personal geodatabases containing sample data and/or metadata for 133 data entities, as shown in Table 20.

Table 20. Data Entities with Sample Data and Metadata.

Subcategory	Data Entity	Priority*
	Administrative Feature	
Federal Feature	Census Block	8
	Census Block Group	9
	Census Tract	9
	Indian Reservation Boundary	1
	Metropolitan Statistical Area	5
	Urban Area	N/A
	Urbanized Area	7
	US Postal Service Facility	0
	ZIP Code Area Three Digit	3
	ZIP Code Area Five Digit	3
Planning Feature	MPO Boundary	10
	Neighborhood	2
Political Subdivision Feature	City Limit	9
	City Point	5
	Country	4
	County	7
	Mexican State	3
	State	3
	Extra Territorial Jurisdiction Zone	5
Property Feature	Original Texas Land Survey	0
	Parcel Plat	4
	Subdivision Boundary	2
School Feature	School District	3
TxDOT Administrative Feature	TxDOT District Boundary	4
	Environmental Feature	
Air Quality Feature	Point Source Air Emission Site	3
	CO Nonattainment Area	1
	Ozone Nonattainment Area	5
	PM10 Nonattainment Area	3
	PM2.5 Nonattainment Area	2
Biological Resource Feature	Coastal Species Site	0
	Natural Ecoregion	2
	Natural Sub-Ecoregion	2
	Seagrass Bed Area	0
Disposal Facility Feature	Municipal Solid Waste Facility	2
Environmental Impact Feature	TEAP Composite Grid	3
	TEAP Diversity Grid	3
	TEAP Rarity Grid	3
	TEAP Sustainability Grid	3
	GISST Texas Grid	3
Hazardous Material Feature	Hazardous Waste Site	3
	Radioactive Waste Site	1
	Superfund Site	2
	Toxic Release Inventory Site	1
Water Quality Feature	Water Discharge Outfall	
	Imagery and Digital Elevation	
Aerial Image	National Agriculture Imagery Program	2
	Texas Orthographic Program Image	1
Digital Elevation Feature	Digital Elevation Model	3
	National Elevation Data	2
	Shoreline Digital Elevation Model	1
	Shuttle Radar Topography Mission	1

Table 20. Data Entities with Sample Data and Metadata (continued).

Subcategory	Data Entity	Priority*
Satellite Image	LandSAT 5	1
	LandSAT 7	1
	SPOT Image	1
Topographic Feature	Shoreline Topographic Line	2
	Hypsography/Contour Line	1
	Sea Floor Features	1
	Sea Floor Survey Index Boundary	1
	USGS DRG Topo Map	1
	USGS Quadrangle Index	2
Infrastructure Feature		
Aviation Feature	Airport Boundary	2
	Airport Location	3
Bicycle or Pedestrian Feature	Bicycle Route	6
Educational or Cultural Feature	Cultural Facility Boundary	0
	School	6
General Feature	Cemetery	0
	Military Facility Boundary	1
	Landmark	N/A
	Health Care Facility Point	3
Industrial Feature	Intermodal Facilities	0
Parks and Wildlife Feature	Park Boundary	2
	Federal Park Boundary	3
	State Park Boundary	3
	State Federal Public Land Boundary	3
	Wildlife Management Area	2
Port Feature	Port of Entry	4
	Border Crossing	
	Water Intermodal Port	0
Rail Feature	Rail Crossing	4
	Railroad	7
Road Feature	Weigh-in-Motion Station	N/A
Roadway Feature	Mexico Highway	N/A
	HPMS Roadway	4
	NHPN Line	4
	NHPN Point	4
	NHS Roadway	5
	StratMap Transportation	3
	TxDOT Off System Roadway	5
	TxDOT On System Roadway	5
	Thoroughfare Route	5
	Toll Road	4
Route Feature	Hazardous Material Route	4
	Evacuation Route	5
	Hazardous Material Route	4
Transit Feature	Transit Rail Line	5
	Transit Rail Station	4
	Transit Bus Route	9
	Transit Bus Stop	5
Water Infrastructure Feature	Waterway	0
Natural Feature		
Geologic Feature	Geologic Atlas of Texas Grid	0
	Geologic Atlas of Texas Area	0

Table 20. Data Entities with Sample Data and Metadata (continued).

Subcategory	Data Entity	Priority*
Soil Feature	Detailed Soil Type Boundary	1
	Soil Type Boundary	1
	Soil Type Linear Feature	0
	Soil Type Point Feature	0
Water Feature	Aquifer Minor	2
	Aquifer Major	2
	Floodplain Area	3
	Hydrologic Unit Boundary	0
	NHD Area	0
	NHD Flow Line	0
	NHD Line	1
	NHD Point	0
	NHD Waterbody	0
	Shoreline	0
System Monitoring		
Count Station Feature	Automatic Traffic Recorder Location	3
Environmental Quality Feature	Air Quality Monitoring Station	6
	Water Quality Monitoring Station	0
Weather Feature	Precipitation Accumulation Area	0
Transportation Planning		
Demographic Feature	Employment Traffic Analysis Zone	7
	Household Census Block	8
	Population Census Block	7
	Population Density Census Block	6
Land Cover Feature	Vegetation Land Cover	0
Land Use Feature	Land Use	7
	Land Cover Diversity Grid	1
	Zoning Area	5
Study Area Feature	Study Corridor	4
Travel Demand Forecast Feature	Traffic Analysis Zone	7
	External Station	5
	TDM Boundary	10
	TDM Network	7
	Traffic Survey Zone	5
	Regional Analysis Zone	5

* Based on responses from 11 MPOs. A score of 10 indicates that all MPOs considered the data entity a high priority. A score of 0 indicates that no MPO considered the data entity a high priority. A score of "N/A" corresponds to spatial data entities identified after the MPO responses.

PROTOTYPE WEB-BASED DATA AND METADATA VIEWER

To facilitate the display and dissemination of transportation planning data (including metadata), the researchers developed a prototype web-based map and metadata viewer called Transportation Planning GIS (TPGIS) Data Viewer. The researchers considered using ESRI Metadata Explorer 9.2™ for displaying metadata using a web-based interface. However, installing and running Metadata Explorer 9.2 proved to be challenging because of the lack of adequate software installation documentation. In addition, ESRI is migrating metadata services to a new platform called GIS Portal Toolkit, which has requirements and functionality beyond the scope of this research (*56*). As a result, the researchers decided to develop a prototype map and metadata viewer using by modifying a map interface the researchers had already developed for other

TxDOT research projects. In some cases, it was necessary to develop and/or customize web pages and functions. However, the level of customization was kept to a minimum.

In general, the TPGIS application development focused on basic data display requirements rather than sophisticated user interface design and support (although, by necessity, the researchers designed and built the user interface in a way that could support the data and map display efficiently). Design and testing of user interfaces for implementation purposes would need to undergo a formal process that identifies comprehensive user interface needs.

TPGIS includes a metadata browser and a map viewer. The metadata browser enables users to explore feature categories, subcategories, and entities, including the retrieval of basic definition and metadata documentation (Figure 24, Figure 25, Figure 26). For convenience, the browser window includes two tabs, as follows:

- **General**. This tab (Figure 24) shows general information about the data entity, such as definition (provided as a "tip" that displays information when users hover the mouse pointer over the definition icon), priority, type, and source.

- **Sample Data**. This tab (Figure 25) shows metadata and sample data information, including a link that users can click to retrieve the metadata document associated with a spatial data entity (Figure 26).

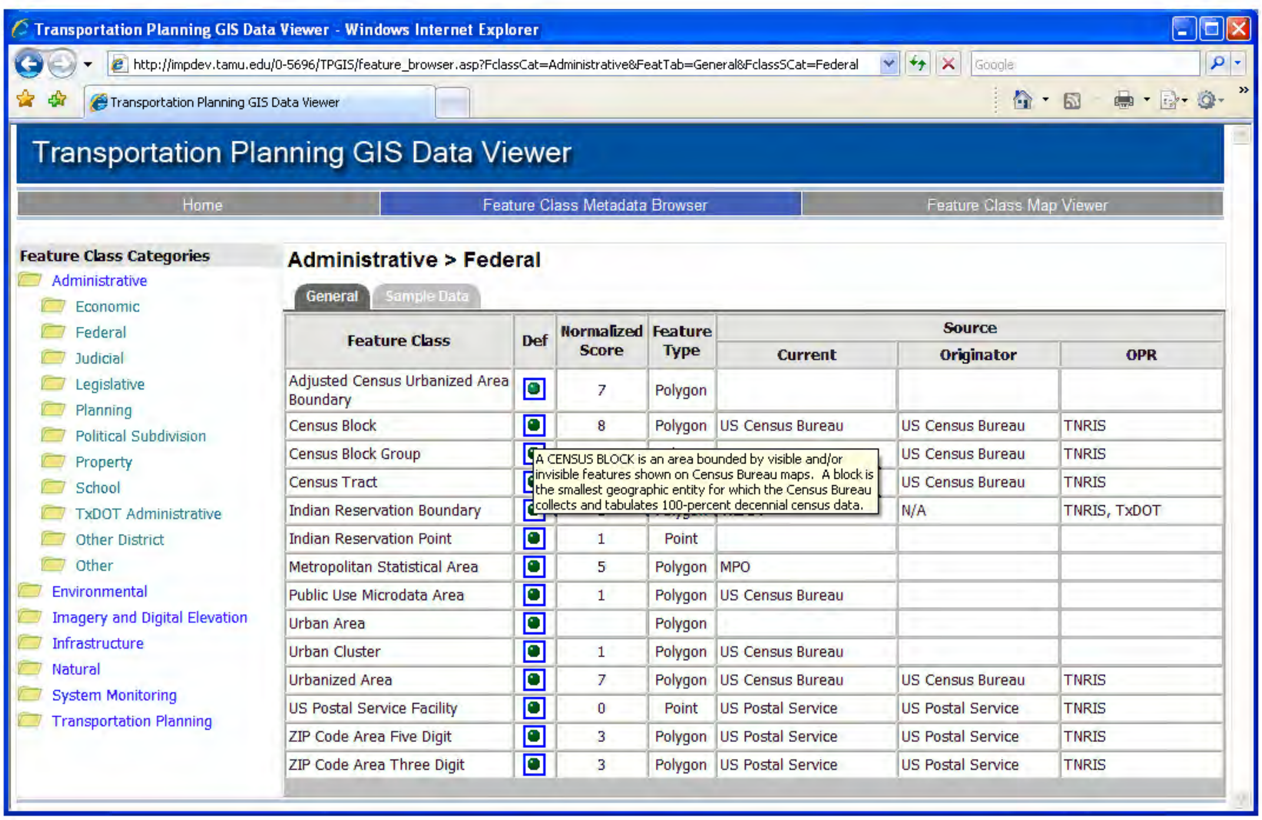


Figure 24. TPGIS Metadata Browser (General Tab).

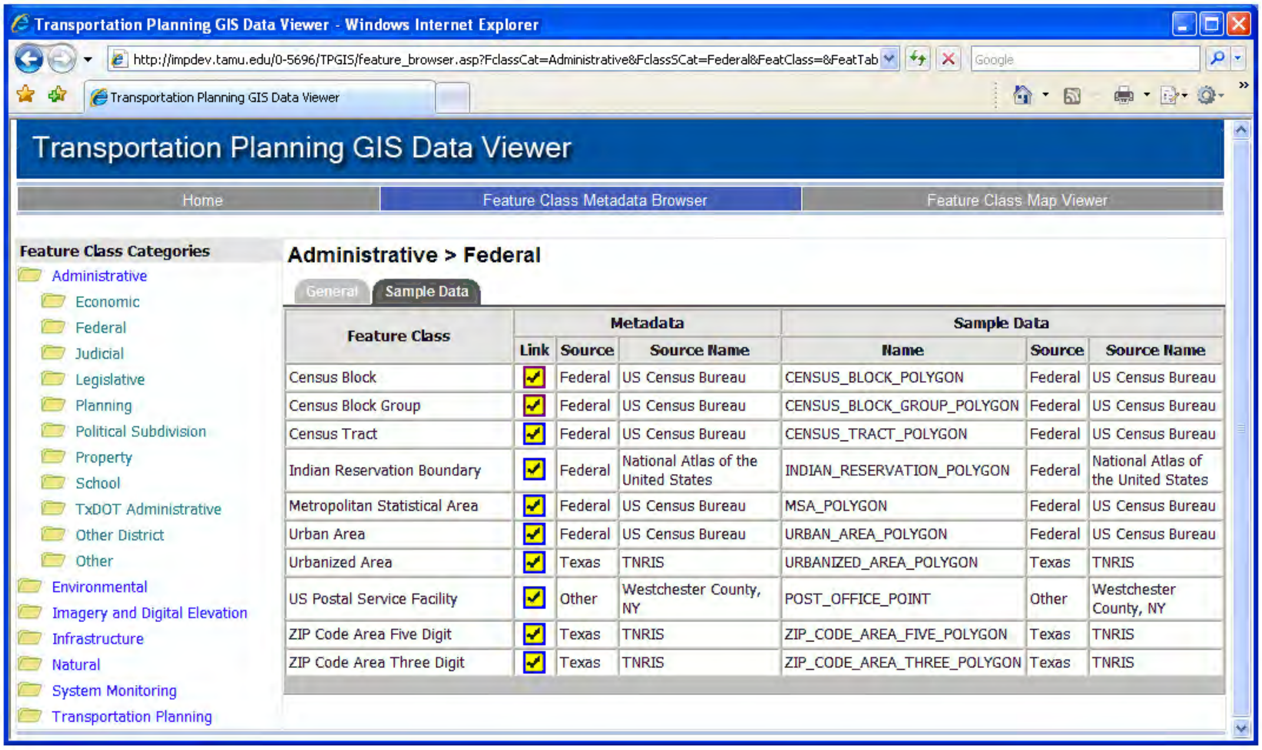
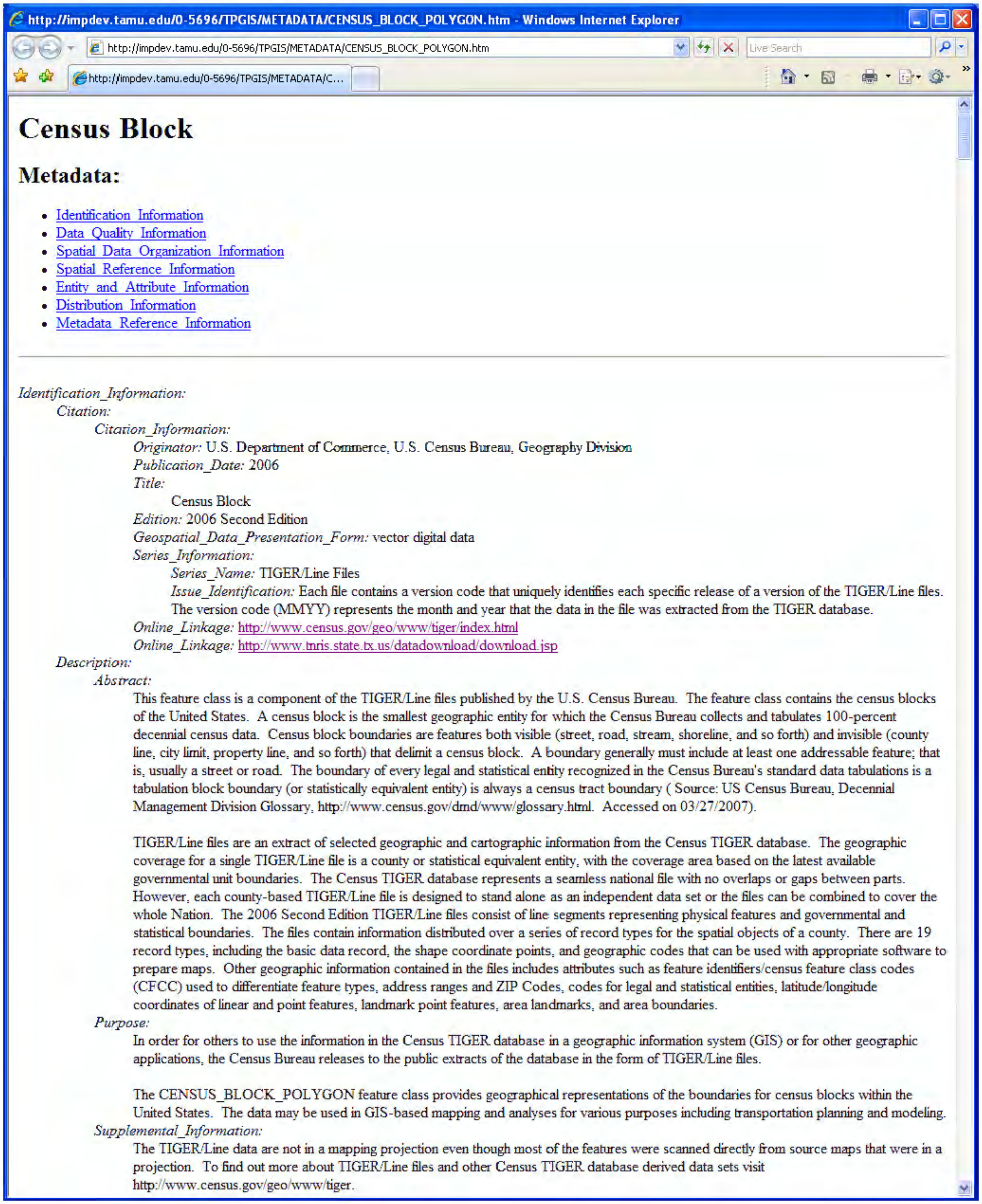


Figure 25. TPGIS Metadata Browser (Sample Data Tab).



Census Block

Metadata:

- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Department of Commerce, U.S. Census Bureau, Geography Division
Publication_Date: 2006
Title:
Census Block
Edition: 2006 Second Edition
Geospatial_Data_Presentation_Form: vector digital data
Series_Information:
Series_Name: TIGER/Line Files
Issue_Identification: Each file contains a version code that uniquely identifies each specific release of a version of the TIGER/Line files. The version code (MMYY) represents the month and year that the data in the file was extracted from the TIGER database.
Online_Linkage: http://www.census.gov/geo/www/tiger/index.html
Online_Linkage: http://www.tnris.state.tx.us/datadownload/download.jsp
Description:
Abstract:
This feature class is a component of the TIGER/Line files published by the U.S. Census Bureau. The feature class contains the census blocks of the United States. A census block is the smallest geographic entity for which the Census Bureau collects and tabulates 100-percent decennial census data. Census block boundaries are features both visible (street, road, stream, shoreline, and so forth) and invisible (county line, city limit, property line, and so forth) that delimit a census block. A boundary generally must include at least one addressable feature; that is, usually a street or road. The boundary of every legal and statistical entity recognized in the Census Bureau's standard data tabulations is a tabulation block boundary (or statistically equivalent entity) is always a census tract boundary (Source: US Census Bureau, Decennial Management Division Glossary, http://www.census.gov/dmd/www/glossary.html. Accessed on 03/27/2007).

TIGER/Line files are an extract of selected geographic and cartographic information from the Census TIGER database. The geographic coverage for a single TIGER/Line file is a county or statistical equivalent entity, with the coverage area based on the latest available governmental unit boundaries. The Census TIGER database represents a seamless national file with no overlaps or gaps between parts. However, each county-based TIGER/Line file is designed to stand alone as an independent data set or the files can be combined to cover the whole Nation. The 2006 Second Edition TIGER/Line files consist of line segments representing physical features and governmental and statistical boundaries. The files contain information distributed over a series of record types for the spatial objects of a county. There are 19 record types, including the basic data record, the shape coordinate points, and geographic codes that can be used with appropriate software to prepare maps. Other geographic information contained in the files includes attributes such as feature identifiers/census feature class codes (CFCC) used to differentiate feature types, address ranges and ZIP Codes, codes for legal and statistical entities, latitude/longitude coordinates of linear and point features, landmark point features, area landmarks, and area boundaries.
Purpose:
In order for others to use the information in the Census TIGER database in a geographic information system (GIS) or for other geographic applications, the Census Bureau releases to the public extracts of the database in the form of TIGER/Line files.

The CENSUS_BLOCK_POLYGON feature class provides geographical representations of the boundaries for census blocks within the United States. The data may be used in GIS-based mapping and analyses for various purposes including transportation planning and modeling.
Supplemental_Information:
The TIGER/Line data are not in a mapping projection even though most of the features were scanned directly from source maps that were in a projection. To find out more about TIGER/Line files and other Census TIGER database derived data sets visit http://www.census.gov/geo/www/tiger.

Figure 26. TPGIS Metadata Browser (Metadata Document View).

The map viewer provides a navigable map that enables users to view and identify sample datasets (Figure 27). Notice that the map includes a customized table of contents (TOC) tool that opens a sidebar on the right of the map showing an expandable list of categories, subcategories, and spatial data entities. A checkbox in front of a spatial data entity enables the user to display that spatial data entity. As needed, the user can display and overlay several spatial data entities at the same time. A radio button in front of a spatial data entity enables the user to make that data entity the active layer. Once a data entity is the active layer, the user can query any feature on that active layer (using the standard Identify tool) and retrieve the metadata document (Figure 26) by clicking on the Metadata button at the top of the TOC.

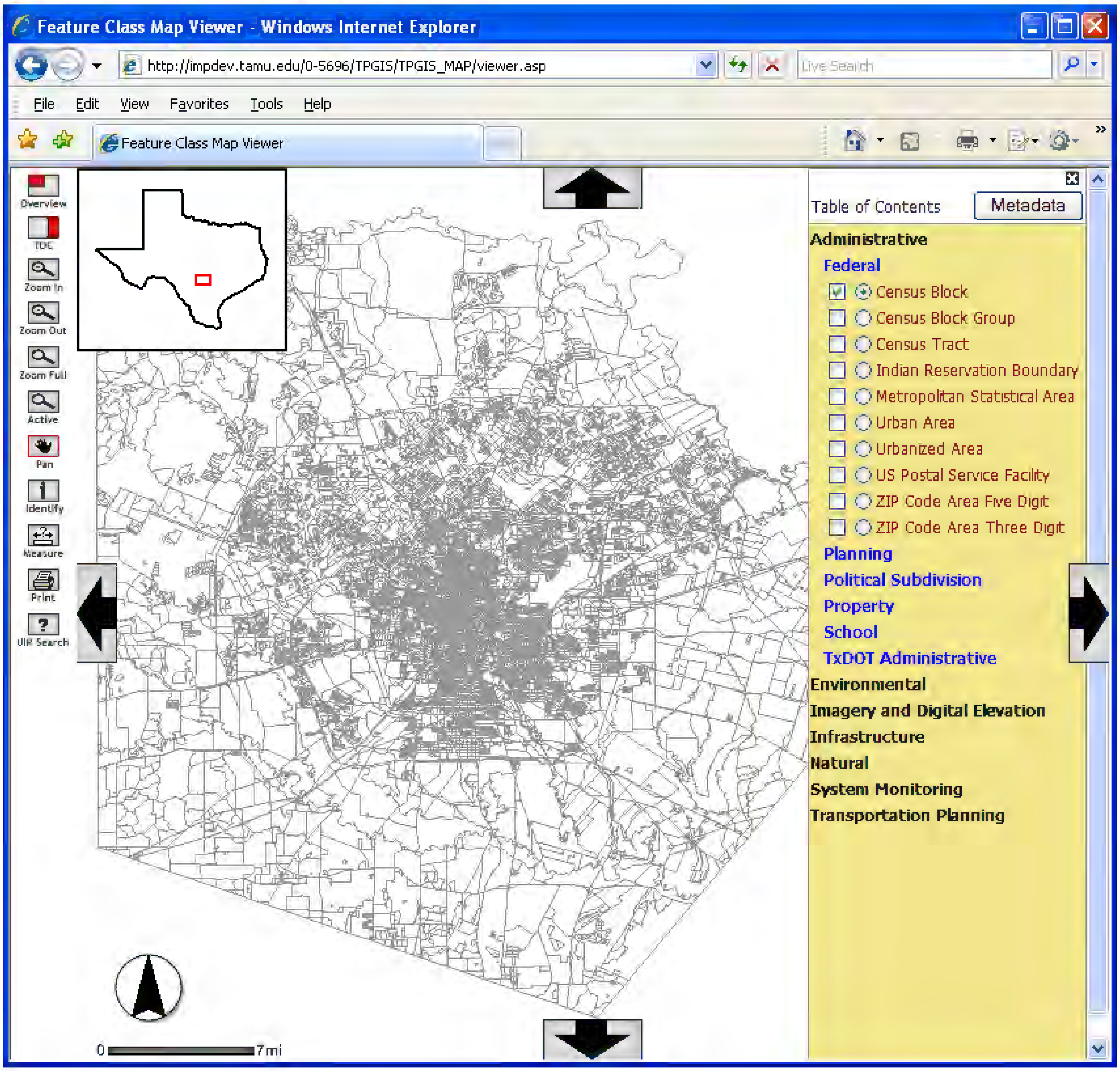


Figure 27. TPGIS Map Viewer with Interactive TOC Sidebar.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF FINDINGS

Transportation planning requires substantial amounts of data and cooperation among transportation planning agencies. Advances in computer technology and the increasing availability of GIS are giving transportation planners the ability to develop and use data with a much higher degree of efficiency. However, as information systems advance, the need to provide effective data integration/exchange protocols and procedures to reduce redundancy and data collection costs is becoming more important. Many factors influence the effectiveness of data exchange and data integration efforts, such as data compatibility, data access, data quality, completeness, metadata, hardware, software, and staff expertise.

This research resulted in a catalog of spatial data sources available to transportation planning agencies in Texas. The work included a synthesis of current transportation planning practices in Texas with a focus on spatial data integration and exchange issues, meetings with transportation planning and data stakeholders, the development of a map of data sources, the development of a preliminary logical data model of spatial data entities, and a compilation of metadata documents for a sample of data sources.

Transportation Planning Spatial Data Integration and Exchange Issues

This research included a review of the transportation planning process in Texas, although by necessity the review focused on spatial data integration and exchange issues.

Although TxDOT produces and distributes transportation planning datasets to MPOs using a highly structured, standardized process, these datasets primarily support the metropolitan transportation plan production process. In reality, federal and state legislation require the consideration of many different planning factors, such as system preservation and management. To support these functions, MPOs need to use datasets from a variety of data sources.

To properly characterize transportation planning spatial data integration and exchange issues in Texas, the researchers met with many stakeholders, including MPO officials and representatives of other agencies that interact with the MPO (e.g., TxDOT district liaisons, COGs, city, and transit agencies). The researchers also met with representatives of other agencies that provide data to and/or have worked with the MPOs in order to gather additional information about concerns and data needs. In addition, the researchers conducted an online workshop to receive feedback from stakeholders.

Interaction with stakeholders typically covered the following subject areas:

- land use, economic development, and smart growth;
- travel demand forecasting;
- freight movement and port planning;
- transit planning;
- system management and operations;

- safety and security;
- bicycle and pedestrian planning;
- congestion management, mobility, and transportation management;
- asset management;
- air quality and conformity;
- public involvement;
- Title VI and environmental justice; and
- NEPA process, environmental concerns, and ecological approaches.

Chapter 3 documented specific feedback that stakeholders provided for each of these subject areas. Specific trends and issues that are of interest in this chapter include the following:

- **Spatial technologies**. All MPOs use GIS and other spatial technologies to support the transportation planning process, although practices vary widely across the state. Increasingly, MPOs use spatial technologies for a wide range of activities, including travel demand modeling, data collection, demographic forecasting, subdivision screening, bicycle and pedestrian analysis, public involvement, facility inventories, corridor studies, thoroughfare planning, congestion analysis, economic development, environmental modeling, environmental justice, emergency preparation, public safety, accident analysis, transit, and MTP project mapping.

- **Data documentation and standards**. Most MPOs reported having at least partial documentation about the datasets they use. This documentation included lists of datasets and attributes, formal data models, dataset metadata, and key attributes for each dataset. Most MPOs do not use metadata standards. In some cases, they rely on the cities and counties for directions regarding standards, including metadata.

- **Data access**. MPOs use data from a variety of sources, including TxDOT, appraisal districts, the U.S. Census Bureau, cities, COGs, counties, Emergency 911, FEMA, TNRIS, TWC, and utilities. Some MPOs have developed data warehouses to facilitate internal and external access to data. MPOs identified a number of issues and challenges in this area including TxDOT and other agencies not always being forthcoming with requests for needed datasets, e.g., transportation datasets, and difficulty to find high quality data with proper attributes. MPOs also commented that they often have to use networking and barter to obtain data and often do not have agreements in place to access data. MPOs also noted that TxDOT and local governments frequently do not notify them about changes in the operational status of highway facilities, e.g., roadway openings and closings. This situation makes more difficult for MPO staff to update the travel demand models.

Data Map of Available Data Sources

From the meetings with the various MPOs and by evaluating a variety of data sources, the researchers developed a catalog of spatial data layers and elements MPOs use for transportation planning. Developing that catalog was critical because it provided the foundation for the definition of a formal data model for spatial transportation planning data in Texas. The review of existing documentation at the MPOs and the applications and/or datasets at TxDOT produced a list of about 13,000 spatial data instances, where a spatial data layer or element was either displayed or there was a reference for it in the document. To facilitate the analysis, understanding, and potential use of these spatial data entities, the researchers developed a three-level grouping structure composed of categories (mostly by subject matter), subcategories, and spatial data entities.

To assist in this process, the researchers conducted a literature review of national practices to determine how agencies that produce and serve spatial data organize data, either at the logical level or at the physical level. An analysis of the various practices for cataloguing spatial data revealed a variety of approaches for cataloguing spatial data. In general, agencies organize data by subject, geographic region, and/or data format. When an agency needs to manage a large number of datasets, it is common to organize the data into categories and subcategories. In particular, the review revealed the lack of a generic catalog of categories, subcategories, and data entities for transportation, let alone transportation planning, highlighting the need for the development of such catalog.

Developing the catalog of categories and subcategories for transportation planning spatial data was an iterative process that involved several rounds of data entity categorization; analysis of the resulting structure for inconsistencies, gaps, and redundancies; and subsequent changes to the data entity categorization scheme. In the end, the three-level grouping structure resulted in 7 categories, 63 subcategories, and 589 spatial data entities (Table 21). Table 12 lists all the subcategories developed as part of this research. The appendix shows the list of spatial data entities.

Table 21. Transportation Planning Spatial Data Categories.

Category	Total Subcategories	Total Spatial Data Entities
Administrative Feature	11	65
Environmental Feature	6	61
Imagery and Digital Elevation	4	18
Infrastructure Feature	23	282
Natural Feature	3	42
System Monitoring Feature	7	34
Transportation Planning Feature	9	87
Total	**63**	**589**

Prototype Logical Data Model for Transportation Planning Spatial Data

Using ERwin, the researchers developed a logical data model of spatial data entities following the data catalog structure described in Chapter 3. Because the model contains a large number of entities, the researchers created a separate subject area for each category in ERwin to improve its organization and readability. In addition, the researchers also created a Main Categories subject area that contains only the seven major data categories, and an Overall subject area that contains a hierarchy of all categories and subcategories showing the data organizational structure.

TxDOT's requirements for the development of data dictionaries include definitions (for entities) and definition, purpose, example, valid values, and format (for attributes) (*53*). While these requirements could apply in the case of geospatial data, there is a national standard that is more appropriate for geospatial metadata (CSDGM) that includes a much larger number of metadata elements. While the use of CSDGM is mandatory for federal geospatial datasets, many states, including Texas, have adopted the standard (*55*). Part of the research effort, therefore, involved generating CSDGM-compliant metadata documents. In practice, it was not feasible during the research phase to develop comprehensive metadata documents for all the 589 spatial data entities. In agreement with the project advisors, the researchers selected a sample of entities to compile (and/or develop as needed) associated metadata documentation. The effort also included developing sample geodatabases and a web-based viewer to enable stakeholders to view both sample map and metadata documents online.

The researchers used ArcGIS for developing the sample geodatabases. A limitation of the ArcGIS model is that ArcGIS only supports a two-level grouping structure within geodatabases, e.g., feature classes and feature datasets (which can contain multiple feature classes but not nested feature datasets) for vector data. The researchers addressed this limitation by creating separate geodatabases for individual categories and by creating feature datasets for individual subcategories. For simplicity and for portability during the research phase, the researchers used personal geodatabases (which store all the data in single Microsoft Access .mdb files). However, a similar structure may be possible when using file geodatabases or geodatabases.

Another limitation of the ArcGIS model is that feature datasets cannot store raster data. As a result, the researchers created separate raster catalogs within the geodatabases to represent data entities that were in raster format. In addition, because raster datasets within raster catalogs cannot have their own individual metadata documents, each raster catalog only stored one raster data entity whose metadata were linked to the catalog.

The researchers collected, modified, or created metadata for each of the data entities that had sample data. The researchers made every effort possible to develop metadata in accordance with CSDGM (*53*). In practice, the level of metadata completeness for individual entities depended largely on the amount and characteristics of the information that was already available. For developing metadata documents, the researchers used ArcCatalog, which includes a CSDGM-compliant editor that allows users to export metadata in a variety of formats.

The researchers found a wide range of metadata completeness practices in the sample data collected. In general, data collected from federal data sources were more likely to be CSDGM compliant than other data sources. Typical challenges found during the metadata collection process included cases of sample data without metadata, sample data with incomplete metadata, and sample data with metadata in 1994 metadata standard format. In the process of modifying sample metadata, the researchers maintained the original content, including the *Citation* > *Citation Title* tag content, as long as the content was up to date and properly related the associated sample data. This practice resulted in occasional name discrepancies between the logical data model and the Citation Titles in the metadata documents. The researchers realize this limitation would need to be addressed during implementation to avoid user confusion. In order to provide as much clarifying information in the metadata as possible, the researchers updated the *Identification Information* tags and *Entity and Attribute Definition* metadata tags. For completeness, the researchers added text in the *Identification Information* > *Supplemental Information* tag to document the metadata development process and to provide information about the research project.

Prototype Web-Based Data and Metadata Viewer

To facilitate the display and dissemination of transportation planning data (including metadata), the researchers developed a prototype web-based map and metadata viewer called TPGIS. In general, the application development focused on basic data display requirements rather than formal user interface design and support (although, by necessity, the researchers designed and built the user interface in a way that could support the data and map display efficiently). Design and testing of user interfaces for implementation purposes would need to undergo a formal process that identifies comprehensive user interface needs.

TPGIS includes a metadata browser and a map viewer. The metadata browser enables users to explore feature categories, subcategories, and entities, including the retrieval of basic definition and metadata documentation (Figure 24, Figure 25, Figure 26). For convenience, the browser window includes two tabs: General and Sample Data. The General tab shows general information about the data entity, such as definition (provided as a “tip” that displays information when users hover the mouse pointer over the definition icon), priority, type, and source. The Sample Data tab shows metadata and sample data information, including a link that users can click to retrieve the metadata document associated with a spatial data entity.

The map viewer provides a navigable map that enables users to view and identify sample datasets (Figure 27). The map includes a customized TOC tool that opens a sidebar on the right of the map showing an expandable list of categories, subcategories, and spatial data entities. A checkbox in front of a spatial data entity enables the user to display that spatial data entity. As needed, the user can display and overlay several spatial data entities at the same time. A radio button in front of a spatial data entity enables the user to make that data entity the active layer. Once a data entity is the active layer, the user can query any feature on that active layer (using the standard Identify tool) and retrieve the metadata document by clicking on the Metadata button at the top of the TOC.

RECOMMENDATIONS

This section includes two general sets of recommendations: (a) recommendations for completing the spatial data catalog and implementing a web-based data/metadata viewer at TxDOT and (b) general recommendations for improving data exchange practices among stakeholders in the transportation planning process.

Recommendations for completing the spatial data catalog and implementing a web-based data/metadata viewer at TxDOT include the following:

- Expand, complete, and update elements of the logical data model, data dictionary, and metadata documentation based on priorities developed through further communication with TxDOT, local government, and MPO officials.

- Investigate implementation options for publishing and displaying transportation planning GIS data and metadata in a web-based environment taking into consideration systems currently in place at TxDOT, including MST, ArcGIS Server, and ArcIMS. The analysis should take into consideration a number of potential levels or tiers of data access depending on the location and characteristics of each spatial data layer, including the following:

    - Level 1: Text description or hyperlink to locations where a data layer may be found
    - Level 2: Tiled map with no or minimum interactive data querying capabilities that provides a link to TxDOT maintained and hosted datasets
    - Level 3: Interactive map that enables data queries but not data downloads (also provides a link to TxDOT maintained and hosted datasets)
    - Level 4: Interactive interface that enables data queries and downloads
    - Level 5: Interactive map that enables a live link connection to external map data sources.

- Develop training materials and conduct outreach seminars to train TxDOT, local government, and MPO personnel on the use of the data model as well as the map/metadata viewer.

General recommendations for improving data exchange practices among stakeholders in the transportation planning process (many of which were based on feedback provided by stakeholders) include the following:

- Facilitate access to data, e.g., by developing web-based applications to store and share data with all local agencies, improving and/or establishing interagency agreements, increasing bandwidth capabilities for large dataset downloads, and establishing data connections with interagency networks. Stakeholders mentioned the need to implement mechanisms to improve the turnaround time of transportation planning data inputs and deliverables. This recommendation is increasingly important considering the additional reporting requirements included in the federal and state legislations. MPOs were particularly interested in having web-based, ready access to datasets such as traffic counts, datasets needed for travel demand modeling, and aerial photography.

- Develop local and regional visions for spatial data and improve practices regarding data storage and archiving, data quality, and data completeness. Regional GIS repositories have improved access to data. However, there is no guidance at the state level for the creation, funding, and maintenance of these repositories.

- Provide more training opportunities to planning agencies on topics such as CRIS; data development, maintenance, exchange, conversion, and standardization; travel demand modeling and software; multiyear planning networks; microsimulation; ecological planning; and integration of GIS GPS technologies in transportation planning.

- Improve hardware and software capabilities at the MPOs to better support the use of GIS software and datasets.

- Develop an automated mechanism to enable TxDOT and local governments to send a notification to the MPO whenever a new facility opens or the characteristics of an existing facility changes.

- Require MPO consultant contracts to include georeferenced data with metadata.

- Include stable employer unique identifiers in the TWC employment datasets. The TWC employer identification numbers are not consistent across employment datasets (i.e., when corrections are made to IDs of a TWC employment dataset, the corrections are not present in the subsequent dataset). This recommendation is a focal point in a new TxDOT research project (0-6325 "Integrating TWC Employment Data into TxDOT Modeling").

- Develop reliable income projection methodology and data. It is challenging for MPOs to accurately predict local income trends. Some MPOs have adopted national projections for their local planning areas, which causes bias to the transportation modeling process. MPOs also identified the potential for TWC to provide income projections.

- Archive GPS data used for travel surveys. Some MPOs indicated that archived GPS data could serve as a valuable future reference for analysis and verification purposes beyond current planning needs. For example, the GPS data collected for travel surveys could be used to augment or even reduce the need for special-purpose travel time and speed data collection programs. For corridor analysis, the GPS data could also be used to assist in the evaluation of bottlenecks and potential traffic signal system adjustments or improvements.

- Add standardized certification and disclaimer text labels to all relevant geospatial documents (including documents in electronic format). In a parallel project (0-5788) (*22*), the researchers included a discussion, which is relevant to this research, about the distinction between survey products and mapping products in the TSPS *Manual of Practice for Land Surveying in the State of Texas* (*39*). In the discussion, the researchers concluded that the existing certification label (for use with survey products) and disclaimer text label (for use with mapping products) were appropriate for printed materials, but not necessarily for electronic documents in an interactive environment that involves access to a database that enables selective filtering, querying, displaying, and feature extraction.

  In the case of mapping products, the researchers recommended using the standard disclaimer text included in the TSPS manual without any changes (reproduced here for convenience):

> This product is a graphic representation of the data shown hereon. It does not represent an on-the-ground survey; is not a Survey Product and only represents the approximate relative location of property boundaries and/or natural and man-made features. This product does not conform to a Class A, GIS/LIS Survey Product as defined in Category 10 of the TSPS Manual of Practice and shall not be relied upon for uses which could affect the health, safety or welfare of the general public.

In the case of survey products, the researchers recommended using a modified version of the standard certification text, as follows:

> I, <first and last names>, a Registered Professional Land Surveyor in the State of Texas, do hereby certify that this product represents the results of a (boundary or geodetic) survey performed under my direct supervision and meets the minimum requirements of an on-the-ground survey as promulgated by the Texas Board of Professional Land Surveying.

In order to use this modified certification label, it would probably be necessary to first amend the current TSPS manual. Therefore, TxDOT should recommend to the Texas Board of Professional Land Surveying the adoption of the proposed label instead of the current one in the TSPS manual.

Both the disclaimer text and the certification text above would be appropriate in a variety of scenarios and conditions, including the following:

- **Feature level**. The certification or disclaimer text would be added as an attribute value associated with each feature in the geodatabase.
- **Metadata level**. The certification or disclaimer text would be included in an appropriate tag in the standard metadata file that accompanies each feature class in the geodatabase.
- **Standalone map** (in paper or digital form, e.g., PDF or tiled image). The certification or disclaimer text would be added as a label that is always displayed with the product.

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APPENDIX – CATEGORIES, SUBCATEGORIES, AND SPATIAL DATA ENTITIES FOR TRANSPORTATION PLANNING

This appendix presents the categories, subcategories, and spatial data entities for transportation planning developed as part of this research. Figure 28 illustrates the organizational structure of data entity categories and subcategories. Table 22 lists categories, subcategories, and data entities. For completeness, this table also shows the normalized score associated with each spatial data entity. Based on responses from 11 MPOs, the normalized score indicates the relative priority of a data entity on a scale from 0 to 10. A score of 10 indicates that all MPOs considered the data entity a high priority. A score of 0 indicates that no MPO considered the data entity a high priority. A score of “n/a” corresponds to spatial data entities identified after the MPO responses.

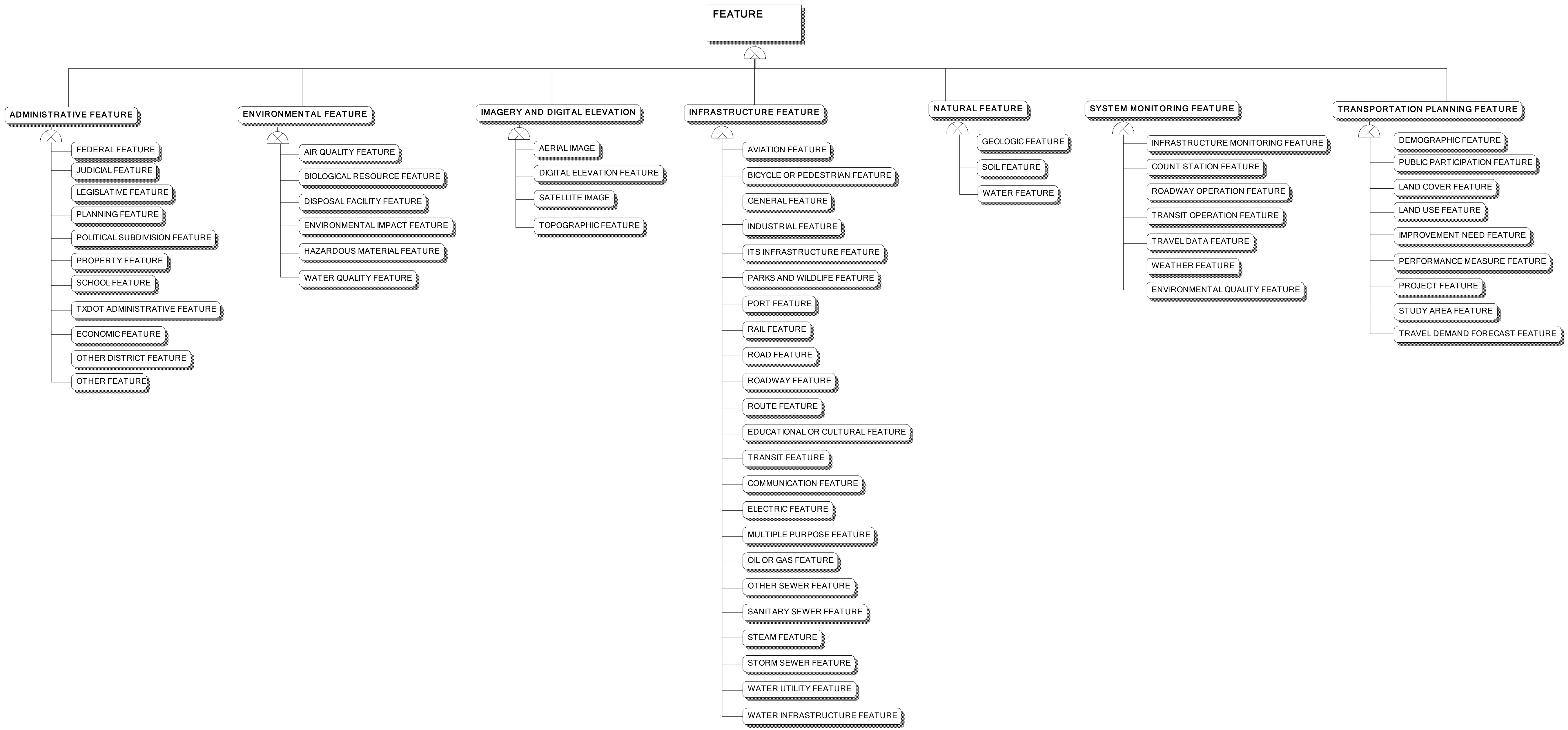

Figure 28. Logical Data Model Categories and Subcategories.

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities.

Category	Subcategory	Entity	Normalized Score*
Administrative	Economic	Community Development Block Grant Area	2
Administrative	Economic	Empowerment Zone Enterprise Community	2
Administrative	Economic	Enterprise Zone	1
Administrative	Economic	Foreign Trade Zone	0
Administrative	Economic	Tax Increment Reinvestment Zone	1
Administrative	Federal	Adjusted Census Urbanized Area Boundary	7
Administrative	Federal	Census Block	8
Administrative	Federal	Census Block Group	9
Administrative	Federal	Census Tract	9
Administrative	Federal	Indian Reservation Boundary	1
Administrative	Federal	Indian Reservation Point	1
Administrative	Federal	Metropolitan Statistical Area	5
Administrative	Federal	Public Use Microdata Area	1
Administrative	Federal	Urban Area	n/a
Administrative	Federal	Urban Cluster	1
Administrative	Federal	Urbanized Area	7
Administrative	Federal	US Postal Service Facility	0
Administrative	Federal	ZIP Code Area Five Digit	3
Administrative	Federal	ZIP Code Area Three Digit	3
Administrative	Judicial	Justice of the Peace District	0
Administrative	Legislative	City Council District	2
Administrative	Legislative	Precinct Commissioner	3
Administrative	Legislative	Precinct Voting	3
Administrative	Legislative	Texas House District	2
Administrative	Legislative	Texas Senate District	2
Administrative	Legislative	US House District	2
Administrative	Planning	Central Business District	n/a
Administrative	Planning	COG Boundary	2
Administrative	Planning	Metropolitan Area Boundary	10
Administrative	Planning	MPO Boundary	10
Administrative	Planning	Neighborhood	2
Administrative	Planning	Water District Boundary	0
Administrative	Planning	Water District Service Area	2
Administrative	Political Subdivision	City Limit	9
Administrative	Political Subdivision	City Point	5
Administrative	Political Subdivision	Country	4
Administrative	Political Subdivision	County	7
Administrative	Political Subdivision	Extra Territorial Jurisdiction Zone	5
Administrative	Political Subdivision	Mexico City Limit	3
Administrative	Political Subdivision	Mexico City Point	2
Administrative	Political Subdivision	Mexico State	3
Administrative	Political Subdivision	State	3
Administrative	Property	Easement	3
Administrative	Property	Original Texas Land Survey	0
Administrative	Property	Parcel Plat	4
Administrative	Property	Property Boundary	4
Administrative	Property	Property Location	2
Administrative	Property	Right Of Way Line	3
Administrative	Property	Subdivision Boundary	2
Administrative	School	Community College District	0
Administrative	School	Education Service Center Region	1
Administrative	School	School District	3
Administrative	School	School Zone	3

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Administrative	TxDOT Administrative	TxDOT District Boundary	4
Administrative	TxDOT Administrative	TxDOT Vehicle Title and Registration Region	1
Administrative	Other District	Municipal Management District Area	0
Administrative	Other District	Pedestrian Bicycle District	2
Administrative	Other District	Police District	1
Administrative	Other District	Public Weather Forecast Zone	0
Administrative	Other District	Special Purpose District	n/a
Administrative	Other District	Subsidence District Boundary	0
Administrative	Other District	Tax Imposing Special Purpose District	n/a
Administrative	Other District	Texas National Register District	0
Administrative	Other District	Groundwater Conservation District Area	0
Administrative	Other	GNIS Domestic Name Location	4
Environmental	Air Quality	Area Source Air Emission Boundary	3
Environmental	Air Quality	CO Nonattainment Area	1
Environmental	Air Quality	Emission Distribution Contour Line	3
Environmental	Air Quality	Mobile Source Air Toxic Boundary	3
Environmental	Air Quality	NOx Nonattainment Area	3
Environmental	Air Quality	Other Nonattainment Area	3
Environmental	Air Quality	Ozone Nonattainment Area	5
Environmental	Air Quality	PM10 Nonattainment Area	3
Environmental	Air Quality	PM25 Nonattainment Area	2
Environmental	Air Quality	Point Source Air Emissions Site	3
Environmental	Biological Resource	Audubon Sanctuary	0
Environmental	Biological Resource	Coastal Species Site	0
Environmental	Biological Resource	Colonial Waterbird Rookery Area	1
Environmental	Biological Resource	Conservation Area	3
Environmental	Biological Resource	Critical Habitat Area	2
Environmental	Biological Resource	Environmental Sensitive Area	5
Environmental	Biological Resource	Environmental Sensitivity Index Point	3
Environmental	Biological Resource	Federal Endangered Species	3
Environmental	Biological Resource	Flora Condition Location	0
Environmental	Biological Resource	National Marine Sanctuary	0
Environmental	Biological Resource	Native Americans Homeland	2
Environmental	Biological Resource	Natural Diversity Database Area	0
Environmental	Biological Resource	Natural Diversity Database Limit	0
Environmental	Biological Resource	Natural Diversity Database Location	0
Environmental	Biological Resource	Natural Ecoregion	2
Environmental	Biological Resource	Natural Sub Ecoregion	2
Environmental	Biological Resource	Seagrass Bed Area	0
Environmental	Biological Resource	State Endangered Species	2
Environmental	Biological Resource	Texas Coastal Preserve	0
Environmental	Biological Resource	Tree Canopy	0
Environmental	Biological Resource	Wildlife Habitat	4
Environmental	Disposal Facility	Composting Facility	0
Environmental	Disposal Facility	Municipal Solid Waste Facility Boundary	2
Environmental	Disposal Facility	Municipal Solid Waste Facility Location	2
Environmental	Disposal Facility	Recycling Facility	0
Environmental	Disposal Facility	Used Oil Collection Center	0
Environmental	Environmental Impact	EPA Facility	n/a
Environmental	Environmental Impact	GISST Texas Grid	3
Environmental	Environmental Impact	Mitigation Bank	1
Environmental	Environmental Impact	TEAP Composite Grid	3
Environmental	Environmental Impact	TEAP Diversity Grid	3
Environmental	Environmental Impact	TEAP Rarity Grid	3

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Environmental	Environmental Impact	TEAP Raw Composite Grid	2
Environmental	Environmental Impact	TEAP Raw Diversity Grid	2
Environmental	Environmental Impact	TEAP Raw Rarity Grid	2
Environmental	Environmental Impact	TEAP Raw Sustainability Grid	2
Environmental	Environmental Impact	TEAP Sustainability Grid	3
Environmental	Hazardous Material	Hazardous Material Release Area	1
Environmental	Hazardous Material	Hazardous Material Release Location	1
Environmental	Hazardous Material	Hazardous Material Site	3
Environmental	Hazardous Material	Hazardous Waste Site	3
Environmental	Hazardous Material	Hazardous Waste Site Boundary	2
Environmental	Hazardous Material	Radioactive Waste Site	1
Environmental	Hazardous Material	Superfund Site	2
Environmental	Hazardous Material	Superfund Site Boundary	2
Environmental	Hazardous Material	Toxic Release Inventory Site	1
Environmental	Water Quality	Wastewater Service Area	0
Environmental	Water Quality	Wastewater Treatment Facility	0
Environmental	Water Quality	Water Discharge Outfall	0
Environmental	Water Quality	Water Quality Contour Map	0
Environmental	Water Quality	Water Treatment Facility	1
Imagery and Digital Elevation	Aerial Image	Mexico Aerial Photography	5
Imagery and Digital Elevation	Aerial Image	National Agriculture Imagery Program Image	2
Imagery and Digital Elevation	Aerial Image	Orthoimage	6
Imagery and Digital Elevation	Aerial Image	Texas Orthographic Program Image	1
Imagery and Digital Elevation	Digital Elevation	Digital Elevation Model	3
Imagery and Digital Elevation	Digital Elevation	LiDAR Grid	2
Imagery and Digital Elevation	Digital Elevation	National Elevation Dataset	2
Imagery and Digital Elevation	Digital Elevation	Shoreline Digital Elevation Model	1
Imagery and Digital Elevation	Digital Elevation	Shuttle Radar Topography Mission Digital Topographic Data	1
Imagery and Digital Elevation	Satellite Image	LandSAT 5	1
Imagery and Digital Elevation	Satellite Image	LandSAT 7	1
Imagery and Digital Elevation	Satellite Image	SPOT Image	1
Imagery and Digital Elevation	Topographic	Hypsography Contour Line	1
Imagery and Digital Elevation	Topographic	Sea Floor Feature	1
Imagery and Digital Elevation	Topographic	Sea Floor Survey Index Boundary	1
Imagery and Digital Elevation	Topographic	Shoreline Topographic Line	2
Imagery and Digital Elevation	Topographic	USGS DRG Topo Map	1
Imagery and Digital Elevation	Topographic	USGS Quadrangle Index	2

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	Aviation	Airport Boundary	2
Infrastructure	Aviation	Airport Location	3
Infrastructure	Aviation	Flight Path	1
Infrastructure	Aviation	Runway	2
Infrastructure	Bicycle or Pedestrian	Bicycle Commuting Center	3
Infrastructure	Bicycle or Pedestrian	Bicycle Lane Shoulder	5
Infrastructure	Bicycle or Pedestrian	Bicycle Parking Area	1
Infrastructure	Bicycle or Pedestrian	Bicycle Pedestrian Facility	4
Infrastructure	Bicycle or Pedestrian	Bicycle Pedestrian Trail	6
Infrastructure	Bicycle or Pedestrian	Bicycle Pedestrian Trail Facility	4
Infrastructure	Bicycle or Pedestrian	Bicycle Pedestrian Trip Barrier	4
Infrastructure	Bicycle or Pedestrian	Bicycle Route	6
Infrastructure	Communication	Communication Duct Bank	0
Infrastructure	Communication	Communication Guy	0
Infrastructure	Communication	Communication Handhole	0
Infrastructure	Communication	Communication Junction Box	0
Infrastructure	Communication	Communication Line	0
Infrastructure	Communication	Communication Manhole	0
Infrastructure	Communication	Communication Pedestal	0
Infrastructure	Communication	Communication Pole	0
Infrastructure	Communication	Communication Pull Box	0
Infrastructure	Communication	Communication Pushbrace	0
Infrastructure	Communication	Communication Splice Enclosure	0
Infrastructure	Communication	Communication Tracer Wire Protector	0
Infrastructure	Communication	Communication Vault	0
Infrastructure	Educational or Cultural	College University Boundary	4
Infrastructure	Educational or Cultural	College University Point	3
Infrastructure	Educational or Cultural	Cultural Facility Boundary	1
Infrastructure	Educational or Cultural	Cultural Facility Point	3
Infrastructure	Educational or Cultural	School	6
Infrastructure	Educational or Cultural	School Boundary	2
Infrastructure	Electric	Electric Duct Bank	0
Infrastructure	Electric	Electric Guy	0
Infrastructure	Electric	Electric Handhole	0
Infrastructure	Electric	Electric Junction Box	0
Infrastructure	Electric	Electric Line	0
Infrastructure	Electric	Electric Manhole	0
Infrastructure	Electric	Electric Pedestal	0
Infrastructure	Electric	Electric Pole	0
Infrastructure	Electric	Electric Pull Box	0
Infrastructure	Electric	Electric Pushbrace	0
Infrastructure	Electric	Electric Transformer	0
Infrastructure	Electric	Electric Vault	0
Infrastructure	Electric	Nuclear Plant	0
Infrastructure	General	Archaeological Project Area	2
Infrastructure	General	Archaeological Project Segment	1
Infrastructure	General	Archaeological Site Boundary	2
Infrastructure	General	Archaeological Site Centroid	1
Infrastructure	General	Archaeological Site Segment	1
Infrastructure	General	Beach Access Point	1
Infrastructure	General	Building Footprint	2
Infrastructure	General	Cemetery	0
Infrastructure	General	Commercial Facility	3
Infrastructure	General	Community Center Boundary	2

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	General	Community Center Point	2
Infrastructure	General	Entertainment Facility Boundary	0
Infrastructure	General	Entertainment Facility Point	0
Infrastructure	General	Fence	0
Infrastructure	General	Gated Community	0
Infrastructure	General	General Amenity	n/a
Infrastructure	General	Government Facility Boundary	1
Infrastructure	General	Government Facility Point	2
Infrastructure	General	Health Care Facility Boundary	2
Infrastructure	General	Health Care Facility Point	3
Infrastructure	General	Hotel Motel Housing Facility	0
Infrastructure	General	Landmark	3
Infrastructure	General	Military Facility Boundary	1
Infrastructure	General	Military Facility Point	2
Infrastructure	General	Recreation Facility Boundary	1
Infrastructure	General	Recreation Facility Point	1
Infrastructure	General	Religious Facility Boundary	0
Infrastructure	General	Religious Facility Point	0
Infrastructure	General	Residential Housing Facility	1
Infrastructure	General	Shopping Center Boundary	1
Infrastructure	General	Texas National Register Historic Place	0
Infrastructure	General	Texas National Register Historic Place Boundary	0
Infrastructure	Industrial	Bulk Commodity Transfer Facility	1
Infrastructure	Industrial	Distribution Facility Warehouse	1
Infrastructure	Industrial	Freight Transportation Facility	3
Infrastructure	Industrial	Industrial Center Area	2
Infrastructure	Industrial	Industrial Center Site	1
Infrastructure	Industrial	Intermodal Facility	n/a
Infrastructure	Industrial	Intermodal Freight Facility Cluster	2
Infrastructure	Industrial	Manufacturing Facility	2
Infrastructure	Industrial	Rail Truck Intermodal Facility	3
Infrastructure	Industrial	Transfer Center	2
Infrastructure	Industrial	Truck to Truck Intermodal Facility	3
Infrastructure	Industrial	Truck Yard Terminal	4
Infrastructure	Industrial	Warehouse	1
Infrastructure	ITS Infrastructure	Auto barrier Gate	0
Infrastructure	ITS Infrastructure	AVI Checkpoint	1
Infrastructure	ITS Infrastructure	CCTV Camera	2
Infrastructure	ITS Infrastructure	Dynamic Message Sign	2
Infrastructure	ITS Infrastructure	Dynamic Reversible Lane System	1
Infrastructure	ITS Infrastructure	Electro Mechanical Sign	0
Infrastructure	ITS Infrastructure	Electronic Toll Collection System	2
Infrastructure	ITS Infrastructure	EMS Preemption System Sensor	0
Infrastructure	ITS Infrastructure	Fiber Optic Cable	0
Infrastructure	ITS Infrastructure	Highway Advisory Radio Tower	0
Infrastructure	ITS Infrastructure	Incident Sensor	1
Infrastructure	ITS Infrastructure	Lane Control Signal	0
Infrastructure	ITS Infrastructure	Parking Lot Sensor	0
Infrastructure	ITS Infrastructure	Railroad Crossing Sensor	0
Infrastructure	ITS Infrastructure	Ramp Meter	1
Infrastructure	ITS Infrastructure	School Zone Sensor	0
Infrastructure	ITS Infrastructure	Traffic Management Center	1
Infrastructure	ITS Infrastructure	Transit Bus Stop Sensor	1
Infrastructure	ITS Infrastructure	Transit Rail Stop Sensor	1

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	ITS Infrastructure	Truck Rollover Warning System	1
Infrastructure	ITS Infrastructure	Weather Sensor	1
Infrastructure	ITS Infrastructure	Wind Sensor	1
Infrastructure	Multiple Purpose	Miscellaneous Line	0
Infrastructure	Multiple Purpose	Miscellaneous Point	0
Infrastructure	Multiple Purpose	Utility Easement	1
Infrastructure	Multiple Purpose	Utility Tunnel	0
Infrastructure	Multiple Purpose	Utility Warning Sign	0
Infrastructure	Oil or Gas	Gas Line	1
Infrastructure	Oil or Gas	Gas Valve	0
Infrastructure	Oil or Gas	Gas Vent	0
Infrastructure	Oil or Gas	Oil Line	1
Infrastructure	Oil or Gas	Oil Valve	0
Infrastructure	Oil or Gas	Pipeline Terminal	0
Infrastructure	Other Sewer	Combined Sewer Line	0
Infrastructure	Parks and Wildlife	City Park Boundary	3
Infrastructure	Parks and Wildlife	City Park Point	3
Infrastructure	Parks and Wildlife	County Park Boundary	3
Infrastructure	Parks and Wildlife	County Park Point	3
Infrastructure	Parks and Wildlife	Federal Park Boundary	3
Infrastructure	Parks and Wildlife	Federal Park Point	3
Infrastructure	Parks and Wildlife	Fish Hatchery Boundary	0
Infrastructure	Parks and Wildlife	Municipal Park Boundary	3
Infrastructure	Parks and Wildlife	Municipal Park Point	3
Infrastructure	Parks and Wildlife	Park Boundary	2
Infrastructure	Parks and Wildlife	Park Point	5
Infrastructure	Parks and Wildlife	State Federal Public Land Boundary	3
Infrastructure	Parks and Wildlife	State Federal Public Land Point	3
Infrastructure	Parks and Wildlife	State Park Boundary	3
Infrastructure	Parks and Wildlife	State Park Point	3
Infrastructure	Parks and Wildlife	Wildlife Management Area	4
Infrastructure	Port	Border Crossing	4
Infrastructure	Port	Port of Entry	4
Infrastructure	Port	Water Intermodal Port	0
Infrastructure	Rail	Rail Crossing	4
Infrastructure	Rail	Rail Facility	2
Infrastructure	Rail	Rail Yard Boundary	1
Infrastructure	Rail	Rail Yard Line	2
Infrastructure	Rail	Rail Yard Location	1
Infrastructure	Rail	Railroad	7
Infrastructure	Rail	Rural Rail Transportation District Area	1
Infrastructure	Road	Bicycle Pedestrian Bridge	5
Infrastructure	Road	Bridge Tunnel Location	4
Infrastructure	Road	Bridge Tunnel Segment	5
Infrastructure	Road	Call Box Pay Phone	1
Infrastructure	Road	Crosswalk	0
Infrastructure	Road	Curb Line	2
Infrastructure	Road	Curb Ramp	0
Infrastructure	Road	Driveway	1
Infrastructure	Road	Emergency Vehicle Signal	1
Infrastructure	Road	Flashing Beacon	0
Infrastructure	Road	Interchange	5
Infrastructure	Road	Intersection	5
Infrastructure	Road	Intersection Functional Limits	1

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	Road	Intersection Geometry	2
Infrastructure	Road	Loop Detector	1
Infrastructure	Road	Median Island	2
Infrastructure	Road	Noise Barrier	3
Infrastructure	Road	Parking Facility Boundary	1
Infrastructure	Road	Parking Facility Location	1
Infrastructure	Road	Pavement Marking Location	0
Infrastructure	Road	Pedestrian only Signal	1
Infrastructure	Road	Railroad Grade Separation	5
Infrastructure	Road	Regulatory Sign	1
Infrastructure	Road	Rest Area	0
Infrastructure	Road	Road Amenity	0
Infrastructure	Road	Road Luminaire	1
Infrastructure	Road	Roadway Grade Separation	2
Infrastructure	Road	Shoulder	1
Infrastructure	Road	Sidewalk	3
Infrastructure	Road	Sign	0
Infrastructure	Road	Speed Hump Bump	1
Infrastructure	Road	Stop Sign	4
Infrastructure	Road	Storm Drain	2
Infrastructure	Road	Texas Historical Marker	3
Infrastructure	Road	Toll Plaza	3
Infrastructure	Road	Traffic Circle	2
Infrastructure	Road	Traffic Signal	4
Infrastructure	Road	Truck Stop	0
Infrastructure	Road	TxDOT Survey Control Station Point	1
Infrastructure	Road	Warning Beacon	2
Infrastructure	Road	Warning Sign	1
Infrastructure	Road	Weigh in Motion Station	n/a
Infrastructure	Road	Yield Sign	2
Infrastructure	Roadway	Cartographic Road	8
Infrastructure	Roadway	HOV Road	2
Infrastructure	Roadway	HPMS Roadway	4
Infrastructure	Roadway	ITS Road	3
Infrastructure	Roadway	Mexico Highway	n/a
Infrastructure	Roadway	NHPN Line	4
Infrastructure	Roadway	NHPN Point	4
Infrastructure	Roadway	NHS Roadway	5
Infrastructure	Roadway	Planning Network Road	8
Infrastructure	Roadway	STRAHNET Roadway	4
Infrastructure	Roadway	StratMap Transportation	3
Infrastructure	Roadway	Street Addressing Network	5
Infrastructure	Roadway	Texas Reference Marker Line	3
Infrastructure	Roadway	Texas Reference Marker Point	3
Infrastructure	Roadway	Thoroughfare Route	5
Infrastructure	Roadway	Toll Road	4
Infrastructure	Roadway	TxDOT Centerline Route	3
Infrastructure	Roadway	TxDOT Control Section Job Line	3
Infrastructure	Roadway	TxDOT Control Section Line	3
Infrastructure	Roadway	TxDOT County Road	5
Infrastructure	Roadway	TxDOT Ground Set Line	1
Infrastructure	Roadway	TxDOT Off System Roadway	5
Infrastructure	Roadway	TxDOT On System Roadway	5
Infrastructure	Route	Congestion Management Process Route	4

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	Route	Courtesy Patrol Route	1
Infrastructure	Route	Emergency Route	2
Infrastructure	Route	Evacuation Barrier	2
Infrastructure	Route	Evacuation Point	2
Infrastructure	Route	Evacuation Route	5
Infrastructure	Route	Hazardous Material Rail Route	4
Infrastructure	Route	Hazardous Material Route	4
Infrastructure	Route	Historic Route	0
Infrastructure	Route	Hurricane Evacuation Zone	4
Infrastructure	Route	Pass Through Finance Route	0
Infrastructure	Route	Radioactive Cargo Route	4
Infrastructure	Route	School Route	1
Infrastructure	Route	Smart Street Road	2
Infrastructure	Route	Truck Route	5
Infrastructure	Sanitary Sewer	Sanitary Sewer Cleanout	0
Infrastructure	Sanitary Sewer	Sanitary Sewer Line	1
Infrastructure	Sanitary Sewer	Sanitary Sewer Manhole	1
Infrastructure	Sanitary Sewer	Sanitary Sewer Valve	1
Infrastructure	Steam	Steam Line	0
Infrastructure	Steam	Steam Valve	0
Infrastructure	Storm Sewer	Detention Pond	0
Infrastructure	Storm Sewer	Storm Sewer Culvert	2
Infrastructure	Storm Sewer	Storm Sewer Headwall	1
Infrastructure	Storm Sewer	Storm Sewer Inlet	2
Infrastructure	Storm Sewer	Storm Sewer Junction Box	1
Infrastructure	Storm Sewer	Storm Sewer Line	2
Infrastructure	Storm Sewer	Storm Sewer Manhole	1
Infrastructure	Storm Sewer	Storm Sewer Wing Wall	1
Infrastructure	Transit	Amtrak Rail Route	3
Infrastructure	Transit	Amtrak Rail Station	2
Infrastructure	Transit	Carpool Location	4
Infrastructure	Transit	Intercity Bus Terminal	3
Infrastructure	Transit	Paratransit Customer Destination	2
Infrastructure	Transit	Paratransit Customer Origin	1
Infrastructure	Transit	Paratransit Provider Headquarters	1
Infrastructure	Transit	Paratransit Service Area	1
Infrastructure	Transit	Transit Amenity	3
Infrastructure	Transit	Transit Bus Route	9
Infrastructure	Transit	Transit Bus Station	8
Infrastructure	Transit	Transit Bus Stop	5
Infrastructure	Transit	Transit Bus Transfer Center	5
Infrastructure	Transit	Transit Maintenance and Storage Facility Boundary	1
Infrastructure	Transit	Transit Maintenance and Storage Facility Location	1
Infrastructure	Transit	Transit Multimodal Center	3
Infrastructure	Transit	Transit Park and Pool Facility	5
Infrastructure	Transit	Transit Park and Ride Facility Area	5
Infrastructure	Transit	Transit Provider Headquarters	2
Infrastructure	Transit	Transit Provider Service Area	5
Infrastructure	Transit	Transit Rail Crossing	2
Infrastructure	Transit	Transit Rail Line	5
Infrastructure	Transit	Transit Rail Route	5
Infrastructure	Transit	Transit Rail Station	4
Infrastructure	Transit	Transit Rail Yard	1
Infrastructure	Transit	Transit Special Event Bus Charter Route	1

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Infrastructure	Water	Public Water Supply System	1
Infrastructure	Water	Water Hydrant	2
Infrastructure	Water	Water Line	3
Infrastructure	Water	Water Manhole	1
Infrastructure	Water	Water Valve	1
Infrastructure	Water Infrastructure	Ferry Route	1
Infrastructure	Water Infrastructure	Ferry Terminal	1
Infrastructure	Water Infrastructure	Marina Location	0
Infrastructure	Water Infrastructure	Navigable Waters	0
Infrastructure	Water Infrastructure	Shipping Lane	0
Infrastructure	Water Infrastructure	Waterway	2
Infrastructure	Water Infrastructure	Waterway Boundary	1
Natural	Geologic	Geologic Atlas of Texas Area	0
Natural	Geologic	Geologic Atlas of Texas Grid	0
Natural	Geologic	Geologic Land Form	0
Natural	Geologic	Mexico Border Geologic Map	0
Natural	Geologic	Texas STATEMAP Geologic Map Area	0
Natural	Geologic	Texas STATEMAP Geologic Map Grid	0
Natural	Soil	Detailed Soil Type Boundary	1
Natural	Soil	Mexico Border Soils Map	0
Natural	Soil	Soil Boring Location	0
Natural	Soil	Soil Type Boundary	1
Natural	Soil	Soil Type Line	0
Natural	Soil	Soil Type Point	0
Natural	Soil	Surface Slope Aspect Area	1
Natural	Water	Aquifer Major	2
Natural	Water	Aquifer Minor	2
Natural	Water	Coastal Barrier Reef	0
Natural	Water	Coastal Ebb Tide Line	0
Natural	Water	Coastal Wetlands	1
Natural	Water	Coastal Zone Boundary	0
Natural	Water	Dune Protection Line	0
Natural	Water	Ecologically Significant Stream Segment	1
Natural	Water	Floodplain 100 Year Area	3
Natural	Water	Floodplain 500 Year Area	3
Natural	Water	Hydrographic Area	2
Natural	Water	Hydrologic Unit Boundary	0
Natural	Water	Hydrology Area	2
Natural	Water	Mexico Border Hydrology Map	0
Natural	Water	National Hydrography Dataset Area	0
Natural	Water	National Hydrography Dataset Flow Line	0
Natural	Water	National Hydrography Dataset Line	1
Natural	Water	National Hydrography Dataset Point	0
Natural	Water	National Hydrography Dataset Waterbody	3
Natural	Water	Regulated Waters	0
Natural	Water	Riparian Zone	0
Natural	Water	Shoreline	0
Natural	Water	Spring	0
Natural	Water	Storm Surge Zone	0
Natural	Water	Tidal Influenced Stream	0
Natural	Water	Wetland Boundary	3
Natural	Water	Wetland Line	2
Natural	Water	Wetland Percentage Area	3
Natural	Water	Wetland Point	1

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
System Monitoring	Count Station	Accumulative Traffic Recorder Location	3
System Monitoring	Count Station	Automatic Traffic Recorder Location	3
System Monitoring	Count Station	Midblock Count Station Location	3
System Monitoring	Count Station	Spot Volume Location	4
System Monitoring	Count Station	Turning Movement Count Station Location	2
System Monitoring	Environmental Quality	Air Quality Monitoring Station	6
System Monitoring	Environmental Quality	Stream Stage Station	n/a
System Monitoring	Environmental Quality	Vehicle Emission Inspection Location	3
System Monitoring	Environmental Quality	Water Quality Monitoring Station	0
System Monitoring	Infrastructure Monitoring	GPS Bicycle Route Trail Point	3
System Monitoring	Infrastructure Monitoring	Roadway Photo Log Location	3
System Monitoring	Roadway Operations	Construction Location	4
System Monitoring	Roadway Operations	Construction Zone	4
System Monitoring	Roadway Operations	Crash Point	5
System Monitoring	Roadway Operations	Incident Point	5
System Monitoring	Transit Operations	Bus AVL Point	3
System Monitoring	Transit Operations	Transit Incident Boundary	3
System Monitoring	Transit Operations	Transit Incident Location	3
System Monitoring	Transit Operations	Transit Incident Segment	3
System Monitoring	Transit Operations	Transit Service Request Location	4
System Monitoring	Travel Data	Cell Phone Location	0
System Monitoring	Travel Data	GPS Travel Point	4
System Monitoring	Travel Data	Transit Trip Point	n/a
System Monitoring	Travel Data	Travel Time Run Segment	5
System Monitoring	Travel Data	Vehicle Location	5
System Monitoring	Travel Data	Vehicle Travel Survey Location	5
System Monitoring	Weather	Automated Surface Weather Observation Station	1
System Monitoring	Weather	Average Rainfall Site	0
System Monitoring	Weather	National Weather System Cooperative Observing Station	1
System Monitoring	Weather	NEXRAD National Doppler Radar Site	1
System Monitoring	Weather	NEXRAD Reflectivity Image	0
System Monitoring	Weather	Precipitation Accumulation Area	0
System Monitoring	Weather	Rainfall Intensity Site	0
System Monitoring	Weather	U.S. Climate Reference Network Site	1
Transportation Planning	Demographic	Employment Density	5
Transportation Planning	Demographic	Employment Traffic Analysis Zone	7
Transportation Planning	Demographic	GDP Metropolitan Area	5
Transportation Planning	Demographic	Household Census Block	8
Transportation Planning	Demographic	Household Income Census Block Group	
Transportation Planning	Demographic	Population Census Block	7
Transportation Planning	Demographic	Population Census Block Centroid	5
Transportation Planning	Demographic	Population Density Census Block	6
Transportation Planning	Demographic	Texas Workforce Commission Employer Location	6
Transportation Planning	Improvement Need	Improvement Need Area	3
Transportation Planning	Improvement Need	Improvement Need Bicycle Suitability Line	4
Transportation Planning	Improvement Need	Improvement Need Line	5
Transportation Planning	Improvement Need	Improvement Need Point	4
Transportation Planning	Improvement Need	TAZ Bicycle Need Index	3
Transportation Planning	Improvement Need	TAZ Pedestrian Need Index	3
Transportation Planning	Land Cover	National Land Cover Dataset	1
Transportation Planning	Land Cover	Texas Land Classification System Land Cover Area	1
Transportation Planning	Land Cover	Vegetation Land Cover	0
Transportation Planning	Land Use	Agricultural Land Use	2

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Transportation Planning	Land Use	Agriculture Census County	n/a
Transportation Planning	Land Use	Building Permit Location	2
Transportation Planning	Land Use	Impervious Surface Land Use	3
Transportation Planning	Land Use	Land Cover Diversity Grid	4
Transportation Planning	Land Use	Land Use	7
Transportation Planning	Land Use	Land Use Accuracy Assessment Point	3
Transportation Planning	Land Use	Land Use Development Boundary	5
Transportation Planning	Land Use	Land Use Development Location	5
Transportation Planning	Land Use	Land Use Land Cover Area	n/a
Transportation Planning	Land Use	Lease or For Sale Property Boundary	0
Transportation Planning	Land Use	Lease or For Sale Property Location	0
Transportation Planning	Land Use	Mexico Border Land Use and Vegetation Map	1
Transportation Planning	Land Use	Mexico Border Potential Land Use Map	2
Transportation Planning	Land Use	Zoning Area	5
Transportation Planning	Performance Measure	Bicycle Compatibility Index Line	4
Transportation Planning	Performance Measure	Bicycle Latent Demand Score Line	2
Transportation Planning	Performance Measure	Congestion Level Boundary	5
Transportation Planning	Performance Measure	Conservation Priority Area	3
Transportation Planning	Performance Measure	Economically Stressed Area	3
Transportation Planning	Performance Measure	Emission Control Strategy Location	2
Transportation Planning	Performance Measure	Emission Control Strategy Section	2
Transportation Planning	Performance Measure	Groundwater Availability Model	0
Transportation Planning	Performance Measure	Lane Density Area	5
Transportation Planning	Performance Measure	Noise Contour Line	3
Transportation Planning	Performance Measure	Road Density Area	4
Transportation Planning	Performance Measure	TMDL 303d Water Quality Grid	2
Transportation Planning	Performance Measure	Transit Accessibility Area	4
Transportation Planning	Performance Measure	Travel Demand Management Area	4
Transportation Planning	Performance Measure	Travel Demand Management Location	4
Transportation Planning	Performance Measure	Travel Demand Management Section	4
Transportation Planning	Performance Measure	Travel Time Contour Line	5
Transportation Planning	Project	Regional Transportation Project Area	5
Transportation Planning	Project	Regional Transportation Project Area High Priority	4
Transportation Planning	Project	Regional Transportation Project Line	5
Transportation Planning	Project	Regional Transportation Project Line High Priority	4
Transportation Planning	Project	Regional Transportation Project Point	5
Transportation Planning	Project	Regional Transportation Project Point High Priority	3
Transportation Planning	Public Participation	Colonia Location	5
Transportation Planning	Public Participation	Environmental Justice Boundary	4
Transportation Planning	Public Participation	Public Meeting Attendee Location	2
Transportation Planning	Public Participation	Public Meeting Location	2
Transportation Planning	Public Participation	Safety Concern Survey Location	2
Transportation Planning	Public Participation	Safety Concern Survey Segment	2
Transportation Planning	Public Participation	Survey Respondent Area	1
Transportation Planning	Public Participation	Survey Respondent Location	2
Transportation Planning	Public Participation	Transportation Improvement Survey Location	3
Transportation Planning	Public Participation	Transportation Improvement Survey Segment	3
Transportation Planning	Public Participation	Travel Delay Survey Location	2
Transportation Planning	Public Participation	Travel Delay Survey Segment	2
Transportation Planning	Study Area	Study Area	4
Transportation Planning	Study Area	Study Corridor	4
Transportation Planning	Study Area	Study Point	1
Transportation Planning	Travel Demand Forecast	Area Type	4
Transportation Planning	Travel Demand Forecast	External Station	5

Table 22. Transportation Planning Spatial Data Categories, Subcategories, and Data Entities (continued).

Category	Subcategory	Entity	Normalized Score*
Transportation Planning	Travel Demand Forecast	Model Screenline	4
Transportation Planning	Travel Demand Forecast	Origin Destination Line	5
Transportation Planning	Travel Demand Forecast	Regional Analysis Zone	5
Transportation Planning	Travel Demand Forecast	Special Generator Activity Center Location	7
Transportation Planning	Travel Demand Forecast	Statewide Analysis Model External Station	1
Transportation Planning	Travel Demand Forecast	Statewide Analysis Model Network	1
Transportation Planning	Travel Demand Forecast	Statewide Analysis Model Zone	1
Transportation Planning	Travel Demand Forecast	Traffic Analysis Zone	10
Transportation Planning	Travel Demand Forecast	Traffic Analysis Zone Centroid	5
Transportation Planning	Travel Demand Forecast	Traffic Analysis Zone Centroid Connector	n/a
Transportation Planning	Travel Demand Forecast	Traffic Serial Zone Centroid Connector	n/a
Transportation Planning	Travel Demand Forecast	Traffic Survey Zone	5
Transportation Planning	Travel Demand Forecast	Travel Demand Model Boundary	7
Transportation Planning	Travel Demand Forecast	Travel Demand Model Network	6

* Based on responses from 11 MPOs. A score of 10 indicates that all MPOs considered the data entity a high priority. A score of 0 indicates that no MPO considered the data entity a high priority. A score of "N/A" corresponds to spatial data entities identified after the MPO responses.