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16. Abstract During the project development process, districts produce enormous amounts of engineering data in a variety of data formats with varying levels of accuracy and resolution on several types of storage media. Examples include aerial photography and topographic information, drawings at various levels of development, survey data, right of way and utility maps, and traffic counts. These data are a valuable asset, and the Texas Department of Transportation (TxDOT) has begun to implement strategies to ensure the usability and integrity of the data. However, the amount of data that districts produce and receive is growing steadily, which makes it increasingly difficult to manage the data effectively. Although district personnel have a wealth of data at their disposal, frequent lack of data integrity, accessibility, quality control, or plain awareness makes it unnecessarily difficult to put the data to good use. These inefficiencies result in redundant data collection efforts and contribute to project delays. This report summarizes research conducted to evaluate and document current engineering design data management practices at TxDOT. The report also describes a prototype engineering data management framework to assist divisions and districts in their effort to manage engineering data effectively. The focus of the report is on data types, spatial and temporal data attributes, and associated documentation used during the design phase of typical highway improvement projects. The report summarizes procedures, practices, and systems TxDOT and other government agencies use for managing engineering design data; describes an integrated geographic information system (GIS)-based data model for engineering design data that complies with TxDOT data architecture requirements; and documents the results of tests completed on the engineering design data model by using offline and online testing environments.					
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ENGINEERING DESIGN DATA MANAGEMENT – PRACTICES AND FRAMEWORK DEVELOPMENT

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The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

2R	Resurfacing or Restoration (Project)
3R	Resurfacing, Restoration, Rehabilitation (Project)
4R	Resurfacing, Restoration, Rehabilitation, Reconstruction (Project)
5R	Mobility Corridor (Project)
AADT	Annual Average Daily Traffic
ACP	Asphalt Concrete Pavement
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
AFA	Advance Funding Agreement
AGC	Associated General Contractors
AIM	Asset and Information Management
API	Application Programming Interface
ArcGIS	Arc Geographic Information System
ArcIMS	Arc Internet Map Server
ArcSDE	Arc Spatial Data Engine
ASP	Active Server Pages
ATR	Automatic Traffic Recorder
BAMS/DSS	Bid Analysis Management System/Decision Support System
BPS	Bid Proposal System
CAD	Computer-Aided Design
CAMS	Condition-Based Asset Management System
CCMO	Consultant Contract Management Office

CCSJ	Controlling Control Section Job
CE	Categorical Exclusion
CEC	Consulting Engineers Council
CIP	Capital Improvement Plan/Project/Program
CIPMS	Capital Improvement Project Management System
CLOMR	Conditional Letter of Map Revision
CMAQ	Congestion Mitigation and Air Quality
CMCS	Construction and Maintenance Contract System
COTS	Commercial-off-the-Shelf
CPM	Critical Path Method
CSF	Combined Scale Factor
CSJ	Control Section Job
CTS	Contract Tracking System
DCIS	Design and Construction Information System
DCO	District Construction Office
DDRT	District Design Review Team
DFO	Distance from Origin
DIR	Department of Information Resources
DMS	Document Management System
DPS	Department of Public Safety
DOD	Department of Defense
DOT	Department of Transportation
DOTS	Data on Terminal Spool

DSO	Design Summary Outline
DSR	Design Support Report
DTM	Digital Terrain Model
DTSRT	District Traffic Safety Review Team
DVD	Digital Video Disk
DXF	Drawing Exchange Format
EA	Environmental Assessment
EC	Environmental Coordinator
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EDDM	Engineering Design Data Model
EDMS	Enterprise Document Management System
EDTIS	Electronic Document Technologies Implementation and Support
EPA	Environmental Protection Agency
EPIC	Environmental Permits, Issues, and Commitments
ER	Entity Relationship
ESA	Environmental Site Assessment
ESRI	Environmental Systems Research Institute
ETS	Environmental Tracking System
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standard

FMS	File Management System
FONSI	Finding of No Significant Impact
FPAA	Federal Project Authorization and Agreement
FUP	Federal Utility Procedure
GAIP	GIS Architecture and Infrastructure Project
GASB	Governmental Accounting Standards Board
GDOT	Georgia Department of Transportation
GENII	Genesis Enterprise Information Integrator
GIMS	Geographic Information and Management System
GIS	Geographic Information System
GISMIS	GIS-Based Management Information System
GPS	Global Positioning System
GS	Ground Set
GSD	General Services Division
GUI	Graphical User Interface
HCPID	Harris County Public Infrastructure Division
HCRS	Highway Condition Reporting System
HPMS	Highway Performance Management System
HPTMS	Highway Project Task Management System
HTML	Hypertext Markup Language
HUB	Historically Underutilized Businesses
IH	Interstate Highway
ISD	Information Systems Division

ITS	Intelligent Transportation Systems
KYTC	Kentucky Transportation Cabinet
LIS	Land Information System
LOA	Letter of Authority
LOMR	Conditional Letter of Map Revision
LPA	Local Participating Agency
LRP	Long Range Project
LUP	Local Utility Procedure
MDSHA	Maryland State Highway Administration
MGE	Modular GIS Environment
MMA	Municipal Maintenance Agreement
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MST	Main Street Texas
MUA	Multiple Use Agreement
NAD	North American Datum
NBI	National Bridge Inventory
NDT	Non-Destructive Testing
NJDOT	New Jersey Department of Transportation
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service

NRP	Non-Reimbursable Procedure
OCR	Optical Character Recognition
ODA	Odessa District
PDF	Portable Document Format
PDP	Project Development Process
PIER	Permitting, Inspection, Enforcement, and Review
PM	Preventive Maintenance (Project)
PMIS	Pavement Management Information System
PSA	Petroleum Substance Agreement
PS&E	Plans Specifications and Estimates
PWE	Public Works and Engineering Department
ROI	Return on Investment
ROD	Record of Decision
ROW	Right of Way
ROWIS	Right of Way Information System
RR	Railroad
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SAS	Statistical Analysis Software
SAT	San Antonio District
SMS	Subcontractor Monitoring System
SQL	Structured Query Language
STIP	Statewide Transportation Improvement Program
StratMap	Strategic Mapping Program

SUE	Subsurface Utility Engineering
SUP	State Utility Procedure
SW3P	Storm Water Pollution Prevention Plan
TACS	Tables and Characteristics System
TAS	Texas Accessibility Standard
TCEQ	Texas Commission on Environmental Quality
TCP	Traffic Control Plan
TEA-21	Transportation Equity Act for the 21 st Century
TEBSS	Texas Eligible Bridge Selection System
TEDD	Traffic Engineering Design Division
TIF	Tagged Image File
TIN	Triangulated Irregular Network
TIP	Transportation Improvement Program
TMS	Traffic Management System
TNRIS	Texas Natural Resources Information System
TPP	Transportation Planning and Programming Division
TREX	Transportation Explorer
TRM	Texas Reference Marker
TRMEOY	TRM End-of-Year
TSID	TxDOT System Interface Diagram
TSPS	Texas Society of Professional Surveyors
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation

UCMP	Utility Cooperative Management Process
USGS	United States Geological Survey
UTP	Unified Transportation Program
VMT	Vehicle Miles Traveled

CHAPTER 1. INTRODUCTION

Streamlined project delivery is one of the five goals outlined in the 2001 Texas Transportation Commission's report "Texas Transportation Partnerships ... Connecting You to the World" (1) to achieve the vision of a more efficient and effective transportation system in Texas. Specific TxDOT actions to achieve that goal include streamlining the internal project delivery process and implementing processes to reduce the time required to design projects. Ready access to the wealth of data in various department systems is a key requirement to streamline project delivery during all phases of the project development process.

During the project development process, districts produce enormous amounts of engineering data in a variety of data formats with varying levels of accuracy and resolution on several types of storage media. Examples include aerial photography and topographic information, drawings at various levels of development, surveying data, ROW, and utility maps, and traffic counts. These data are a valuable asset, and TxDOT has begun to implement strategies to ensure the usability and integrity of the data. However, the amount of data that districts produce and receive is growing steadily, which makes it increasingly difficult to manage the data effectively. Although district personnel have a wealth of data at their disposal, frequent lack of data integrity, accessibility, quality control, or plain awareness makes it unnecessarily difficult to put the data to good use. These inefficiencies result in redundant data collection efforts and contribute to project delays.

The purpose of the research was to develop a prototype engineering design data model and guidelines for managing engineering data in a geographic information system (GIS)-based environment. More specifically, the research resulted in three products:

- 0-5246-P1 (included in the companion digital video disk [DVD]). This product included conceptual, logical, and physical engineering design data models, along with the corresponding data dictionary files.
- 0-5246-P2 (included in the companion DVD). This product included a populated database and sample library structure with project data and query structures for testing the framework.
- 0-5246-P3 (submitted as [Chapter 7](#) in this report). This product included recommendations and implementation guidelines.

This report (0-5246-1) describes the research completed to document current engineering design data management practices at TxDOT and to develop a prototype engineering data management framework to assist divisions and districts in managing engineering data effectively. The report also includes the results of tests conducted to assess the feasibility of the engineering design data model through desktop and Internet-based environments.

This report is organized in chapters as follows:

- [Chapter 1](#) is this introductory chapter.
- [Chapter 2](#) provides a review of engineering design data management practices at TxDOT.
- [Chapter 3](#) provides a review of engineering design data management practices at other agencies.
- [Chapter 4](#) describes the engineering design data model.
- [Chapter 5](#) describes the sample project data used in this research and the conversion, procedures, and issues of using those data to populate the engineering design data physical model.
- [Chapter 6](#) describes the three environments used to test the populated engineering design data physical model and the results, along with user feedback and pending issues.
- [Chapter 7](#) includes a summary of findings and recommendations for implementation.

CHAPTER 2. ENGINEERING DESIGN DATA MANAGEMENT PRACTICES AT TXDOT

INTRODUCTION

This chapter summarizes engineering design data practices at TxDOT in terms of procedures, data flows, and computer resources. To keep the discussion at a manageable level (because TxDOT manages vast amounts of information), this chapter focuses on key project development process (PDP) concepts and data management issues. To gather information, the researchers reviewed relevant manuals and guidelines and met with TxDOT district officials who are involved in several phases of the project development process, including planning, design, and ROW and utilities. The researchers also met with staff from several divisions, including ISD and GSD, to gather detailed information about TxDOT computer systems and standards that involve management of engineering design data. As [Chapter 5](#) describes, the information gathering and review also included sample datasets from four projects in Odessa and San Antonio, which the researchers used for developing and testing the prototype engineering data model.

PROJECT DEVELOPMENT PROCESS REVIEW

Funding Categories, Project Types, and Levels of Authority

The 2003–2007, 2005–2009, and 2007–2011 TxDOT strategic plans streamlined the 10-year Unified Transportation Program (UTP) with respect to the following [\(2\)](#):

- **Objectives.** TxDOT simplified its objectives to five categories, in line with Transportation Equity Act for the 21st Century (TEA-21) requirements that the metropolitan transportation planning process consider projects and strategies that result in reliable mobility, improved safety, system preservation, accelerated project delivery, and economic vitality [\(3\)](#). It may be worth noting the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) preserved these planning objectives [\(4\)](#).
- **Appropriation Strategies.** TxDOT established five appropriation strategies: Plan It, Build It, Maintain It, Maximize It, and Manage It.
- **Funding Categories.** TxDOT reduced the number of project funding categories from 34 to 12 [\(5, 6\)](#). [Table 1](#) summarizes the funding categories with a brief description of the usual project starting points and project selection protocols.

Depending on project characteristics and the corresponding selection process ([Table 1](#)), the path to design, letting, and construction may vary. TxDOT classifies projects according to the categories in [Table 2](#). In general, for a project to proceed through planning and design, the project has to have an associated level of authority, which can be one of the following:

- **Plan (formerly Long Range Project).** This level authorizes TxDOT districts to complete the necessary ROW determination including drafting the ROW map, studying

routes, performing environmental studies (including the preparation of categorical exclusion lists, environmental assessments, and environmental impact statements), and holding public hearings.

- **Develop (formerly Priority 2).** This level authorizes TxDOT districts to prepare construction plans and acquire the necessary ROW. Districts should substantially complete project construction plans (geometric, structural, hydraulic, and pavement design) and required ROW acquisition prior to moving to the Construct level of authority.
- **Construct (formerly Priority 1).** This level authorizes TxDOT districts to complete construction plans, perform utility adjustments, and award a construction contract for the project in the scheduled fiscal year.

Not all projects need to go through all levels of authority. For example, resurfacing, restoration, and rehabilitation (3R) projects (Table 2) typically go through a Plan phase, followed by a Develop phase and then a Construct phase. By comparison, preventive maintenance (PM) projects tend to require only a Construct level of authority, while resurfacing or restoration (2R) projects could require a Develop or a Construct level of authority, depending on the case.

Table 1. Project Funding Categories (Adapted from [6]).

Funding Category	Starting Point	Project Selection
Preventive Maintenance and Rehabilitation	TxDOT district	Districts select projects.
Structures Replacement and Rehabilitation	TxDOT district	Commission approves projects statewide on a cost-benefit basis using the Texas Eligible Bridge Selection System (TEBSS).
Metropolitan Area Corridor Projects	TxDOT district	Commission approves projects in corridors. Projects scheduled by consensus of districts.
Urban Area Corridor Projects	TxDOT district	Commission approves projects in corridors. Projects scheduled by consensus of districts.
Statewide Connectivity Corridor Projects	TxDOT district	Commission approves projects in corridors. Projects scheduled by consensus of districts.
Congestion Mitigation and Air Quality Improvement	TxDOT district	Metropolitan planning organizations (MPOs) select projects in consultation with TxDOT. Commission allocates funds based on population percentages within areas failing to meet air quality standards.
Metropolitan Mobility/Rehabilitation	TxDOT district	MPOs select projects in consultation with TxDOT. Commission allocates money based on population.
Safety	TxDOT district	Projects selected statewide using federally mandated safety indices and prioritized listing. Commission allocates funds to districts.
Transportation Enhancements	TxDOT district	Local entities make recommendations, and a TxDOT committee reviews them. Commission selects and approves on a per-project basis.
Miscellaneous	TxDOT district / other	Traffic Operations Division or Texas Parks and Wildlife Department select projects statewide. Districts select local projects. Commission allocates funds to districts or approves participation in federal programs with allocation formulas.
District Discretionary	TxDOT district	Districts select miscellaneous projects on the state highway system. Commission allocates funds based on vehicle miles traveled (VMT) and registered vehicles.
Strategic Priority	Commission	Commission selects projects on a project-specific basis.

Table 2. Highway Project Categories (7, 8, 9).

Category	Description
PM	Preventive Maintenance. PM projects consist of work proposed to preserve, rather than improve, the structural integrity of the pavement and/or structure. Examples of preventive maintenance activities include asphalt concrete pavement (ACP) overlays (maximum 2 inches thick); seal coats; cleaning and sealing joints and cracks; patching concrete pavement; shoulder repair; scour countermeasures; cleaning and painting steel members to include application of other coatings; restore drainage systems; cleaning and sealing bridge joints; micro-surfacing; bridge deck protection; milling or bituminous level up; clean, lubricate, and reset beatings; and clean rebar/strand and patch structural concrete and seal cracks.
2R	Resurfacing or Restoration. 2R projects consist of non-freeway work on facilities with an average daily traffic (ADT) of less than 3000 that propose to restore the pavement to its original condition. Upgrading roadway components as needed to maintain the roadway in an acceptable condition might be included in restoration work. The addition of through travel lanes is not permitted under 2R. Analyses should be performed to identify high accident locations so that corrective measures can be taken.
3R	Resurfacing, Restoration, Rehabilitation. 3R projects consist of non-freeway transportation projects that extend the service life and enhance the safety of a roadway. In addition to the work described under resurfacing and restoration, the activities include upgrading the geometric design and safety of the facility. Work does not include the addition of through travel lanes. Work may include the upgrading of geometric features such as roadway widening, minor horizontal realignment, and improving bridges to meet current standards for structural loading and to accommodate the approach roadway width.
4R	Resurfacing, Restoration, Rehabilitation, Reconstruction. 4R projects consist of transportation projects to provide a new roadway or upgrade an existing roadway to meet geometric design criteria for a new facility. In addition to work described under resurfacing, restoration, and rehabilitation, reconstruction work generally includes substantial changes to the geometric character of the highway, such as widening to provide additional through lanes and horizontal or vertical realignment, and major improvements to the pavement structure to provide long-term service. Reconstruction work includes bridge replacement work.
5R	Mobility Corridor. 5R projects consist of transportation projects to provide a new roadway or upgrade/reconstruct an existing roadway to meet geometric design criteria for a new high-speed facility. TxDOT intends mobility corridors for long distance travel that may include multiple modes such as rail, utilities, freight, and passenger transportation. A 5R project includes all work described under 4R for mobility corridor projects, but different design standards apply because of the roadway’s higher design speed and multiple participating transportation modes.

“Standard” Project Development Process Phases

The PDP is the process a project undertakes from initial identification of needs to construction letting. Several TxDOT documents describe those steps, outline specific requirements, and/or identify the relationship between PDP components (6, 10, 11, 12). Of specific interest is the TxDOT *Project Development Process Manual*, which provides information about some 200 major tasks, subtasks, responsible parties, and critical sequencing (10). Currently, TxDOT is updating the PDP manual to ensure consistency with the TxDOT strategic plan (2).

A comprehensive characterization of the PDP manual is not practical here. However, a summary of the structure and characteristics of the manual is of interest in order to understand the differences between the “standard” PDP and individual district PDP implementations, which, in turn, is necessary to understand how different districts manage engineering design data and data flow. The PDP manual includes six chapters – one for each major block shown in Figure 1. Each chapter includes sections, subsections (as needed), and tasks. For example, the Plans Specifications and Estimates (PS&E) Development chapter includes 10 sections. One of the

sections in this chapter is Section 2, Begin Detail Design, which includes five subsections. One of the subsections in Section 2 is Subsection Traffic Control, which includes two tasks: 5040 (Plan sequence of construction) and 5050 (Develop conceptual detour/road closure plan). Each task includes content that covers the following items: description, pertinent project types, responsible party, subtasks, helpful suggestions, critical sequencing, authority requirements, and resource material. Table 3 summarizes chapters, sections, and subsections along with an identification of major typical milestones and level of authority requirements. The PDP manual includes a diagram (Figure 2) that shows sections and subsections in the manual as well as arrows that illustrate overall chapter and section interdependence at a very high level of aggregation (11). The diagram also shows project levels of authority.

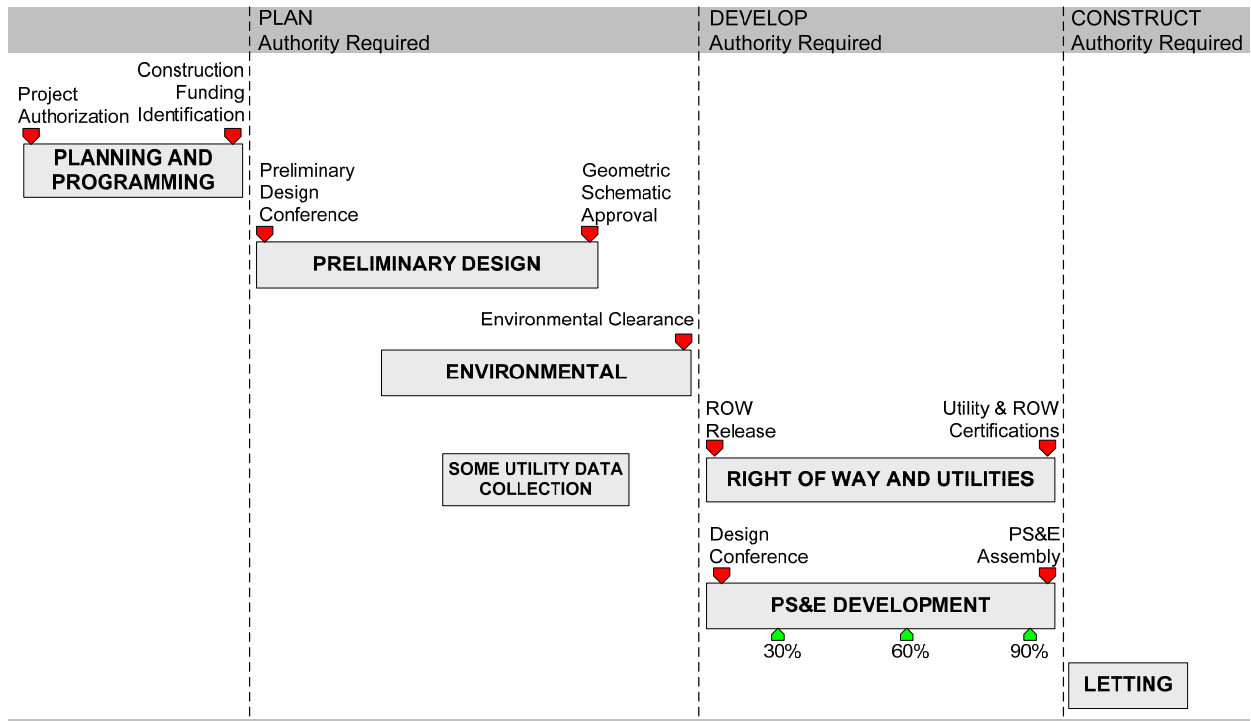


Figure 1. Current Project Development Process at TxDOT (10, 11).

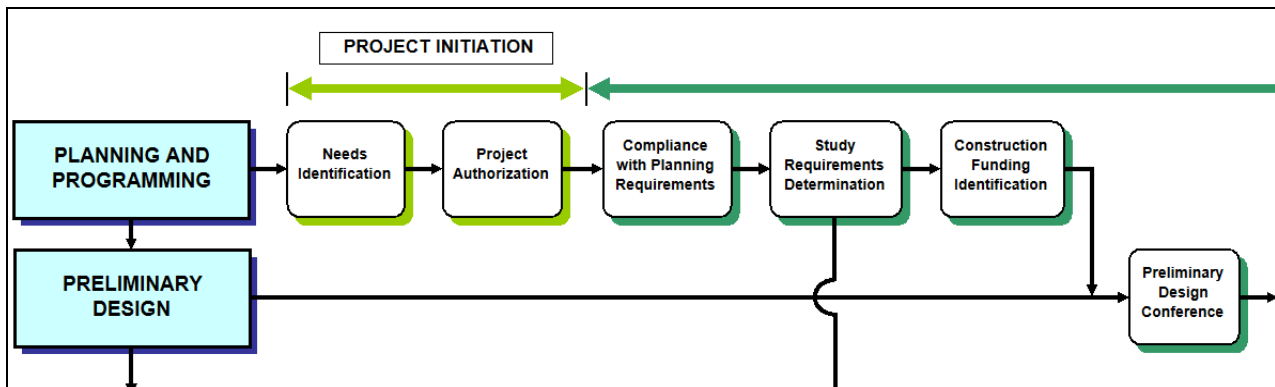


Figure 2. Partial View of the Project Development Process Flowchart (11).

Table 3. Project Development Process Manual Chapters and Sections (10).

Chapter	Section (Subsections)	Major Milestone	Comment
Planning and Programming	Needs Identification		
	Project Authorization	◆	Applies to all projects: Projects receive Plan authorization
	Compliance with Planning Requirements		Applies to all projects
	Study Requirements Determination		Applies to all projects
	Construction Funding Identification	◆	Includes obtaining Develop or Construct authorization
Preliminary Design	Preliminary Design Conference	◆	Requires Plan authorization
	Data Collection/Preliminary Design Preparation		Requires Plan authorization
	Public Meeting(s)		Requires Plan authorization
	Preliminary Schematic (Alternative Selection, Geometrics, Update Cost Estimate)		Requires Plan authorization
	Geometric Schematic		Requires Plan authorization
	Value Engineering		Requires Plan authorization
	Geometric Schematic Approval	◆	Requires Plan authorization
Environmental	Preliminary Environmental Issues		Requires Plan authorization
	Interagency Coordination/Permits		Requires Plan authorization
	Environmental Documentation		Requires Plan authorization
	Public Hearing		Requires Plan authorization
	Environmental Clearance	◆	Requires Plan authorization
Right of Way and Utilities	Right of Way and Utility Data Collection		Requires Plan authorization
	Right of Way Map and Property Descriptions		Requires Plan authorization
	Right of Way Appraisals and Acquisition		ROW release typically happens after obtaining Develop authorization
	Utility Adjustments	◆	Adjusting reimbursable utilities normally requires Develop authorization
PS&E Development	Design Conference	◆	Requires Develop authorization
	Begin Detailed Design (Traffic Control, Permits and Agreements, Design Data Collection, Stream Crossing Hydraulics)		Requires Develop authorization
	Final Alignments/Profiles		Requires Develop authorization
	Roadway Design (Earthwork, Landscape and Aesthetics, Plan/Profile and Roadway Details, Railroad Agreements)		Requires Develop authorization
	Operational Design (Illumination, Intelligent Transportation System, Signals, Signing and Striping)		Requires Develop authorization
	Bridge Design (Final Geotechnical Surveys, Bridge Layouts, Bridge Design and Details)		Requires Develop authorization
	Drainage Design (Hydraulic Design, Drainage Details, Storm Water Pollution Prevention Plan)		Requires Develop authorization
	Retaining/Noise Walls & Miscellaneous Structures (Retaining/Noise Wall Layouts, Retaining/Noise Wall Design and Details, Miscellaneous Structures)		Requires Develop authorization
	Traffic Control Plan (Sequence of Work, Detour Plans, Temporary Signing, Striping, and Pavement Marking, Contract Provisions, Review)		Requires Develop authorization
	PS&E Assembly/Design Review	◆	Requires Construct authorization
Letting	Final Processing and Letting	◆	Requires Construct authorization

A more detailed description of sections and tasks that involve typical major project milestones follows:

- **Project Authorization.** This section describes the tasks needed for authorization of the project as Long Range Project (LRP) (i.e., Plan) status. These tasks include preparing a cost estimate in the Design and Construction Information System (DCIS), preparing a programming assessment, obtaining approval, and obtaining a project-specific minute order, if required.
- **Construction Funding Identification.** This section includes identifying potential design/construction funding alternatives, preparing and executing advance funding agreements with other entities, obtaining (if appropriate) Develop or Construct authorization, placing the project in the Transportation Improvement Program (TIP) and one-year letting schedule, developing the Statewide Transportation Improvement Program (STIP), and participating in the annual federal fund sharing meeting.
- **Preliminary Design Conference.** The preliminary design conference is a meeting to agree on fundamental aspects, concepts, and preliminary design criteria of a project.
- **Geometric Schematic Approval.** This section describes the tasks to obtain geometric schematic approval. Typical tasks include circulating the geometric schematic for district review, reviewing the geometric schematic with stakeholders, obtaining approval of the geometric schematic before public hearing, revising the geometric schematic based on input from a public meeting, and obtaining approval of the final geometric schematic.
- **Environmental Clearance.** This section includes a number of tasks that identify and document potential environmental impacts, prepare mitigation plans as needed, conduct public hearings and respond to public hearing comments, and obtain environmental clearance. Obtaining environmental clearance involves preparing a document that incorporates comments from the public and regulatory and/or resource agencies and identifies required changes in the proposed project (mitigation measures) resulting from the comments received, as well as submitting the final environmental document for review and approval. Environmental clearance is a prerequisite to ROW release and the design conference.
- **Obtain Authority for Right of Way Project Release.** This task enables TxDOT to incur ROW acquisition and utility adjustment costs. Prerequisites to ROW release include environmental clearance, production of a district-approved ROW map, and execution of agreements with local participating agencies. Under certain circumstances (land donations, hardship cases, and protective acquisition), TxDOT can acquire ROW parcels in advance of the “official” ROW release.
- **Utility Adjustments.** This section describes the process to relocate utilities in preparation for the highway construction work. Major tasks include coordinating utility adjustment plans, preparing and executing utility adjustment agreements, adjusting utilities, preparing utility clearance certifications, and reimbursing utilities for eligible

adjustment costs. The goal is to have all utilities adjusted before a project goes to letting. This is not always possible. As a result, the utility clearance certification must state whether any utility adjustments remain uncompleted.

- **Design Conference.** This section describes the process that officially starts detailed design work and PS&E development. The purpose of the design conference is to review basic design parameters, concepts, and criteria, and obtain concurrence with decisions.
- **PS&E Assembly/Design Review.** This section describes the steps to assemble and review the PS&E package, submit the package to the Design Division, and, if needed, obtain approval for program overruns. Additional tasks might include an environmental re-evaluation, collection of funds based on advance funding agreements, and a final review of permits and agreements by the district. The PS&E Preparation Manual (12) provides further details on the assembly process, including pre-assembly activities, plan set development, specifications, estimate, PS&E submissions and processing, and pre-letting and post-letting.
- **Final Processing and Letting.** This section describes the steps to review and process the completed PS&E package before the project goes to letting, as well as the general steps to advertise the request for bids, award the contract, notify the public in advance of construction, and store and retain project records. The Design Division has primary responsibility for reviewing the PS&E package up to letting. Divisions with secondary review responsibility include Traffic Operations, Construction, and General Services. FHWA also has review responsibility in the case of projects having FHWA oversight.

For each task in the PDP, there is documentation that can be in the form of drawings (e.g., layouts, schematics, and plans), submission/review forms, surveys, raw data, analyses, and lists, as well as communication and coordination documents such as meeting minutes, phone logs, transmittals, emails, and faxes. Core supporting documents are the Design Summary Report (DSR) (13) and Form 1002 (14). The DSR form is a 20-page document that can be partially completed during the Preliminary Design Conference, reviewed in detail during the Design Conference, and updated throughout the development of the project. The DSR summarizes basic project information such as the following:

- programming and funding data (e.g., financing, funding participation, and agreements);
- existing elements on the project site (e.g., typical section, bridge, stream, ROW data, existing constraints, and railroad crossings);
- advance project development elements (e.g., surveying, schematic development, environmental commitments, and issues);
- proposed ROW and utility elements (e.g., easements, control of access, relocation assistance, utility inventory, and conflicts);
- proposed geometric design elements (e.g., design criteria, and proposed roadside and roadway surface features);

- proposed bridge design data (e.g., structure design data);
- proposed hydraulic elements (e.g., design frequencies for structure types, and required structures);
- proposed pavement structure elements (e.g., proposed pavement structure);
- proposed traffic operation elements (e.g., proposed signalization, lighting, and intelligent transportation systems [ITS]);
- proposed miscellaneous elements (e.g., geotechnical exploration, construction sequence, and permits);
- accelerated construction procedures (e.g., contracting procedures and exceptions); and
- documentation for preliminary design and design conferences (e.g., suggested attendance, agenda and report material, generic form for comments, concurrence, and signatures).

Form 1002 is a four-page checklist for assembling the PS&E package. Major items in the package are plan sheets, standard and special specifications, general notes, special provisions, project agreements, and the cost estimate. Pages 1 and 2 of Form 1002 include a checklist of required project documents and plans (e.g., plans estimate, plans prints, supplemental sheets, and certifications), funding and financing participation, agreements, clearances, contract time, contacts, and an estimated cost. Page 3 summarizes proposed project basic design data. Page 4 indicates if, and what, accelerated construction provisions are necessary for the project.

Several documents support the design process but are not included in the PS&E package, including environmental document and clearance, ROW map and ROW release, un-cleared ROW parcel map, right of entry requests, final geometric schematic, lighting justification report, driveway tie-in permission requests, hazardous materials site assessment and remediation plans, and public hearing certification and summary.

Although TxDOT intended the PDP manual to provide a clear and consistent definition of project processes and component tasks, in actual practice the manual has several limitations that tend to hinder its usability. Examples of issues the researchers found include the following:

- The PDP manual chapter structure attempts to follow major PDP workflow activities: planning and programming, preliminary design, environmental, ROW and utilities, PS&E development, and letting. The PDP flowchart (11) also follows this structure. At first glance, organizing both manual and flowchart around major workflow activities makes sense. However, a closer analysis reveals a significant drawback of the existing PDP flowchart. Major workflow activities, which the PDP diagram also shows as “swim lanes,” suggest levels of responsibility along functional areas for each of the boxes that represent sections and tasks in the diagram. One of the problems of the current flowchart is that major workflow activities, as structured in the PDP manual, do not necessarily correspond to functional areas within TxDOT. For example, the diagram shows ROW and utility data collection within the ROW and Utilities “swim lane.” However, TxDOT ROW personnel are not typically in charge of collecting ROW and utility data. That activity is usually the responsibility of the preliminary design project manager.

- The PDP diagram suggests major workflow activity and section dependencies that frequently do not correspond to text or task dependencies in the PDP manual. For example, the arrow connecting the Preliminary Design and Environmental chapter boxes (Figure 2) suggests all preliminary design activities should finish before starting environmental activities. While this dependence is obviously false, at a minimum the presence of that arrow in the diagram could cause confusion because the same diagram shows other arrows connecting preliminary design boxes with environmental boxes – as well as arrows connecting environmental boxes with preliminary design boxes.
- Likewise, arrows connecting section boxes suggest data and workflow dependencies that do not necessarily correspond to PDP manual task dependencies. For example, the PDP diagram suggests ROW appraisals and acquisition need to finish before utility adjustments can start. In reality, several utility adjustment tasks (e.g., coordinate utility adjustment plans, prepare and execute utility adjustment agreements) can take place concurrently with, or even before, ROW acquisition.
- The PDP diagram does not include decision points and feedback mechanisms, which are critical to characterizing business process activities properly. This limitation results in a diagram that suggests the PDP is linear, when in reality the actual process can be quite convoluted, requiring several iterations until a final design emerges.
- The PDP diagram is a “catch all” diagram that attempts to represent all types of projects and situations. While seasoned planners and designers know from experience the PDP components that apply for specific types of projects, less experienced officials do not necessarily have that knowledge. For them, relying on the current PDP diagram to identify which PDP components apply or even where to start can be daunting, if not intimidating.
- The PDP manual is not consistent in the way it treats responsible parties, subtasks, and critical sequencing for individual tasks. For example, subtask bullets are frequently not descriptions of subtasks but merely tips and suggestions. Likewise, references to responsible parties tend to be generic or aggregated rather than specific (e.g., the most frequently named responsible party is “roadway design engineer”). Critical sequencing text frequently does not include complete from-dependence and to-dependence information, which forces the reader to navigate through chapters and sections throughout the manual to find that information.
- Although the PDP manual uses technical terminology quite consistently, there are cases where inconsistencies in the use and application of technical terms can produce confusion. For example, the terms “layouts,” “planimetric map,” “geometrics,” “schematics,” and “plans” can have different meanings both within the PDP manual and during the course of technical discussions with district officials. A “layout” typically means a high-level drawing (particularly during discussions with district officials), but it could also refer to detailed computer-aided design (CAD) drawings. A “planimetric map” is usually a map that shows the horizontal position of features (which typically involves some level of digitization), but it can also refer simply to a raster aerial

photograph printout. Geometrics can be conceptual horizontal corridors or alignments, considered in the PDP manual to be preliminary schematics. A “plan” typically means a design phase drawing, but it is also common to use “layouts” and “plans” interchangeably.

In a similar fashion, the terms “standards” and “details” could have differing meanings. “Detail” sheets could refer to typical standard elements (e.g., fire hydrant or curb cut), elements that are non-standard (e.g., new type of guardrail), or details of design elements (e.g., large-scale plan and elevation view of a gatehouse or footing). In addition, there are terms that seem out of place in the PDP manual without background knowledge. For example, the PDP manual recommends using “as-built construction plans” at a project design conference, i.e., before design and construction have taken place. However, it is not immediately evident whether those plans refer to plans of the existing roadway constructed at an earlier time.

Sample District PDP Implementations

Although district PDP implementations follow the general guiding principles of the PDP manual, there are considerable differences in interpretation and implementation. As an illustration, this section summarizes the main characteristics of the PDP implementations at two sample districts: San Antonio and Odessa.

San Antonio District

In addition to standard statewide TxDOT form templates, the San Antonio District uses checklists for 30 percent, 60 percent, 90 percent, and 100 percent design (15). The district also uses a flowchart and companion guidelines that focus on critical milestones that define the relationship between the PDP and the utility adjustment process (16). Table 4 describes the meaning and purpose of each milestone. These guidelines started in the late 1990s as a memorandum of understanding (MOU) between TxDOT and utility companies to outline expectations and responsibilities during the utility adjustment process. Over time, the guidelines have evolved into a PDP management tool that includes a milestone flowchart, milestone purpose definitions, and typical activities and general document requirements associated with each milestone.

Table 4. San Antonio District PDP Milestones (Adapted from [16]).

No.	Milestone	Purpose
1	Project Selection (TIP)	Review selected projects
2	Agency Scoping Meeting	Reach consensus for project development, including project design requirements and agency responsibilities, and develop preliminary project development time line
3	Begin Preliminary Engineering and Field Data Gathering	Begin design process
4A	District Design Review Team Review – 30% Design	District review of schematic
4B	Preliminary Design Meeting – 30% Design	Coordinate preliminary design information with agencies
5	Special Review	Receive early approval for critical information coordinated with others
6	Intermediate Design Phase – 60%	Identify subsurface information required for utility companies in order to adjust the design to avoid possible conflicts
7A	District Design Review Team (DDRT) Review – 60%	Review 60% plans
7B	District Traffic Safety Review Team (DTSRT) Review	District review of sequence of work and traffic control
7C	Substantial Completion Meeting	Provide substantially completed plans to utilities companies for their design
7D	Associated General Contractors (AGC) Review for Comments	Allow representatives from the contracting community to review plans prior to letting and offer any suggestions that would result in a safer, more cost-effective project
8	Utility Schedule Review Meeting	Review 60% utility designs, provide face to face discussions on utility-related project issues, and ensure utility plans are underway
9	Final Design Review Meeting – 90%	“Pull together” final design plans and agency coordination efforts
10	Agency Approval for Letting	PS&E processing and letting
10A	TxDOT Area Office Approval	Finalize review – TxDOT area office
10B	Agency Approval and Funding	Execute advance funding agreements with utility companies
10C	TxDOT District Approval	Finalize review – TxDOT district office
10D	Pre-letting Utility Schedule Update	Update utility adjustment schedule
10E	TxDOT Division Approval	Finalize review – TxDOT Design Division
11	Utility Adjustment Implementation	Implement (non-joint bid) utility adjustments

The notation for some of the meetings in the San Antonio PDP implementation is not the same as in the PDP manual. For example, the Agency Scoping Meeting in San Antonio is roughly equivalent to the “standard” PDP Preliminary Design Conference, whereas the Preliminary Design Meeting in San Antonio is roughly equivalent to the “standard” PDP Design Conference. In addition, perhaps because the PDP milestone guidelines in San Antonio tend to focus on the utility adjustment process, most of which takes place during the design phase, the San Antonio PDP milestone guidelines only provide an aggregate view of the planning and preliminary design process (essentially compressed to milestones 3 and 4A in [Table 4](#)).

The San Antonio District’s goal is for projects to be roughly at 30 percent design complete by the time they reach the Preliminary Design Meeting (milestone 4B in [Table 4](#)). Increasingly, district officials see a need to compress PDP activities, e.g., by moving some of the traditional design-phase activities to the planning phase and by adjusting start-to-finish work elements to start-to-start elements. District officials view their PDP guidelines and the schedule compression

that results from reaching the “official” design phase when the project is already 30 percent design complete as helping them to cope with accelerated project schedule demands.

The District Design Review Team (17) and the District Traffic Safety Review Team (18) evolved in response to the need to support the PDP and improve work zone safety. DDRT meetings occur prior to 30 percent and 60 percent design completion. DDRT membership includes representatives from several sections across the district, including construction, bridge, design, and planning. The DTSRT meeting occurs between 60 and 90 percent design completion. The objective of this meeting is to review the sequence of work and traffic control plans.

Project design work is typically the responsibility of an area office, although if an area office cannot handle the design task, the project may go to the central design office. Bridge design is normally the responsibility of the Structure Design and Bridge Maintenance Section. If the central design office is unable to work on the project, the design is normally given to a consultant. Projects at the San Antonio District tend to have several project managers, depending on where the project is along the PDP. In general, project managers hand over projects to the next project manager (e.g., advance planning project manager to design project manager), which includes handing over all related documentation associated with the project. As a result, project managers tend to keep very little information about the project (with the exception of electronic files that might reside on local computer drives).

According to district officials, PDP activities that impact projects the most are utility adjustments, railroad agreements, environmental assessments, and scope review. Other issues district officials highlighted included diminished quality of consultant work and enforcement of digital submission and file management standards.

Odessa District

In addition to standard statewide TxDOT form templates, the Odessa District uses district-developed standard operating procedures for project selection and development (19) and PS&E development and review (20). The procedure for project selection and development includes the requirement for Design Summary Outline (DSO) documents. DSOs are dated documents, and there may be several versions in the project file, as the project moves through planning, design, construction, completion, and archiving. As Table 5 shows, DSOs can be in one of three forms:

- **Preliminary Estimate Worksheet (19).** This is a two-page document, which, in practice, the Odessa District uses for all types of projects.
- **Design Conference Form (21).** This eight-page form contains more detail than the preliminary estimate worksheet. It also includes a PDP flowchart, which includes work elements and decision points (Figure 3). The Odessa District routinely uses this form instead of the standard 20-page TxDOT DSR as a tool to streamline project documentation.
- **TxDOT DSR (13).** This form only documents new location projects.

Table 5. Design Summary Outlines in the Odessa District (Adapted from [19]).

Project Type	Design Summary Outline			Comment
	Preliminary Estimate Worksheet	Design Conference Form	Design Summary Report	
New Location			X	
Added Capacity		X		
Reconstruction		X		
Rehabilitation		X		
Restoration	X			
Resurface	X			
Districtwide Seal Coat				n/a
Hazard Elimination	X			
Traffic Operations	X			
Bridge Repair/Rehabilitation	X			
Landscape				n/a

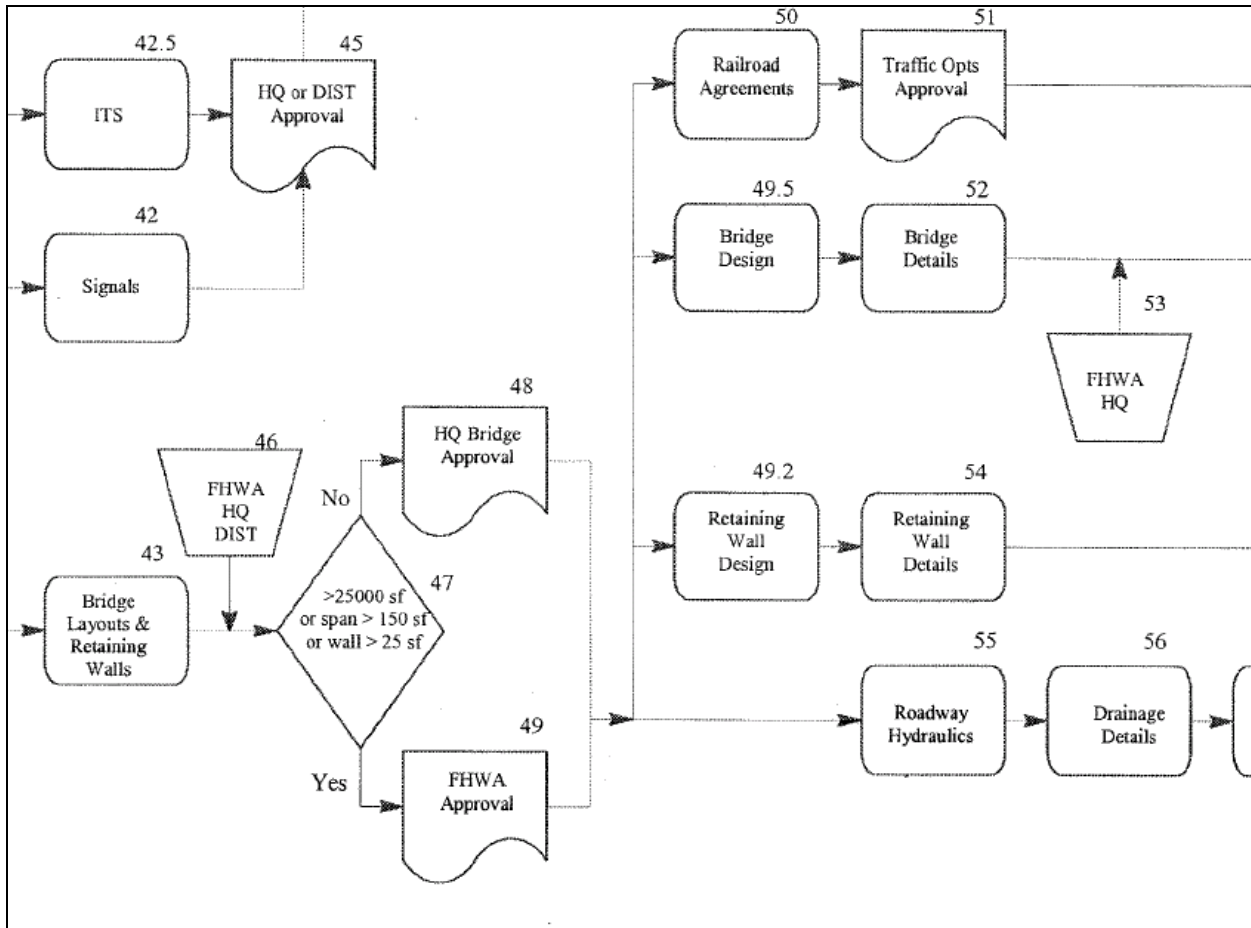


Figure 3. Partial View of the Odessa District PDP Flowchart (Adapted from [19]).

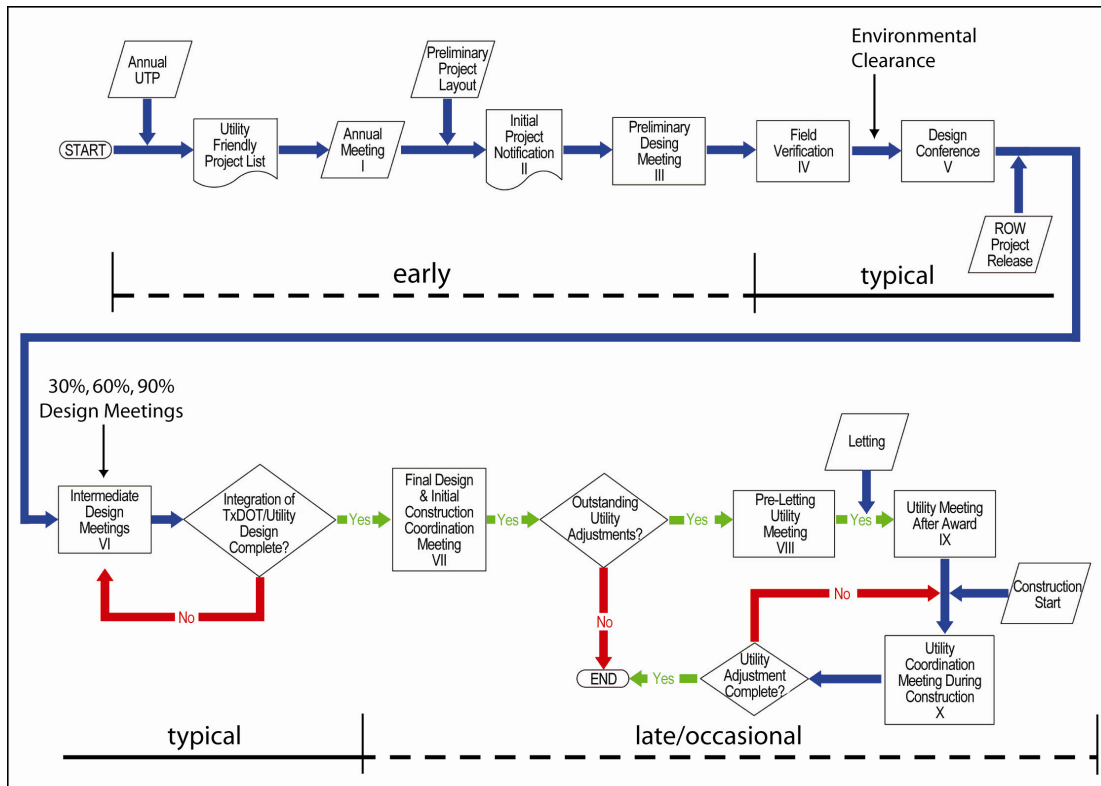
There are several differences between the Odessa District PDP flowchart (Figure 3) and the PDP manual flowchart (Figure 2). As opposed to the “standard” PDP flowchart, which only depicts chapters and sections of the PDP manual in a linear fashion, the Odessa District PDP flowchart contains work elements and decision points. Some Odessa District work elements are similar to the PDP manual flowchart, but not all elements map directly or follow the same sequence. For example, the Project Concept Conference & Develop Programming Estimate in the Odessa District PDP flowchart is analogous to the “standard” PDP flowchart Preliminary Design Conference. Similarly, the Design Concept Conference and Update Preliminary Estimate in the Odessa District PDP flowchart are analogous to the “standard” PDP flowchart Design Conference. In general, while the “standard” PDP flowchart follows a quasi-swim-lane diagram structure, the Odessa District PDP flowchart does not group activities by functional area. The Odessa District PDP flowchart provides numerical codes for every activity, but the codes do not match those in the “standard” PDP manual (10).

According to district officials, most projects at the Odessa District are relatively straightforward projects that do not involve components such as environmental clearance, retaining walls, ITS, or bridges. As opposed to larger districts, the Odessa District typically handles project design work in house. District personnel routinely take multiple roles in the development of a project, which is typical for rural districts. At the Odessa District, it is not unusual for area engineers to function as project managers from project authorization to construction. There are exceptions, e.g., in the case of large projects that require specialized planning activities, in which case different groups handle planning and design activities. Likewise, district headquarters normally handles survey and ROW acquisition activities. With increasing project regulations, many of which affect planning, the district is increasingly using consultants to tackle planning activities.

Other PDP Implementations

Other TxDOT units have also developed customized versions of the PDP process and flowchart to suit their business processes. For example, to organize utility adjustment and subsequent reimbursement activities, the ROW Division encourages the use of the Utility Cooperative Management Process (UCMP) (22). This process defines authorities and responsibilities for related procedures and aims to improve utility adjustment accounting procedures. Figure 4 shows a schematic view of that process.

A component of the UCMP is the utility adjustment subprocess, which includes four separate adjustment procedures: Federal Utility Procedure (FUP), State Utility Procedure (SUP), Local Utility Procedure (LUP), and Non-reimbursable Procedure (NRP). The main differences between procedures are with regard to contracts and responsibilities between TxDOT, local participating agencies (LPAs), and utilities, in addition to reimbursement rules and eligibility.



Notes: "Early," "typical," and "late/occasional" signify the phase when utility conflict detection normally occurs.

Figure 4. TxDOT Utility Cooperative Management Process (Adapted from [22]).

Similarly, the environmental process covers activities associated with the development of environmental documentation needed during the project development process (23). A summary of those activities follows:

- **Preliminary office research.** The district environmental coordinator (EC) identifies the project purpose and need, scope, and preliminary alternatives. The EC also researches the project area using data such as available maps, databases, and survey data.
- **Field survey.** The EC uses field surveys to review existing land use, water resources, and the potential for endangered species habitat, historic and/or archeological sites, hazardous material sites, and other environmental issues that may affect project development.
- **Early coordination.** The EC coordinates with county, state, and federal resource or regulatory agencies.
- **Public involvement.** The district conducts public meetings to solicit input on the proposed project and proposed alternatives.

- **Detailed engineering and environmental analysis.** The district develops schematic alternatives for the proposed project and evaluates permit and mitigation requirements for alternatives.
- **Environmental document preparation.** Depending on the results of the previous two steps, the district prepares the necessary environmental documents, which in most cases are a Categorical Exclusion (CE) and/or an Environmental Assessment (EA). Projects requiring additional environmental assessment may include the preparation of an Environmental Impact Assessment (EIA) or an Environmental Impact Statement (EIS).
- **Environmental review.** The Environmental Affairs Division completes this review.

TxDOT’s goal is to complete the environmental process prior to the beginning of the engineering design phase. Due to unforeseen circumstances or a compressed letting schedule, the environmental process may stretch into the engineering design phase. Whenever possible, TxDOT tries to avoid this situation because a negative outcome of the environmental process can have a significant impact on project design and/or delivery, therefore increasing TxDOT’s risk. In addition, TxDOT does not want to convey the message that it might be “rubber-stamping” the environmental process by developing detailed design plans concurrently with or before completing the environmental analysis.

DATA MANAGEMENT-RELATED PRACTICES AND PLANS

Document Archival Processes

TxDOT has well defined project-based hardcopy data archival and retention practices required under the Texas Administrative Code (24). The State of Texas Records Retention Schedule for the Texas Department of Transportation (25) and the District Record Copy Responsibility List (26) document data archival requirements and practices.

The Texas Records Retention Schedule (25) documents retention periods, security codes, archival location, and medium (e.g., paper, microfilm, computer printout, electronic, or other) of record classifications for a given division, section, or district. A code with an optional number (e.g., “AC+4,” where “AC” represents terminated or completed, and “4” indicates number of years) notes document retention periods. In general, TxDOT scans documents and archives the corresponding digital images. Except for specific documents (25), TxDOT destroys the original hardcopy documents. Table 6 lists division document files TxDOT divisions need to retain for the life of the asset or keep permanently.

The District Record Copy Responsibility List (26) is similar to the Texas Records Retention Schedule for TxDOT but only indicates retention periods for record types at the district level. The list makes a distinction between vital records, which are the first records to recuperate after a disaster, and non-vital records. Table 7 shows a summary of records districts need to retain.

Table 6. Documents TxDOT Divisions Need to Keep for the Life of the Asset or Permanently (Adapted from [25]).

TxDOT Division	Document
Bridge	Gauging station records and other instrumentation attached to bridges Bridge design exceptions Bridge special inspection reports Bridge inspection database Bridge project drilled shaft and pile driving records Statewide standard drawing file
Design	Design exception files
Information Services	Aerial photography files
Right of Way	Non-ROW acquisitions Selected records in Final ROW project files containing ROW conveyances and judgments, final ROW maps, title insurance policies, or other instruments pertaining to the state's title to land or interests
Traffic Operations	Railroad agreements and exhibits pertaining to specific crossing projects and railroad spur tracks crossing state highways

TxDOT typically retains construction project records for four years after closing a project (normally after the engineer in charge has accepted delivery of the finished construction project). The archival process includes the following activities (27):

- send Mylar[®] plans (construction, change orders, and as-builts) to the Design Division;
- send a hardcopy of as-built plans back to the district;
- store district copy at the district planning or construction sections;
- scan Mylar plans and post scanned images on the Intranet using the Plans Online system (28) (note: scanned plans are also available on the TxDOT Internet but only for a short period of time during letting);
- shred Mylar plans;
- in Austin, retain hardcopies of the project proposal and contract for four years;
- at the district office, retain project folder, project certifications, permits, and in-house/consultant electronic documentation for four years; and
- at the district office, retain hardcopies of as-built plans permanently.

In the case of electronic records, both the Texas and district retention schedules require the retention of documents for a minimum of four years after project closing (24). Retention of electronic documents beyond the minimum number of years varies based on district, office, and project manager practices. With new and anticipated initiatives such as FileNet and ProjectWise, described in subsequent sections, it is likely that electronic document management at TxDOT will become more structured, thereby facilitating project information access, querying, and reporting.

Table 7. Documents TxDOT Districts Need to Retain (Adapted from [26]).

District Section/Area	Document
Accounting and Fiscal Records	Federal grant information
Administrative Records	Administrative correspondence Performance measures documentation Agency rules, policies, and procedures Performance bonds Tort claim records maintained in district offices
Bridge Operations	Records related to agreements with local participating agencies for bridge and other projects Records related to Waiver of Local Match Fund Participation requirements for off-system bridge projects Consultant contract files Consultant contract procurement file Design waiver records Bridge folders containing the original bridge inventory report, map, sketches, initial and subsequent inspection reports, appraisal worksheets, National Bridge Inventory (NBI) printout, and so on. Documents and exhibits that support railroad agreements related to grade separation projects (not vital) Historic bridge project records (not vital) Bridge inspection summary reports (not vital)
Design, Engineering, and Construction Records	Building construction project files Building plans and specifications Bridge engineering records
Design Records	Consultant contract files Consultant contract procurement file Design waiver/variance records (not vital)
Maintenance/Facility Management Records	Agreements and permits Maintenance safety: local disaster plan Radio base station and mobile licenses Adopt-a-Highway agreements and documentation Certificates of insurance for maintenance projects Maintenance project contract files managed in districts District buildings plans and records Traffic signal maintenance files (not vital)
Maintenance Section/Operations Records	Maintenance contract records Documentation of “Watch for Ice on Bridge Signs” Records related to underground storage tanks and aboveground storage tanks (not vital) Underground storage tank subsystems (not vital)
Transportation Planning and Development Records	Federal Transit Authority Public Transportation Grant Program files for equipment and facilities (not vital)
Right of Way Records	ROW project files for state, federal, and local participating agency ROW acquisition Non-ROW acquisitions District ROW leasing files Utility Agreements Outdoor advertising sign permit files
Traffic Operations Records	Traffic management project records for projects done by contract forces

Note: Records in bold represent district documents retained for the life of the asset or kept permanently.

PDP Supporting Information Systems

TxDOT uses a variety of information systems to support the project development process. As an illustration, this section describes the Design and Construction Information System, the Right of Way Information System (ROWIS), and the Texas Reference Marker (TRM) System.

Design and Construction Information System

TxDOT uses DCIS to track projects throughout the project development process (29). DCIS includes a large number of project, contract, and utility screens that enable authorized users to complete data inputs and updates and run queries and reports. The screens cover a wide range of topics, including project identification and evaluation data, project planning and finance data, project estimate data, and contract summary data.

DCIS runs on an Adabas non-relational database platform. There are several files in Adabas that handle data needed for DCIS (30), including File 121 (DCIS-PROJECT-INFORMATION), File 122 (DCIS-WORK-PROGRAM), File 123 (DCIS-PROJECT-ESTIMATE), and File 124 (DCIS-CONTRACT-LETTING). DCIS also relies on a Tables and Characteristics System (TACS) that contains lookup codes and corresponding names and descriptions for a wide range of fields. Examples include control section, county number, manager number, project class, work program number, apportionment code, category, function code, and city code. DCIS uses the control section job (CSJ) number to identify projects uniquely. Table 8 shows a sample of fields in DCIS Files 121, 122, 123, and 124.

Over the years, TxDOT has developed online and/or batch linkages between DCIS and other TxDOT systems. Examples include the Bid Analysis Management System/Decision Support System (BAMS/DSS), the Bid Proposal System (BPS), the Contract Tracking System (CTS), the Subcontractor Monitoring System (SMS), the Construction and Maintenance Contract System (CMCS), and the Environmental Tracking System (ETS). Districts have also developed systems that connect to DCIS. Typically, the connection is a read-only connection, where a batch process downloads data from DCIS on a regular basis, e.g., every night. For example, the Corpus Christi District's Highway Project Task Management System (HPTMS), which runs on a Microsoft® Access™ relational database platform, downloads data from DCIS using Statistical Analysis Software (SAS®) scripts. In addition to presenting DCIS-generated project data to users, HPTMS tracks preliminary engineering, environmental assessment, ROW, PS&E, and plan review tasks by completion date, hours, and percent complete. HPTMS does not have a graphical user interface with the ability to display plans or data on maps.

The San Antonio District also uses HPTMS with the San Antonio District Construction Office (DCO) database (also called the SAT Construction Project Database) (31). The DCO database tracks items such as change orders, subcontractors, final estimate processing times, claims/disputes, and contract acceleration strategies. District officials enter most of the data in DCO manually, except for pre-construction data, which they download from HPTMS. The district makes the data available to district users using a read-only version of the database. The San Antonio District plans to extend the DCO database to transfer data from SiteManager™.

Table 8. Sample DCIS File Fields.

File 121 (DCIS-PROJECT- INFORMATION)	File 122 (DCIS-WORK- PROGRAM)	File 123 (DCIS-PROJECT- ESTIMATE)	File 124 (DCIS-CONTRACT- LETTING)
COMMON-DATA	WORK-PROGRAM	COMMON-DATA	COMMON-DATA
CONTROL-SECT-JOB	CONTROL-SECT-JOB	CONTROL-SECT-JOB	CONTRACT-CSJ
DISTRICT-NUMBER	DISTRICT-NUMBER	LAST-REVISION	LAST-REVISION
LAST-REVISION	DATE-LAST-REV	USER-LAST-REV	DATE-LAST-REV
DATE-LAST-REV	TIME-LAST-REV	DATE-LAST-REV	TIME-LAST-REV
TIME-LAST-REV	TOTAL-DATA	TIME-LAST-REV	RECORD-TYPE
REQUIRED-ID-DATA	FIS-YEAR	PLANS-ESTIMATE-DATA	BIDITEM-SUMMARY-DATA
COUNTY-NUMBER	YEARS-ACTIVE	LINE-NUMBER	BIDITEM-SEQUENCE-NO
HIGHWAY-NUMBER	TOTAL-OBLIG-AMT	CARD-TYPE	ALTERNATE-GROUP-NO
PROJ-LENGTH	TOTAL-ALLOC-AMT	ALTERNATE-GROUP-NO	BIDITEM-NO
CATEGORY	DISTRICT-ARRAY25	BIDITEM-SPECPROV	BIDITEM-DESC-CODE
ELIG-FED-FUND	DIST-ALLOC-AMT	BIDITEM-NO	SPECIAL-PROV-NO
PROJ-CLASS	DIST-OBLIG-AMT	BIDITEM-DESC-CODE	SPECIAL-ACCT-NO
MANAGER-NUMBER	CZ-FILLER-FIELD	SPECIAL-PROV-NO	QUANTITY
EST-CONST-COST	STATE-TRANS-IMPRV-PGM- GRP	BIDITEM-REF-NO	ESTIMATED-PRICE
DATE-EST-COST	STIP-MPO-CODE	SPCL-000-PROV-TEXT	DUP-PRICE-INDICATOR
AUTO-LINE-NUMBER	STIP-FY	SPECIAL-ACCT-NO	BIDDER-CONTROL-DATA
TYPE-OF-WORK	STIP-PROJECT-ID	ENG-QUANTITY	BIDDER-SEQNO
LIMITS-FROM	STIP-PROJECT-NBR	ENG-ESTIMATE-PRICE	TOTAL-BID
LIMITS-TO	STIP-PHASE-CODE	UNIT-PRICE	VERIFY-CODE
LAYMAN-DESCRIPTION1	STIP-FEDERAL-COST-PCT	BIDITEM-FLAG	BIDDER-RANKNO
LAYMAN-DESCRIPTION2	STIP-STATE-COST-PCT	BIDITEM-DESCRIPTION	INCOMPLETE-FLAG
BEG-MILE-POINT	STIP-LOCAL- CONTRIBUTIONS-AMT	UNIT-WORK	VENDOR-NOS
END-MILE-POINT	STIP-LOCAL-COST-PCT	COMMENT	BI-SEQNO-DISCREP31
OPTIONAL-ID-DATA	STIP-EST-CONSTRUCTION- AMT	CATGWORK-DESC	BIDITEM-ALT-FLAG9
CONTRACT-CSJ	STIP-FUNCTIONAL-CLASS- CODE	CATGWORK-MILES	BIDITEM-ALT-FLAG
PROJ-SUSP	STIP-STATE-CATEGORY-CODE	FUND-SOURCE-GROUP3	BIDITEM-DETAIL-11
PRIORITY-CODE	STIP-DISTRICT-EST-LET-DATE	FUND-SOURCE	UNIT-PRICE
PDP-LET-DATE	STIP-EXISTING-LANE-AMT	PERCENT-PART	BID-AMOUNT
DIST-LET-DATE	STIP-PROPOSED-LANE-AMT	BRIDGE-COST-DATA	ALTERNATE-GROUP
ORIGINAL-PLANNED-LET- DATE	STIP-PROJECT-LENGTH-MEAS	BRIDGE-LENGTH-EXISTING	BI-INCOMPLETE-FLAG
DIST-LET-CHANGES-NBR	STIP-LOCATION-FROM-DESC	BRIDGE-LENGTH-PROPOSED	CONTRACT-SUMMARY
APPRVD-LET-DATE	STIP-LOCATION-TO-DESC	BRIDGE-WIDTH-EXISTING	CONTRACT-NUMBER
ACTUAL-LET-DATE	STIP-LAYMANS-DESC	BRIDGE-WIDTH-PROPOSED	WORKING-DAYS
BACKLOG-PROJ	STIP-PROJECT-CMNT	BRIDGE-REMOVAL- BREAKBACK	LETTING-STATUS-CODE
EST-ROW-COST	STIP-REVISION-DATE	OLD-NBI-NUMBER	RECEIVED-UNTIL-TIME
DATE-EST-ROW	STIP-LOCK-FLAG	NEW-NBI-NUMBER	RECEIVED-UNTIL-DATE
RA-FLAG	STIP-IMPLEMENT-AGENCY- CMNT	BRIDGE-WORK-TYPE	ENGINEER-INFO
OTHER-PART	STIP-PROGRAM-COST	OLD-BRIDGE-TYPE	ENG-NO
PROJECT-NUMBER	STIP-APPORTIONMENT-CODE	NEW-BRIDGE-TYPE	ENG-NAME
CONST-COMP	STIP-FEDERAL-COST-TOTAL	ROADWAY-CLEAR-WIDTH	ENG-ADDRESS
PSE-COMP	STIP-STATE-COST-TOTAL	BRIDGE-NAME	ENG-CITY
ROW-COMP	STIP-LOCAL-COST-TOTAL	BRIDGE-SYSTEM-ID	ENG-ZIPCODE
HIGHWAY-SYSTEM	STIP-PROJ-LENGTH-METRIC	BRDG-COST-GRP	ENG-PHONE
REMARKS	STIP-FHWA-APPROVAL-DATE	BRDG-LENGTH	MBE-WBE-FLAG
MISCELLANEOUS-FIELDS	MINUTE-ORDER-GRP	BRDG-NBI-NUMBER	PROPOSAL-GUARANTY-AMT
DIST-ENG-EST	MINUTE-ORDER-NBR	BRDG-WORK-TYPE	WAIVER-FLAG
D8-ENG-EST	MINUTE-ORDER-DATE	BRDG-TYPE	DIVISION-RESPONSIBLE
MISC-COST	MINUTE-ORDER-REMARKS	BRDG-SYSTEM-ID	INCLUDED-PROJECTS191
PROJ-BID-AMOUNT		BRDG-DECK-AREA	COMBINED-FLAG191

According to TxDOT officials, TxDOT is planning to convert DCIS to a relational database platform. As part of this process, TxDOT developed a preliminary data model and corresponding data dictionary for File 121. TxDOT is also looking at other potential strategies,

e.g., the implementation of an Adabas replicator. In the short term, development of the current DCIS implementation continues. For example, because of SAFETEA-LU requirements for states to provide adequate project financial integrity, delivery, and oversight (4), TxDOT is implementing a total project cost initiative, where districts are becoming responsible for all the cost components of a project. To support this effort, DCIS recently underwent modifications to display total project cost estimates on DCIS screens.

Right of Way Information System

The ROW Division implemented ROWIS in 1997 to track and report financial data associated with the ROW acquisition process (32). The system enables users to track ROW parcel development and fee appraiser work orders during events such as negotiations, settlements, or eminent domain proceedings. The ROW Division also uses ROWIS to track reimbursable utility agreement payments.

ROWIS runs on a Microsoft Structured Query Language (SQL) Server™ database platform. The system interface includes screens that display data on topics such as projects, parcels, tasks, owners, CSJs, minute orders, and public agencies. ROWIS lacks the ability to display ROW parcels and utility-adjustment data on a map or link to plans that show that information.

Texas Reference Marker System

TRM is a mainframe-based system that documents physical and performance characteristics of the state-maintained highway network using the statewide reference marker network (Figure 5) as a geo-referencing tool (33, 34). With TRM, the location of features on the ground is defined in terms of mileage displacement from the nearest marker. TRM is centerline based, although it does provide for the identification of features on either side of the centerline. Although TRM relies on displacement from markers as the mechanism to reference features to the highway network, the system also enables the calculation of cumulative distances by using the relative location of the markers along the highway network. This conversion enables the production of maps documenting feature locations and characteristics in a GIS environment.

TRM is currently the major repository of state highway network and associated data. Examples of roadway attribute data include annual average daily traffic (AADT), classification, surface type, location of features (e.g., culverts, signs, and streams), and administrative data (e.g., county and district). Several data attributes in TRM are directly relevant to this research, including ROW width, surface width, roadbed width, and section length. TPP produces a variety of data files based on TRM, e.g., the RHiNo file, the Point file, the GEO-Point file, the GEO2-HINI file, and the TRM end-of-year (TRMEOY) file. Likewise, several TxDOT asset management systems rely on TRM data, e.g., the Pavement Management Information System (PMIS), the Highway Performance Management System (HPMS), and the Bridge Information System. TxDOT also relies on TRM data for the production of traffic count maps (33), which is a core data source for highway project development. These systems produce roadway assessment and status data that divisions and districts use through customized mapping applications.

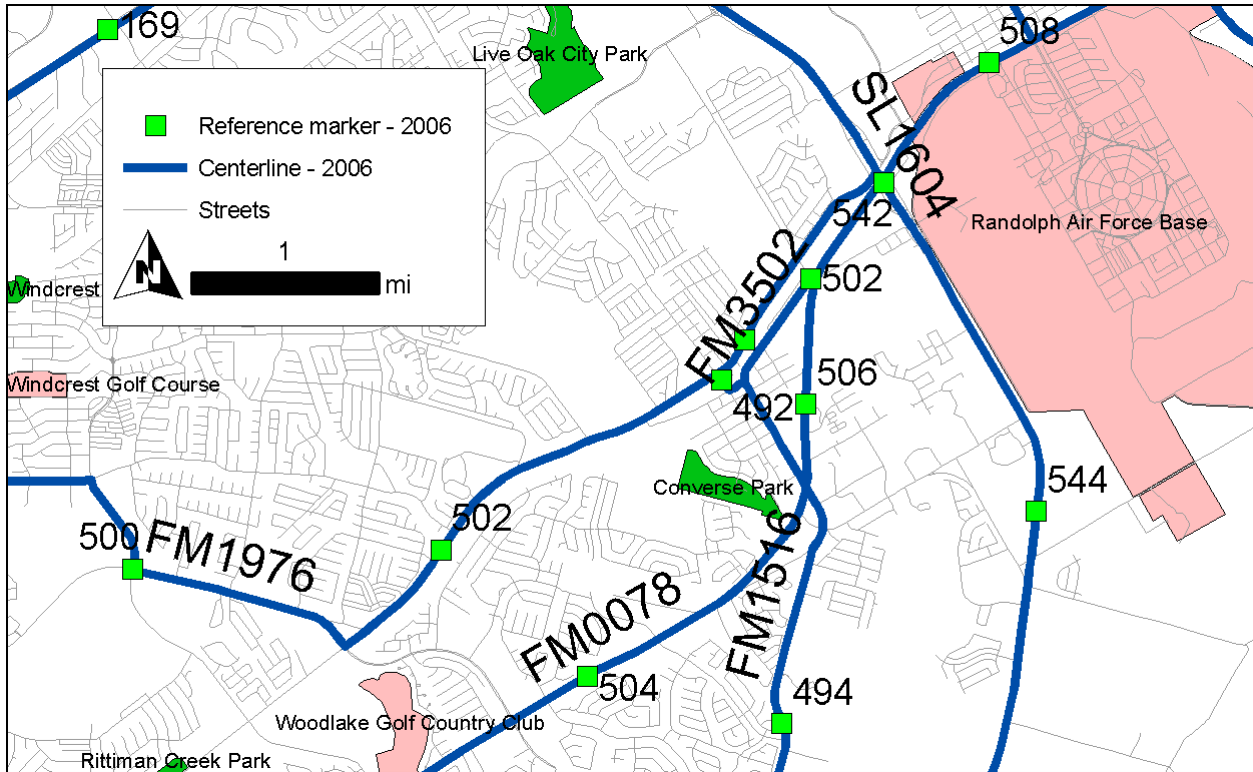


Figure 5. Reference Markers (Green Dots) on the State Highway Network (in Red).

While TRM provides data for a wide range of reporting options, the structure and characteristics of the data have shortcomings that limit the usability of the system, particularly during the project development process. For example, TRM is centerline based, which means the positional accuracy of any feature or measure (such as ROW width, roadbed width, or beginning and ending project limits) cannot be better than the positional accuracy of the underlying centerline map. The lateral positional accuracy of the official TxDOT centerline map varies by location, from a few feet in most cases to much larger values where 100 feet or more are not unusual. TRM is also cumulative distance dependent, which means the positional accuracy of any feature or measure cannot be better than the longitudinal positional accuracy of *both* reference markers and the underlying centerline map. Although reference markers are supposed to be permanent features on the ground, the reality is frequently quite different. As a result, it is very difficult to determine the actual location of features using cumulative distances alone.

As an illustration, [Figure 6](#) shows the location of reference marker 492 along FM 1516. Although the reference marker is physically attached to a sign on the roadside – and TxDOT has begun to collect coordinate data for reference markers using global positioning system (GPS) receivers ([34](#)) – in practice, it is as if the reference marker had been located on the map representation of the centerline of FM 1516. The reason is that in TRM all measures are given as displacements from the nearest reference marker *along* the highway centerline. As a result, in TRM, all the signs, pavement markings, and other features appear to be located on the centerline, even if they are physically located on either side of the road.

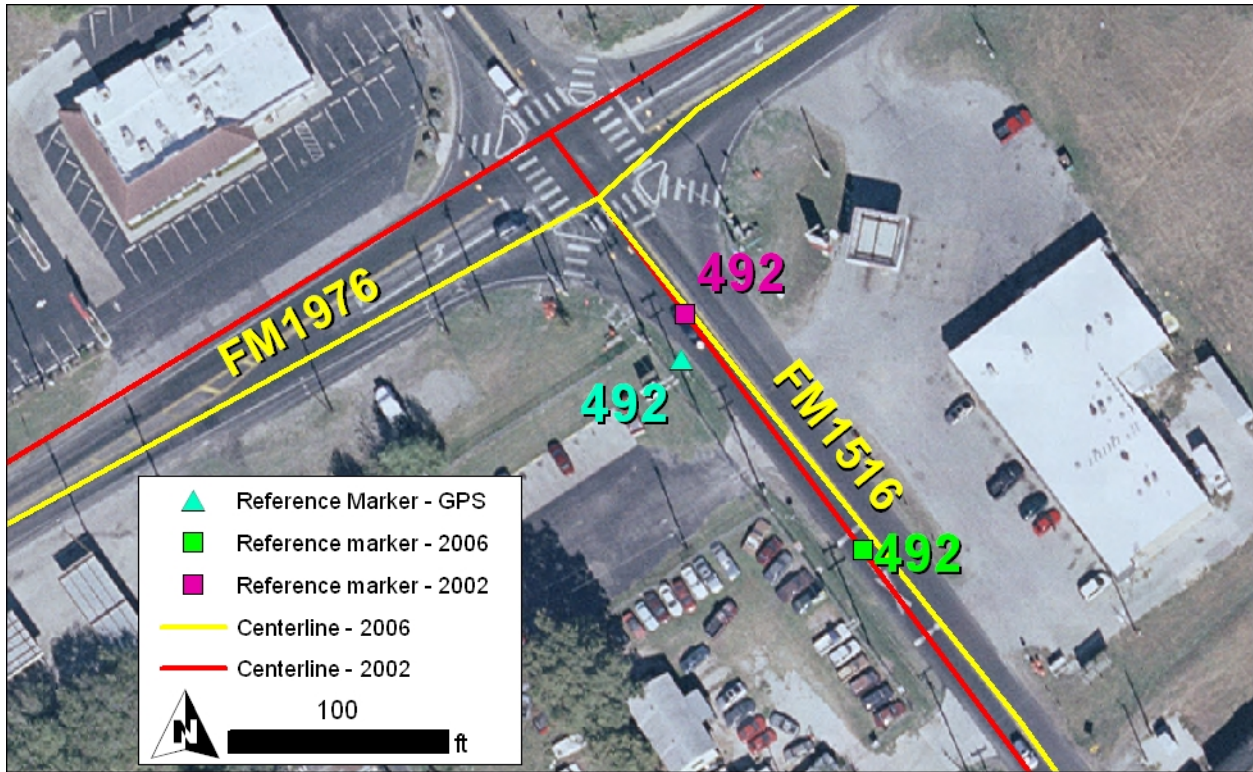


Figure 6. Reference Marker 492 on FM 1516.

If the cumulative distance associated with a reference marker along the centerline of a route is “correct” (i.e., the only error in the location of the reference marker is due to the lateral displacement between the reference marker and the roadway centerline), the error associated with any measure would also be limited to lateral displacement effects. In practice, since it is common to define reference markers in terms of cumulative distances along the roadway centerline – and there may be measurement errors associated with longitudinal distances – the total potential location error could be much larger. Figure 6 contains two representations of the TxDOT centerline network (years 2002 and 2006) and two corresponding representations of reference marker 492. As a reference, Figure 6 also shows the actual location of reference marker 492 on the ground (collected with a meter-level GPS receiver). In the year 2002 version, the attribute table shows the reference marker as being 0.02 miles (106 feet) from the beginning of FM 1516. In the 2006 version, the attribute table shows 0.046 miles (243 feet) from the beginning of FM 1516. However, both reference marker points are displayed on the same horizontal alignment as the 2002 centerline map, which suggests the use of a route event in Environmental Systems Research Institute® (ESRI) Arc Geographic Information System™ (ArcGIS) (using the 2002 centerline dataset) to generate both reference marker GIS features. Notice further that in the 2006 version the beginning of FM 1516 is offset 38 feet relative to the 2002 version. In the absence of relevant metadata, it is not possible to explain why the reference marker moved 0.026 miles (137 feet) from the year 2002 location to the year 2006 location. It is also not possible to explain why the 2006 version of the reference marker was not defined relative to the 2006 version of the centerline map.

Document Management Systems (DMS)

With the enormous amount of data that TxDOT manages in a variety of data formats with varying levels of accuracy and resolution, TxDOT divisions and districts have recognized a growing need to implement electronic document management strategies to address the issue of decreasing file room space. As a result, several districts and divisions have implemented (or are in the process of implementing) systems to manage data. As an illustration, this section describes FileNet[®], ProjectWise[®], the San Antonio and Odessa Districts' file management approaches, and Plans Online.

FileNet

Currently, most TxDOT districts and divisions follow ad-hoc procedures to manage electronic documentation. In 1996, the Houston District started using FileNet to track construction project as-built drawings, PS&E documents, and correspondence. FileNet is an enterprise document management system (EDMS) that enables sharing and managing access to files, generating database records to keep track of every document processed, and producing queries and reports based on a number of attributes (35). TxDOT is currently implementing FileNet statewide and in several divisions (such as Motor Carrier, Motor Vehicle, Finance, and Occupational Safety). TxDOT's goal is to implement FileNet separately for each business unit within the organization.

In the TxDOT implementation, the system stores document-related data in a centrally located Microsoft SQL Server database. The database also contains pointers to files that are physically stored on a dedicated server at every business unit where TxDOT has implemented FileNet. Users interact with FileNet through an interface similar to the Microsoft Windows Explorer[®] interface, with additional functionality such as viewing current file users, assigning file attributes or tags, querying, searching, and file versioning. Currently, TxDOT uses two FileNet configurations: a "thick-client" configuration (which involves the use of a special-purpose client application on user computers) and a "thin-client" configuration called TxDocsOnline (which is web based and uses an Internet Explorer browser to interact with the database and the FileNet file server). The TxDOT FileNet implementation does not support viewing GIS or CAD documents, although this functionality is possible through third-party programs (35). The web-based implementation at TxDOT is called TxDocsOnline.

In the TxDOT FileNet implementation, libraries represent the structure each business unit chooses to organize documents. For example, there is a library for Motor Carrier Division documents, a separate library for Finance Division documents, and so on. There is also a library for districts (organized around functional areas), which TxDOT developed using lessons learned from the Houston District's experience with FileNet. The Houston District organized its FileNet implementation around projects. According to TxDOT officials, one of the reasons to develop a "standard" district library around functional areas instead of projects was that a structure based on functional areas could reduce document redundancy more effectively. A potential disadvantage of this approach is the risk of losing the "natural" linkage that exists among documents that pertain to the same project. To reduce this risk, the CSJ number is a mandatory attribute for project-related documents in FileNet.

Following the Electronic Document Technologies Implementation and Support (EDTIS) Project Content Services library standards, FileNet uses document classes, record types, and document types to organize documents in libraries (36, 37). Document classes represent the highest folder aggregation level, with one document class per library (Table 9). Document classes have record types, and record types have document types (Table 10). In addition, documents have a pre-defined set of attributes, which could vary by library (Table 11). Each document class, record type, and document type has a numerical code (e.g., 12 for document class “Project Design,” 1 for record type “Bridge Engineering Reference,” and 1 for document type “Computer Graphic”). The combination of the three numerical codes is a unique file code (e.g., 12.1.1) that represents a unique document class/record type/document type combination. Notice that the relationship between document classes and their corresponding numerical codes is one to one. However, the same is not necessarily true for record types or document types, where the same record type or document type in different document classes may have different numerical codes. This situation prevents the use of generic lookup tables to index record types and document types.

Table 9. Document Classes in the TxDOT FileNet Implementation (Adapted from [36]).

Document Class Code	Document Class	Document Class Code	Document Class
1	Administrative	10	Information Systems
2	Advance Project	11	Maintenance Operations
3	Construction	12	Occupational Safety
4	Contracts Leases and Agreements	13	Project Design
5	Environmental Affairs	14	Purchasing and Warehouse
6	Equipment and Facilities	15	Right of Way
7	Finance	16	Traffic Operations
8	Human Resources	17	Transportation Planning
9	Incoming Mail	18	Travel and Public Information

Note: TxDOT is currently revising the EDTIS library standards (38).

Table 10. Project Design (Document Class 12) Record Types and Document Types (Adapted from [36]).

Document Class	Record Type	Document Type	File Code
Project Design	Bridge Engineering Reference	Computer Graphic	12.1.1
Project Design	Bridge Engineering Reference	Drainage Notes and Calculations	12.1.2
Project Design	Bridge Engineering Reference	Foundation Drilled Shaft or Pile	12.1.3
Project Design	Bridge Engineering Reference	Geotechnical Notes and Calculations	12.1.4
Project Design	Bridge Engineering Reference	Hydraulic Notes and Calculations	12.1.5
Project Design	Bridge Engineering Reference	Mill Test Report	12.1.6
Project Design	Bridge Engineering Reference	Schematic	12.1.7
Project Design	Bridge Engineering Reference	Shop Drawing	12.1.8
Project Design	Bridge Engineering Reference	Standard Drawing	12.1.9
Project Design	Bridge Engineering Reference	Structural Notes and Calculations	12.1.10
Project Design	Bridge Engineering Reference	Working Drawing	12.1.11
Project Design	Bridge Folders and Inspections	Bridge Inspection Follow Up Action Worksheet	12.2.1
Project Design	Bridge Folders and Inspections	Bridge Inspection Photo	12.2.2
Project Design	Bridge Folders and Inspections	Bridge Inventory Record	12.2.3
Project Design	Bridge Folders and Inspections	Bridge Plan	12.2.4
Project Design	Bridge Folders and Inspections	Bridge Summary Sheet Off System	12.2.5

**Table 10. Project Design (Document Class 12) Record Types and Document Types
(Adapted from [36]) (Continued).**

Document Class	Record Type	Document Type	File Code
Project Design	Bridge Folders and Inspections	Cross Section	12.2.6
Project Design	Bridge Folders and Inspections	Drawing	12.2.7
Project Design	Bridge Folders and Inspections	Form 1085 Bridge Inspection Record	12.2.8
Project Design	Bridge Folders and Inspections	Form 1387 Bridge Appraisal Worksheet	12.2.9
Project Design	Bridge Folders and Inspections	Load Rating	12.2.10
Project Design	Bridge Folders and Inspections	Location Map	12.2.11
Project Design	Bridge Folders and Inspections	NBI Printout	12.2.12
Project Design	Bridge Folders and Inspections	Plan	12.2.13
Project Design	Bridge Folders and Inspections	Scour Reports and Photos	12.2.14
Project Design	Bridge Folders and Inspections	Sketch	12.2.15
Project Design	Bridge Folders and Inspections	Special Inspection Fracture Critical	12.2.16
Project Design	Bridge Folders and Inspections	Special Inspection Underwater	12.2.17
Project Design	Bridge Folders and Inspections	Structural Condition History Off System	12.2.18
Project Design	Bridge Folders and Inspections	Structural Condition History On System	12.2.19
Project Design	Bridge Folders and Inspections	Underclearance Sketch	12.2.20
Project Design	Bridge Folders and Inspections	Upstream Channel Cross Section Measurements	12.2.21
Project Design	Bridge Folders and Inspections	Upstream Channel Cross Section Sketch	12.2.22
Project Design	Design Engineering Reference	Cross Section	12.3.1
Project Design	Design Engineering Reference	Diary	12.3.2
Project Design	Design Engineering Reference	Drawing	12.3.3
Project Design	Design Engineering Reference	Drawing	12.3.3
Project Design	Design Engineering Reference	Environmental	12.3.4
Project Design	Design Engineering Reference	Materials	12.3.5
Project Design	Design Engineering Reference	Schematic	12.3.6
Project Design	Design Engineering Reference	Survey Book	12.3.7
Project Design	Design Policy	Design Policy	12.4.1
Project Design	Design Waiver and Exception	Exception	12.5.1
Project Design	Design Waiver and Exception	Variance	12.5.2
Project Design	Design Waiver and Exception	Waiver	12.5.3
Project Design	Letting Plans	Letting Plan	12.6.1
Project Design	Logs and Logbooks	Logbook	12.7.1
Project Design	Plans Specifications and Estimates	Addendum	12.8.1
Project Design	Plans Specifications and Estimates	Approval	12.8.2
Project Design	Plans Specifications and Estimates	Authorization	12.8.3
Project Design	Plans Specifications and Estimates	Environmental Clearance or Permit	12.8.4
Project Design	Plans Specifications and Estimates	Design Study	12.8.5
Project Design	Plans Specifications and Estimates	Estimate	12.8.6
Project Design	Plans Specifications and Estimates	Form 1002 PS&E Submission Data Sheet	12.8.7
Project Design	Plans Specifications and Estimates	Form 1814 Proposed Special Provision or Special Specification	12.8.8
Project Design	Plans Specifications and Estimates	General Notes	12.8.9
Project Design	Plans Specifications and Estimates	Plan	12.8.10
Project Design	Plans Specifications and Estimates	ROW Utility	12.8.11
Project Design	Plans Specifications and Estimates	Special Provision	12.8.12
Project Design	Plans Specifications and Estimates	Special Specification	12.8.13
Project Design	Plans Specifications and Estimates	Specification	12.8.14
Project Design	Project Records Non Construction	Correspondence	12.9.1
Project Design	Project Records Non Construction	Meeting Minutes and Notes	12.9.2
Project Design	Project Records Non Construction	Plan	12.9.3
Project Design	Project Records Non Construction	Report	12.9.4
Project Design	Project Records Non Construction	Working Paper	12.9.5
Project Design	Proposal Development	Acceptance	12.10.1
Project Design	Proposal Development	Advertisement	12.10.2
Project Design	Proposal Development	Bid Analysis	12.10.3
Project Design	Proposal Development	Bid Proposal Successful	12.10.4
Project Design	Proposal Development	Bid Proposal Unsuccessful	12.10.5

**Table 10. Project Design (Document Class 12) Record Types and Document Types
(Adapted from [36]) (Continued).**

Document Class	Record Type	Document Type	File Code
Project Design	Proposal Development	Bond and Insurance	12.10.6
Project Design	Proposal Development	Checklist	12.10.7
Project Design	Proposal Development	Child Support Form	12.10.8
Project Design	Proposal Development	Contract	12.10.9
Project Design	Proposal Development	Contract Award	12.10.10
Project Design	Proposal Development	Correspondence	12.10.11
Project Design	Proposal Development	Historically Underutilized Businesses (HUB) Form	12.10.12
Project Design	Proposal Development	Letter of Authority	12.10.13
Project Design	Proposal Development	Letting	12.10.14
Project Design	Proposal Development	Negotiation	12.10.15
Project Design	Proposal Development	Pre Bid Conference	12.10.16
Project Design	Proposal Development	Prequalification	12.10.17
Project Design	Proposal Development	Proposal Accepted	12.10.18
Project Design	Proposal Development	Proposal Rejected	12.10.19
Project Design	Proposal Development	Selection	12.10.20
Project Design	Working Papers	Working Paper	12.11.1

Table 11. Project Design (Document Class 12) Required and Optional Attributes (36).

Attribute Name	Display Name	Property Type	Required/Optional
Title	Title	System	Required
Record_Type	Record Type	Document	Required
Document_Type	Document Type	Document	Required
File_Code	File Code	Document	Required
Document_Date	Document Date	Document	Required
Document_Status	Document Status	Document	Required
Version_Status	Version Status	Version	Optional
Destruction_Date	Destruction Date	Document	Optional
Comment	Comment	System	Optional
Addressee_To	Addressee To	Document	Optional
CC	CC	Document	Optional
Ending_Date	Ending Date	Document	Optional
External_Document_Location	External Document Location	Document	Optional
Business_Function	Business Function	Document	Optional
Program_Project_Name	Program Project Name	Document	Optional
Project_Number	Project Number	Document	Optional
Consultant_Vendor	Consultant Vendor	Document	Optional
Organization_Entity	Organization Entity	Document	Optional
CSJ	CSJ	Document	Required
Roadway_or_Highway	Roadway or Highway	Document	Optional
County	County	Document	Optional
Limits_From	Limits From	Document	Optional
Limits_To	Limits To	Document	Optional
Type_of_Work	Type of Work	Document	Optional
Letting_Date	Letting Date	Document	Optional
CCSJ	CCSJ	Document	Optional

ProjectWise

Highway projects at TxDOT typically involve the development of MicroStation®-format files. Managing large numbers of MicroStation files effectively can be challenging in an environment where there may be many files that need to reference other files (which themselves can be active design files), while at the same time complying with TxDOT's CAD standards and procedures (including font library, resource file, plot files, seed files, and standard sheets [39]).

As part of the SH 130 design-build project in Central Texas, which has produced more than 30,000 files occupying more than 20 gigabytes of hard drive space (40, 41), TxDOT is evaluating the effectiveness of Bentley's ProjectWise in assisting with the management of MicroStation-format files. ProjectWise is an EDMS that specializes in the management and production of MicroStation files – although it also supports other file formats. As a client-server application, ProjectWise stores MicroStation files on a main server. A user edits a file by “checking out” the file from the server, which in practice means creating a local copy of the file and blocking write-access to the file by other users. After the user finishes editing the file, the system places the edited file back on the server, lifts the write-access block to the file, and deletes the local file. Like FileNet, ProjectWise manages files and provides querying and reporting capabilities. Unlike FileNet, ProjectWise includes tools and templates to automate the production of MicroStation files, including setting and enforcing project-specific templates, allowing integration of CAD standards, enforcing file naming conventions, and document creation wizards. ProjectWise also retains the structure of MicroStation reference files.

While ProjectWise is an EDMS, TxDOT sees ProjectWise as a special-purpose application to support the project development process, not as an eventual replacement for FileNet. As mentioned previously, TxDOT is currently evaluating ProjectWise, and it is therefore too early to know whether ProjectWise will become a standard tool for the department.

San Antonio District's File Management System (FMS)

Like other TxDOT districts, the San Antonio District found the need to develop standardized procedures to organize and manage project data more efficiently. Prior to the recent introduction of FileNet, the San Antonio District developed FMS as an arrangement of folders, files, and procedures to provide uniformity in project development and documentation (42). In general, FMS needs a manager to maintain the integrity of the project files. This manager reviews and incorporates all work into the primary files, maintains backups, and coordinates multi-user project development.

FMS stores all electronic files associated with a project in a root folder. The naming convention for project folders is as follows:

\Projects\

where <CSJ> represents the project CSJ number. As Table 12 shows, each CSJ folder contains 25 subfolders. In general, MicroStation files can be primary or secondary files. The ReferenceFiles subfolder includes primary files. Subfolders that are in uppercase (e.g.,

ROADWAY) contain secondary files. As [Table 13](#) shows, there are 11 primary file types for every project. Primary files are attached as references to the secondary files. To minimize erroneous modifications, only the file manager can access the primary files. The primary file naming convention is as follows:

<prefix><abbreviation>.<file extension>

where <prefix> is the roadway or project-specific area, <abbreviation> is the file abbreviation ([Table 13](#)), and <file extension> is the file extension. An example of a primary file name is IH410map.dgn.

Secondary files are the PS&E plan sheets. They may or may not require the use of primary files as references. The secondary file naming convention is as follows:

<prefix><abbreviation><sheet number>.<file extension>

where <prefix> is the roadway or project-specific area, <abbreviation> is the file abbreviation ([Table 14](#)), <sheet number> always begins with 01, and <file extension> is the file extension. An example of a secondary file name is IH410prj01.dgn.

FMS includes a starting library (LEVELS.dgnlib) for MicroStation level naming conventions, color, line style, and line weight. A list of line weights, line styles, and other drafting guidelines is available in the *PS&E Preparation Manual (12)* and online ([39](#)).

Odessa District's Project File Management Procedure

Until the recent introduction of FileNet, the Odessa District used a relatively simple arrangement of folders, files, and procedures for project documentation. Typically, there is a folder on a server for every project. Examples include:

\\CONTROL-SECTION-JOB HWY\
\\CONTROL-SECTION HWY\JOB NUMBER\

Each CSJ project folder contains a set of typical subfolders (e.g., Core Information, Plan Sheets, Preliminary, and Standards), but the subfolders are not standard (i.e., a user can add subdirectories). This simple arrangement will change as the Odessa District implements FileNet to manage project documents.

Table 12. San Antonio District File Management System Folders (Adapted from [42]).

Folder	Description
Batchplot	Batchplot
BRIDGE	Bridge design
Change Orders	Change orders
Correspondence	Project related letters, memos, etc.
PDP	Project development process correspondence documents grouped by stakeholder (utilities, project engineer, TxDOT, traffic management center, etc.)
ENV	Environmental correspondence documents
DRAINAGE	Culvert layouts, storm sewer layouts, hydraulic data, etc.
ENVIRONMENTAL	Storm water pollution preventions plans; Environmental Permits, Issues, and Commitments (EPIC) sheets
Estimate	Estimates
Preliminary	Preliminary estimates
File Structure	Level assignment (.dgnlib)
GENERAL	Title sheet, project layout, typical sections
GEOPAK	GEOPAK files
MISC	Landscape and irrigation layouts
Old Files	Files no longer needed are moved here rather than deleted
P3	Contract, time determination and schedules
Construction	Construction schedules
Design	Design schedules
Pavement Design	Pavement design
PS&E	Necessary paperwork for PS&E submission
ReferenceFiles	Primary files only
ROADWAY	Plan sheets and miscellaneous roadway details
Driveways	Driveway layouts, pictures of driveways
Standards	District standards included in PS&E package
Bridge	Bridge standards
Drainage	Drainage standards
Illumination	Illumination standards
Electrical	Electrical standards
Retaining Walls	Retaining walls standards
Roadway	Roadway standards
Signing	Signing standards
Pavement Markers	Pavement markers standards
SW3P	Storm Water Pollution Prevention Plan (SW3P) standards
TCP	Traffic control plan (TCP) standards
Traffic Signals	Traffic signals standards
TMS	Traffic Management System (TMS) standards
Summaries	Project summaries
Excel	Excel summaries for calculations and linking
Survey	Survey data
TCP	Traffic control plans, schedule of barricades and warning device
Phase I	Phase I of TCP
Phase II, etc.	Phase II, etc. of TCP
TRAFFIC	Illumination, sign, pavement markings, signal, and TMS layouts
UTILITY	Utility layouts
WALLS	Retaining wall layouts
Xsec	Cross sections

Table 13. San Antonio District Primary File Types (Adapted from [42]).

Primary File	Abbreviation	Purpose
Map	map	Existing topography
Roadway	rdwy	Surface improvements
Horizontal Alignment	haln	Horizontal control
Vertical Alignment	valn	Vertical control
Drainage	drn	Subsurface improvements
Utility	util	Existing and proposed utilities
TCP-SW3P	tcp-sw3p	Traffic control and pollution control items
Traffic	traf	Proposed pavement markings, signs, signals, and illumination
Border	bord	Sheet border with title block and legends
Pattern	patt	Patterns and/or shading to differentiate project aspects
Quantity Box	qbox	Linked plan sheet quantity boxes and summaries

Table 14. San Antonio District Secondary File Types (Adapted from [42]).

Folder	Abbreviation	Sheet Type	
GENERAL	TSH	Titlesheet	
	IND	Index of sheets	
	PRJ	Project layout	
	TYP	Typical section	
	SUM	Project summary	
TCP	TCP	Traffic control plan	
	BAR	Barricades and warning devices	
	ROADWAY	HC	Horizontal control data
		VC	Vertical control data
		PP	Plan and profile
PLN		Plan view	
PRF		Profile view	
WALLS	DET	Plan detail	
	RMV	Removal layout	
	RW	Retaining wall layout	
DRAINAGE	HYD	Hydraulic computations	
	DA	Drainage area layout	
	STR	Culvert layout	
	SD	Storm drain layout	
UTILITY	UTL	Utility layout	
BRIDGE	BRG	Bridge	
TRAFFIC	SIG	Signal layout	
	ILM	Illumination layout	
	SGN	Signing layout	
	PM	Pavement marking layout	
	TMS	Traffic management system	
ENVIRONMENTAL	SW3P	SW3P layout	
MISC	LS	Landscape layout	

Plans Online

Plans Online is a web-based application that TxDOT uses to manage the storage, archival, and delivery of project plans and related documentation to internal and external users (28). Project documents typically include letting, contract, and final/as-built plans; proposals; project addenda; and bid tabs. Internet access to Plans Online is limited to letting documents for construction and maintenance projects over a five-month period: the current month, the next month, and the prior three months. Plan sheets are available in two formats: tagged image file (TIF) and portable

document format (PDF). Internet access also includes post-letting bid tabulation and bid total data for a three-month period: the current month and the previous two months. By comparison, Intranet access to Plans Online is much more comprehensive and includes pre-letting, post-letting, and archived documents and data. TxDOT maintains a permanent archive of as-built plans (in digital format – TxDOT does not archive the original Mylar plans that divisions provide). In addition, TxDOT maintains a 10-year archive of letting database records.

Plans Online includes a Captaris Alchemy[®] viewer that enables users to browse through database contents in a folder hierarchy (Figure 7). The viewer also enables users to run queries by project attributes, document attribute fields, document content, file name, folder attribute fields, and document annotations. As a reference, Table 15 includes the list of project and document attributes in Plans Online. To populate these attributes, TxDOT follows a standardized procedure that involves scanning and indexing documents. For indexing, TxDOT uses optical character recognition (OCR) software to extract document titles from sheet index plan images. The process also includes manually cleaning these titles and importing the resulting data into the database.

Currently, TxDOT is evaluating platforms for upgrading Plans Online, including the implementation of a GIS-based interface to facilitate document querying and viewing.

Table 15. Plans Online Project and Document Attributes (28).

Project Attributes		Document Attributes
Controlling CSJ Number (CCSJ)	Limits From	Document Title
County Name	Limits To	File Name
District Name	Reference Marker From	Sheet Number
Job Type	Reference Marker To	CCSJ Number
Job Class	Description of Project	Letting Year
Other CSJs	Letting Month	Letting Month
Project Number	Letting Day	
Highway Number	Letting Year	

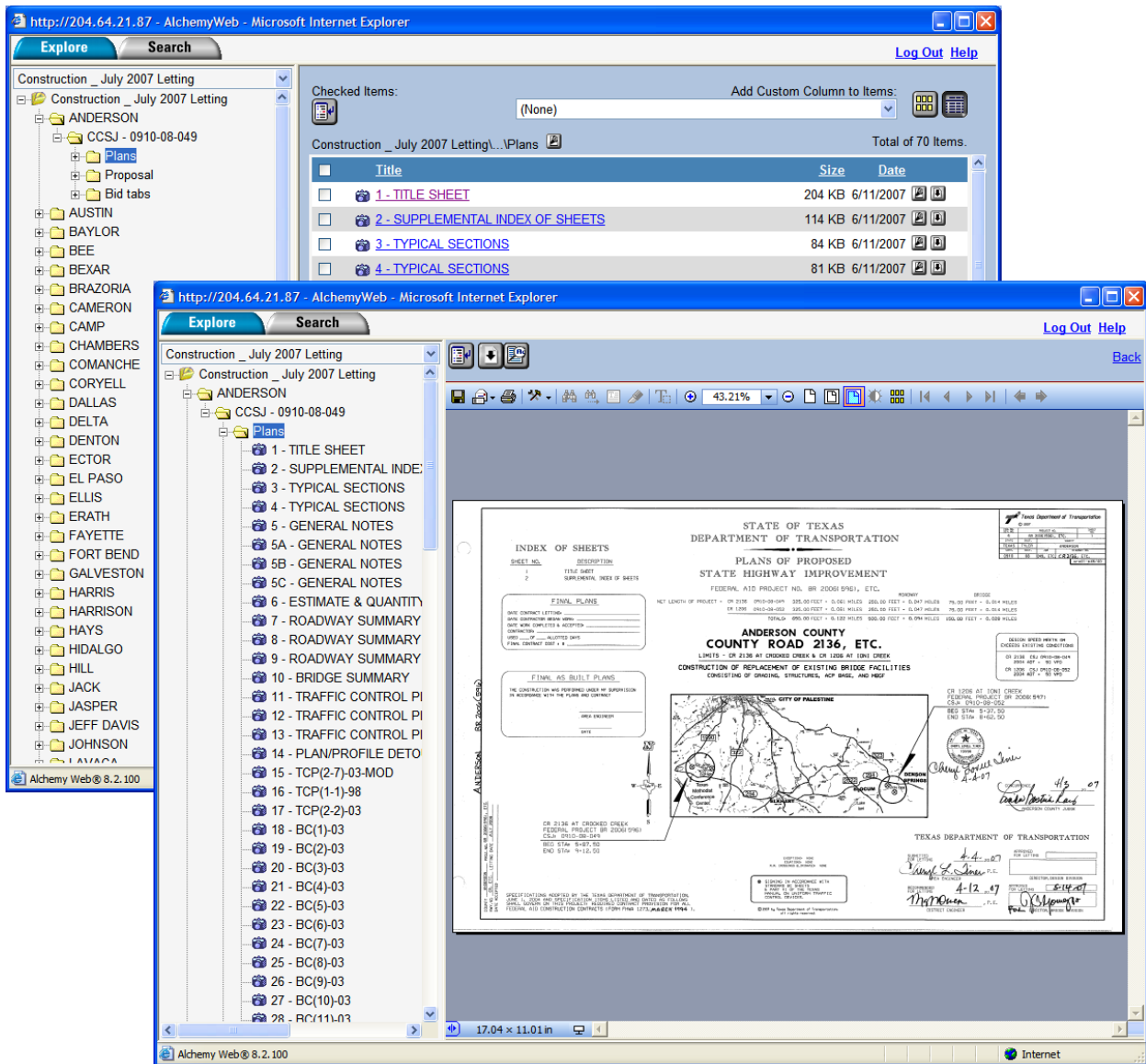


Figure 7. Plans Online Interface (28).

Data Architecture and Data Modeling Practices

Data architecture is “the manner in which data components are organized and integrated” (43). The TxDOT *Data Architecture Manual* documents standards for diagramming, data modeling, special standards for GIS data, and a process for integrating commercial-off-the-shelf (COTS) software with TxDOT data (43). 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 (44), 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 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. ISD creates and maintains TSIDs.

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 (45, 46). For example, through the Texas Strategic Mapping Program (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 the Texas Natural Resources Information System (TNRIS) (47). Table 16 provides a summary of production GIS datasets at TxDOT, with an indication of the source (TxDOT or other agency).

As mentioned previously, 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.

Table 16. Production GIS Datasets at TxDOT (48).

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

A significant development at TxDOT in recent years to improve spatial and temporal characterization of GIS datasets has been the “second generation” enterprise GIS framework called GIS Architecture and Infrastructure Project (GAIP) (49). The GAIP architecture replaces the traditional linear referencing method with another method called “dynamic location” (50). The traditional linear referencing 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 17 shows sample records in a route event table that could be used to generate both reference marker points in Figure 6. Notice the same basic structure could be used to generate linear segments (in this case, the To DFO attribute would not be blank).

Table 17. 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” entities tends to decrease, making data management more difficult. As an illustration, the TxDOT centerline dataset includes approximately 5500 route records. Each record in this dataset describes basic state route characteristics, e.g., name, class, prefix, suffix, and length. By comparison, the RHiNo file, which is one of several roadway inventory files TPP maintains, includes some 96,000 state highway records that cover 137 attributes and represent a wide range of items. Examples include reference marker displacement, highway status and type, functional class, maintenance responsibility, AADT for the previous 10 years, truck percentage, urban/rural status, shoulder width, median width, ROW width, roadbed width, posted speed limit, surface type and characteristics, and load limits. This level of segmentation can make the analysis of information as well as the production of queries and reports quite challenging.

With dynamic location, each data element of interest is managed independently through tables that contain both spatial and non-spatial attribute values that characterize each attribute record spatially and temporally. Because the tables contain the geographic extent of each data record through a shape field, it is no longer necessary to rely on event tables to generate those records, therefore facilitating the use of more accurate location techniques such as GPS or fine-resolution aerial photography to develop GIS data inventories. As an illustration, [Table 18](#) shows the structure of a dynamic location-compatible interpretation of the reference marker points in [Figure 6](#). Notice the table does not include attributes to describe the route and the corresponding location of the reference markers along the route. Strictly speaking, GAIP enables the calculation of those attribute values “on the fly” by applying spatial intersect joins that overlay the reference marker dataset to the centerline dataset and extract the route and corresponding cumulative distances.

Table 18. Dynamic Location-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, ROW, and geopolitical boundaries. As an illustration, [Figure 8](#) shows five roadside features: a pole, an aerial communication line, and three roadway signs. [Figure 8](#) also shows how GAIP would handle feature changes over time. When there is a feature change (either spatially or non-spatially), GAIP “retires” the old feature and, as needed, generates a new feature with new attribute values. Retiring a feature does not mean the system deletes the feature from the database. Instead, the system populates a time stamp field indicating the completion of the life cycle for that feature.

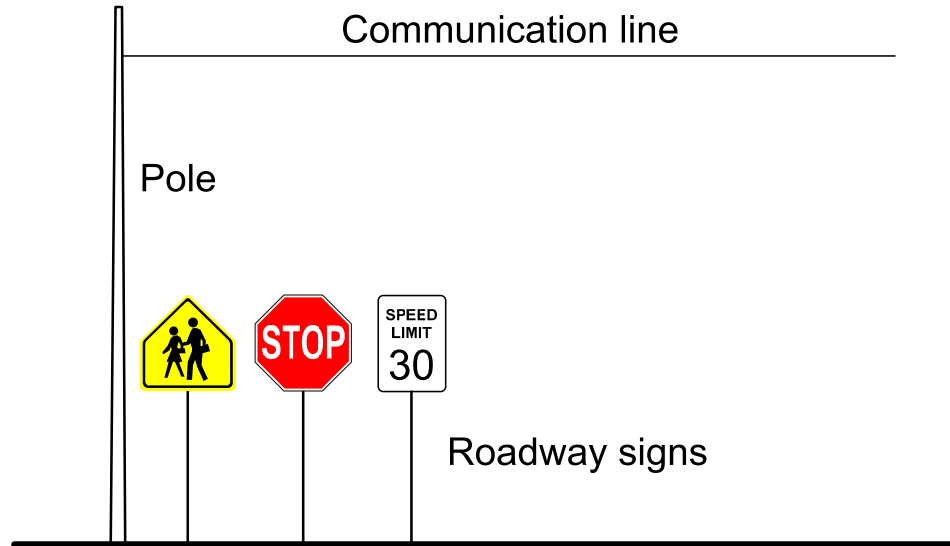
A key element of the GAIP architecture is the TxDOT network ground set (GS), which is composed of a cartographic set of centerlines and roadbeds ([49](#)). As a reference, the TxDOT Glossary defines centerlines and roadbeds as follows ([51](#)):

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 ([49](#)). 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 ([51](#)), the standard does not conform to established survey standards. As

a reference, the *TxDOT Survey Manual (52)* and the Texas Society of Professional Surveyors (TSPS) *Manual of Practice for Land Surveying in the State of Texas (53)* 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.



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 8. Conceptual Representation of Roadside Features in GAIP.

TxDOT classifies GS components according to jurisdiction, engineering function, and cartographic support, 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 19](#) 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 19. Ground Set and Linear Referencing System Attributes (Adapted from [49, 54]).

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
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. Some of the systems relevant to this research include the following:

- Main Street Texas (MST);
- Right of Way Map Locator;
- Survey Primary Control Markers; and
- Highway Condition Reporting System (HCRS).

Main Street Texas

MST is a web-based information system TxDOT is using to implement GAIP (55, 56). MST runs on the Genesis Enterprise Information Integrator (GENII)[™] (57), which is a web-based portal that enables spatial intersect and relational queries for the production of tabular and mapping reports. TxDOT envisions MST to become a basic platform for developing, managing, and serving GAIP-compliant GIS data to TxDOT users. TxDOT has incorporated a number of GIS-based datasets into MST, including bridges, roadbeds, ROW maps, recycled material facilities, and primary survey control points. MST runs on an Oracle database platform, both for spatial data (using ESRI's Arc Spatial Data Engine[®] [ArcSDE]) and non-spatial data.

Right of Way Map Locator

The Right of Way Map Locator is a web-based application that TxDOT developed to facilitate the delivery of copies of ROW maps to interested users (58). Traditionally, districts provide paper copies of ROW maps in response to internal or external inquiries. However, finding the correct ROW map(s) and making the corresponding paper copies can be time consuming. The web-based ROW map locator application automates this process by providing an interactive map that enables users to navigate and zoom to a specific control section. Clicking a point along a control section displays a list of ROW map image files the user can view, download, or print (Figure 9). Currently, the ROW map locator application includes ROW map image files from three TxDOT districts: San Antonio, Fort Worth, and Pharr. TxDOT is planning to extend the system statewide.

The ROW map locator application is GAIP compliant and is included in the MST portal. In the system, each ROW map is a separate object with spatial and non-spatial attributes. For the spatial component, TxDOT modeled the geographic extent of each ROW map by using a copy of the corresponding control section linear feature. Since from and to data were not readily available (it would be necessary to manually extract this information visually from each map), TxDOT decided to assume the geographic extent of each ROW map *was the same as* that of the corresponding control section. As a result, when users click a control section on the system interface map, the spatial intersect join query retrieves all the ROW map files associated with that control section, even if there is only one ROW map (or none at all) associated with the specific point that the user clicked. Notice further that the system does not store information to enable users to overlay ROW map images correctly. After downloading a file, users must

manually scale, rotate, and/or translate downloaded files in order to overlay those files in a CAD or GIS environment.

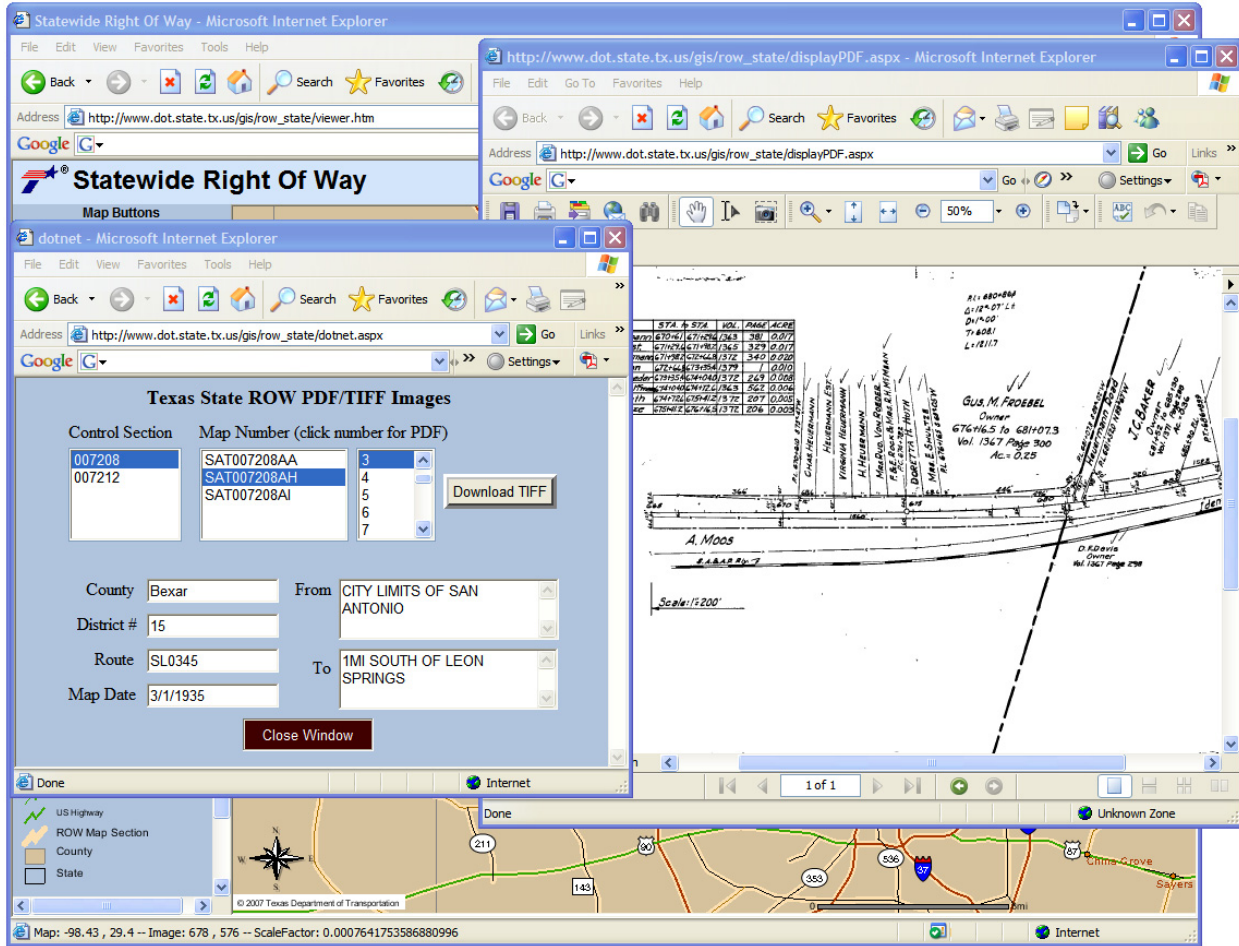


Figure 9. Right of Way Map Locator Interface (58).

Survey Primary Control Markers

Survey Primary Control Markers is a web-based GIS application TxDOT uses to facilitate delivery of geodetic control station data to interested internal and external users (59). This application provides an interactive map that enables users to view and query survey control points. The system shows query results in a popup window that displays relevant survey control data such as county, district, route, name, and horizontal and vertical datum. The tool also provides links to control point description files, which include data such as projection zone, geoid model, geographic and state plane coordinates, scale, elevation and combined factors, and a description of how to reach the station.

Highway Condition Reporting System

The Highway Condition Reporting System is a web-based GIS application TxDOT uses to summarize roadway conditions on state-maintained highways (60). The application shows highway conditions as either points or segments with the following condition types: closed, contraflow, evacuation lane, accident, ice/snow, flood, bridge closed, construction, damage, and other. The system allows users to query condition type points or segments and displays a summarized table with the following data: condition type, highway name, county name, common name, direction, from location, to location, reported date/time, expected end date/time, description, if the location is in a metropolitan area, if there is a detour, and if a delay is expected.

Information System Consolidation Trends

Although not directly related to this research, it may be worth noting that in 2005, the Texas Legislature passed House Bill 1516 authorizing the establishment of statewide technology centers managed by the Department of Information Resources (DIR). The mission of the statewide technology centers, including the San Angelo Texas State Data Center funded in 1996, is to provide services to state agencies related to information resources and the development and deployment of statewide applications (61, 62, 63). One of the effects of the statewide technology centers is a drastic consolidation of data management practices in the state, including mainframe operations, server hardware and software management, storage and disaster recovery, and security support and maintenance. TxDOT is one of 27 state agencies DIR prioritized for the initial consolidation and participation in the statewide technology center implementation.

CHAPTER 3. ENGINEERING DATA MANAGEMENT PRACTICES AT OTHER AGENCIES

INTRODUCTION

This chapter summarizes practices at other state departments of transportation (DOTs) and various local government agencies in Texas regarding engineering data management.

STATE DEPARTMENTS OF TRANSPORTATION

The researchers conducted an online search, which indicated that most state DOTs use document management systems to support business operations. In general, the use of these systems tends to fall into two categories: document management during the project development process and document archival of completed projects. Several state DOTs are currently in the process of, or are considering, linking document management systems to a GIS. Although linking GIS with images and documents is not new, most out-of-the-box GIS applications only provide basic table joining capabilities, making simple “hotlinking” inadequate in an environment where projects may generate thousands of documents. To address this limitation, a number of applications have appeared over the last few years that customize document management systems by including GIS interfaces and query forms that combine data elements from both document management system and GIS environments. A small sample of applications of GIS techniques at the state DOT level to support document management processes follows:

- **Georgia DOT (GDOT).** GDOT’s Transportation Explorer (TREX) is a web-based GIS application that displays a wide range of transportation datasets, including the location of active and completed projects, traffic cameras and traffic counts, bus and bike routes, aviation facilities, rivers and lakes, and railroad facilities (64, 65). Project data include attributes such as project identifier, project type, location description, and status. The interface also provides links to documents such as preconstruction or construction status report and plans. TREX uses ESRI ArcGIS Server™, Oracle, and Falcon/DMS®.
- **Kentucky Transportation Cabinet (KYTC).** KYTC’s Project Managers Toolbox is a set of web-based tools designed to monitor and analyze project data (66, 67). The application enables users to query project budget, expenditure data, and corresponding funding documents. The toolbox also displays maps of active construction projects and projects in the six-year plan. Along with scheduling and construction status data, the interface can load a separate map using ESRI Arc Internet Map Server™ (ArcIMS) that shows the project extent and other relevant map layers.
- **Maryland State Highway Administration (MDSHA).** MDSHA’s Traffic Engineering Design Division’s (TEDD) Plan Locator is a web-based GIS application that enables the capture and display of archived signal, signing, lighting, and pavement records and plans (68). The system runs on ESRI ArcIMS and an Oracle database.

- **New Jersey DOT (NJDOT).** Through Rutgers University, NJDOT developed a prototype GIS-based management information system (GISMIS) that integrates a database of scanned roadway plans and ROW maps with highway features (69). The system interface enables users to click on map locations to retrieve route information and associated documents. GISMIS runs on a platform that includes GeoMedia Professional™, Intergraph® Modular GIS Environment™ (MGE), and Falcon/DMS.

LOCAL TEXAS AGENCIES

The researchers contacted a sample of jurisdictions in Texas to develop an understanding of current engineering data management practices and plans around the state. The focus of the inquiry was the use of document management/imaging technologies and integration of GIS and CAD technologies. The researchers contacted the cities of Austin, Dallas, Denton, Houston, Richardson, and San Antonio, as well as Bexar and Harris counties.

City of Austin

In the City of Austin, different groups use GIS for a variety of applications. For example, the Austin Water Utility uses an Intranet portal, which includes a viewer that displays water and sanitary sewer facilities, as well as tools for feature location and editing. The utility also uses Hansen's GeoAdministrator™ to assist with asset management activities such as work orders, requests, and project tracking (70). The system facilitates linking documents and data to GIS features. The Public Works Department uses GIS primarily as a tool to provide base data, e.g., by converting GIS data (e.g., parcels, streets) to drawing exchange format (DXF) for import into MicroStation. The department uses MicroStation for capital improvement plan (CIP) projects. The city has standards for levels, cell libraries, and project folders but not for file naming conventions. No formalized process exists for managing engineering documentation throughout the project development process. Consultants are required only to provide hardcopies of construction and as-built plans. However, the city has started to encourage submission of as-built plans in digital format.

Austin uses a legacy system called Permitting, Inspection, Enforcement, and Review (PIER), originally designed for permitting functions, for document archival. PIER stores several types of documents: permits, water taps, sewer taps, subdivision plats, and engineering plans. In general, the archival process involves converting as-built CAD files or Mylar plans to TIF format and indexing the files using attributes such as street name and project name. The city is replacing PIER with a CSDC Systems' AMANDA™ enterprise application (71), which will include document archival and permitting, as well as a GIS component for visualization.

City of Dallas

The City of Dallas' Development Services Department uses Intergraph's Asset and Information Management™ (AIM) system for building inspection, planning, and subdivision plats. The system contains about 1.6 million records, a third of which are engineering or architectural

drawings, including scanned paper plans. On average, some 100 external users per week use AIM. The system does not have a GIS component, does not interface with other city systems, and has limited search capabilities. The department also uses Computronix POSSE[®] land management system (72) to consolidate the review process (e.g., permitting and inspections) of private development initiatives. Although the system can store video files, pictures, and scanned documents, the system is not geared for large construction drawings. The city does not use the system to archive historical maps or subdivision plats. The system has interfaces to other systems, e.g., the department's GIS system, which enables linking permits to address locations as well as documents to parcels. Users access the system through a client server application or via the Internet using security options and restricted access. Several city departments use the system. In general, several city departments have their own document imaging systems, which has prompted the city to implement a new citywide document imaging/management system.

City of Denton

The City of Denton recently implemented a LaserFiche[®] document imaging system. Several departments are now using the system, including the Engineering Department, which uses LaserFiche to manage a variety of files such as easement documents, ordinances, as-built drawings, plats, contracts, and project files. The system also has about 650 gigabytes of data covering 950,000 pictures and video files showing city street conditions and ground penetrating radar-produced imagery. These data are geo-referenced, which facilitates their display in a GIS environment. Documents accessed the most are as-built drawings, plats, and water and sanitary sewer camera video files. To facilitate access to documents and data, including work orders, the city developed a web-based application called One Stop Street Information Access Tool that integrates LaserFiche and Cartegraph's Work Order[®] databases (73, 74). The web-based GIS viewer displays a wide range of layers such as streets, work orders, sanitary sewer lines, work orders, buildings, and pavement condition. The LaserFiche implementation received the 2003 Best of Texas "Most Innovative Use of Technology" award and a Public Technology Institute Solutions award in 2004 (75).

City of Houston

The City of Houston's Public Works and Engineering Department (PWE) uses ePlus' DigitalPaper XE[®] document imaging system to store and archive TIF and PDF versions of CAD files. The system supports a wide range of page sizes, from letter size to E size. Through an interface with PWE's Capital Improvement Project Management System (CIPMS), DigitalPaper XE enables inspectors to access scanned project documents wirelessly and enables customers to submit electronic drawings instead of paper plans.

PWE's CIPMS is a web-based system to manage and centralize CIP data (76). CIPMS has a series of dropdown menus based on facility type (street and traffic, storm drainage, water, and sanitary sewer). Each project has a summary table containing key contacts and project data. Associated with each project is a set of documents, which are grouped according to category (planning, engineering, construction, or reports) and subcategory.

PWE's Graphics and Engineering Management Group maintains a web-based application called the Geographic Information and Management System (GIMS), which enables users to access a wide range of datasets grouped under categories such as reference, land base and roads, boundaries, underground utilities, buildings and structures, environmental, permits, solid waste, construction projects, aerial photography, and miscellaneous (77). GIMS also enables users to access other related web-based applications, e.g., applications devoted to ROW and street cut permitting, utility analysis, and traffic engineering. GIMS runs on an Azteca Systems' Cityworks™ platform.

City of Richardson

At the City of Richardson, the Capital Projects Department and the Engineering and Planning Department use FileNet for managing engineering documentation (78). The system enables users to store scanned documents (mainly TIF versions of CAD files) and characterize each document using with a wide range of custom properties. One of the properties is sheet type (e.g., drainage, sewer, or plat). The system allows associating sheets with multiple types (i.e., drainage and sewer). System access is possible through an online FileNet viewer, an ArcIMS-enabled website, or an ArcGIS extension in ArcMap™, which provides document "hotlinking" to GIS features such as subdivision polygons, CIP polygons, and water line segments. Currently, the system has about 70,000 documents, occupying about 500 gigabytes. The city is currently expanding the use of FileNet to other departments.

City of San Antonio

The City of San Antonio's Public Works Department follows a traditional paper-based engineering document management approach. Consultants provide the vast majority of CIP plans in the department. In general, the department keeps plan sheets in MicroStation and paper formats. Hardcopy plan sheets are stored in pigeonholes, and project documentation (e.g., cost estimates, preliminary design reports, correspondence, fees, change orders, and accounting information) is stored in project folders and/or on shelves. The department provides printed construction drawings and other relevant materials to prospective bidders. Construction specifications are available online (79), although the department can provide printed copies if required.

GIS is used primarily for planning purposes within the Planning Department, not for design or documentation. Nonetheless, the Public Works Department uses GIS to produce maps for council members and meetings and to add new subdivision parcels into the city's parcel GIS dataset.

Bexar County

There are two document management initiatives at Bexar County: one for active CIP projects and the other one for historical documents. For CIP projects, the goal is to store all drawings and as-built plans in PDF format. Consultants handle most, if not all, project design work. They

typically submit drawings throughout the project development process (in PDF format), as well as as-built drawings (in both PDF and hardcopy formats). The county stores all digital versions of the plans. As needed, the county digitally “redlines” scanned PDF files or re-scans redlined paper plans. After project completion, the county moves digital project files from “active” to “completed” folders and moves paper project documents to offsite storage. In general, the policy is not to scan paper project documents such as reports.

For historical documents, the county is scanning engineering documents that go back at least to the 1920s. These documents include construction data, plats, flood maps, and permits. Scanned documents are saved in PDF format, and physical documents are stored in a vault. Folder structures for scanned historical documents replicate the corresponding physical folder structures. An Access database contains an index of scanned documents along with searchable attributes such as project names, roadways, and grid locations.

The county maintains GIS datasets for CIP and maintenance projects. The CIP project dataset has fields for name, extent, and status, along with an overall indication of project status (design, construction, or complete). The county uses this information to generate project status reports (80).

Harris County

The Harris County Public Infrastructure Division (HCPID) has started the implementation of an asset management system called the Condition-Based Asset Management System (CAMS) (81) to comply with Governmental Accounting Standards Board (GASB) reporting standards, in particular GASB-34 (82). The system architecture covers a wide range of county-controlled assets (e.g., roads, bridges, tunnels, parks, buildings, utility, and land improvements). The county has developed a prototype viewer that enables users to extract project data by navigating an interactive map and selecting the project of interest. The application breaks down reports into smaller deliverables (e.g., cover, executive summary, or design). Associated with each document are custom properties that provide metadata and allow searching. The preview runs on a Microsoft SQL Server/SharePoint™ platform.

Consultants submit paper documents, which the county scans and converts to PDF format. Consultants are not required to submit electronic documents. Internally, the county generates plans in AutoCAD and then converts those files to PDF format. The county developed CAD standards and ensures compliance with those standards by applying quality control checks via code (e.g., to ensure features are located on their designated layers). The county is also scanning historical plans and moving paper plans to an off-site location.

Common Trends and Issues

The researchers made the following general observations from the interaction with the various agencies:

- Consultants tend to generate the vast majority of design and construction plans, with the rest completed by in-house staff. In most cases, consultants are only required to submit paper copies, although agencies are beginning to encourage or require the submission of plans in digital format. Typical file submission formats include native CAD file formats and PDF. Internally, the agencies tend to archive digital files in TIF or PDF. Some agencies have developed standards for symbology and layers, and at least one agency has developed quality control checks via code to ensure features are located on their designated layers.
- The use of EDMS is increasing, with different agencies at different stages in the implementation of those systems. Implementation approaches vary widely, ranging from systems developed internally to COTS software combinations. Integration of GIS into EDMS also varies widely, from no integration to relatively simple interfaces to more sophisticated custom-built interfaces. Agencies noted many benefits derived from the implementation of EDMS, which are consistent with literature reports (83, 84). Examples include the following:
 - reduction in the amount of time waiting for plan reviews;
 - improvements in document production and processing accountability;
 - elimination of time-consuming paper document searches, enhanced record security, and substantial reduction in physical storage space requirements and costs; and
 - increased access by internal and external users, particularly using web-enabled interfaces and procedures.
- Issues that various agencies noted in relation with the implementation of EDMS and the integration of GIS technologies into those systems include the following:
 - **Data quality and completeness.** In addition to scanning efforts, populating document indexes is a major effort, often performed by consultants. The quality and completeness of document index data is a serious issue. Some agencies have had to assign staff members to clean large amounts of index data and/or work with consultants to ensure the quality of the data.
 - **System redesigns and adjustments.** As system implementations progress, some agencies have found it necessary to make adjustments. Examples include revising file naming standards, adding library structures due to limitations on the number of physical documents stored in folders, and reducing the number of document custom properties.
 - **Acceptance.** Agencies linked success in the implementation of an EDMS to the identification of strong project champions, subject matter experts, and supportive management and decision makers. Agencies also mentioned off-site hardcopy storage as a strategy to encourage users to start relying on on-site digital copies because users do not have to use paper documents unless there are quality control problems or the need to double check documentation content. Also important is

the availability of large-format scanners and large flat-panel monitors to facilitate document viewing by users.

- **Maintenance costs.** In addition to the cost of the original investment, agencies are realizing the cost to maintain the system is quite substantial, to the point that some agencies are beginning to consider other strategies for document management (e.g., using a system from a different vendor). Some agencies noted the need to include appropriate contingencies in the budget to minimize cost overruns.
- **Implementation strategy.** Different implementation strategies have met different challenges. For example, one agency focused on scanning documents first but paid little initial attention to the indexing effort. As a result, finding documents quickly became difficult. In another case, two parallel systems were in place (the old one and the new one) at the same time, forcing users to use two systems depending on the date of a project.
- **Standardization.** Some agencies noted that the lack of standardized enterprise-wide GIS data models and database implementations has resulted in serious data translation and compatibility issues, limiting the usability of the data.

CHAPTER 4. ENGINEERING DESIGN DATA MODEL

INTRODUCTION

The review of engineering design data practices at TxDOT and other agencies described in Chapters 2 and 3 led to the development of a prototype data model for managing engineering design data in a GIS environment at TxDOT. This chapter describes the process used to develop the corresponding conceptual, logical, and physical data models. Subsequent chapters describe the development and implementation of a prototype database and the corresponding testing results. For convenience, the researchers named the prototype model “Engineering Design Data Model” (EDDM).

GENERAL REQUIREMENTS AND SCOPE

For the development of the prototype data model, the researchers took into consideration a number of requirements that guided the development and testing phases. A summary of general requirements and guiding principles used during the research phase follows:

- **Data integration.** To optimize existing computing resources, the researchers identified integration points with TxDOT existing systems, such as DCIS, FileNet, and MST. Chapter 2 provides a summary of these systems, which are also described in published TxDOT documents (43). Readers should note that the identification of integration points with existing TxDOT systems was at a high conceptual/logical level because with the exception of MST, detailed database design documents of other systems were not available to the researchers. In the specific case of FileNet, unfortunately, TxDOT did not provide samples of database representations of district or division FileNet libraries. The alternative would have been to acquire a FileNet license during the research phase to develop the prototype model using the FileNet database structure directly. However, the cost associated with the deployment of a single FileNet license to support the research would have been extremely high – in addition to the license fee, it would have been necessary to acquire a dedicated server and incur additional vendor-mandatory installation fees – making this option infeasible. Given these limitations, the researchers decided to create “place holders” in the prototype database structure for tables and fields that are related to project data (which are DCIS related) or engineering documents (which are FileNet related). During implementation, it should be possible to replace the “place holders” with pointers to relevant existing systems, provided the necessary application programming interface (API) components are in place.
- **Compatibility with existing TxDOT information systems.** The data model developed in this research is compatible with existing TxDOT data architecture requirements (43). To the extent possible, the prototype is also compatible with other existing engineering data standards, e.g., TxDOT’s CAD standards.
- **Focus on architecture, not on graphical user interfaces (GUIs).** At TxDOT’s request, the research focused on data modeling and identification of implementation issues, not on GUI development. For data model testing purposes, the researchers developed simple

offline (standalone) and online prototype GUIs. As described in [Chapter 6](#), the offline prototype GUIs used standard ArcGIS and Access interfaces, while the online prototype GUI used ArcIMS-based web pages. Readers should note that the level of functionality of the prototype GUIs, while adequate for assessing the feasibility of the data model and conducting database tests, would not necessarily be an accurate reflection of the level of functionality expected of a production-level system. However, whenever possible, the researchers included data elements in the database design to make sure the database would support appropriate GUI developments.

CONCEPTUAL AND LOGICAL DATA MODELS

At the highest level, managing engineering design data involves managing three types of data: data about documents, data about features on the ground (under design or existing), and data about projects. In reality, documents, features, and projects are not standalone entities. For example, a project can have many documents and/or be associated with many features, a document can be associated with many projects and/or features, and a feature can be associated with many documents and/or projects. As [Figure 10](#) shows, the relationship among projects, documents, and features is clearly many to many.

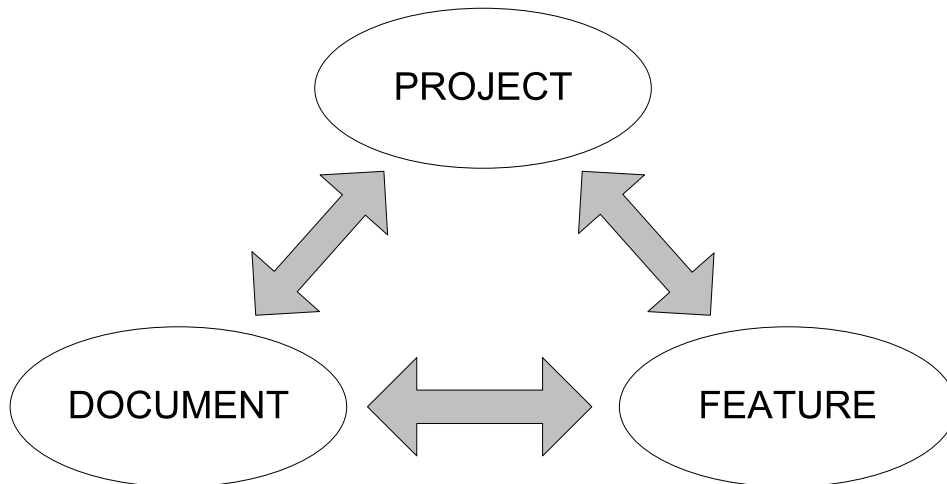


Figure 10. Engineering Design Data Model – Conceptual Design.

The approach to modeling documents, features, projects, and their corresponding interrelationships depends on a number of factors, including business processes, implementation strategies, and available supporting technologies. Traditionally, agencies have implemented information systems to support and vertically integrate business processes within major areas (projects, documents, or features), while only providing limited support for data exchange and relationship handling among those major areas. As [Chapters 2 and 3](#) documented, improvements in technology have resulted in systems that routinely handle two of the three major areas in [Figure 10](#) and their relationships, mainly projects and documents. With improvements in GIS technology over the last few years, it is becoming increasingly feasible to incorporate features and the relationships between features and documents and between features and projects.

Most reports in the literature describe modeling approaches to integrate document and project data. In some cases, the reports focus on implementation technology issues (e.g., web-based versus client server architecture) (85) or on the development of procedures to assemble document packages based on specific project characteristics (86). In other cases, they focus on automating processes to extract relevant project data from documents. For example, Caldas, Soibelman, and Han developed a prototype application to classify text-based construction project documents, highlighting that many construction project documents tend to be unstructured and stored in different systems, computers, and organizations (87). Hajjar and AbouRizk developed a model that integrates document, project, and company data (where company data include elements such as organizational structure, departments, and employee data) (88). In a structure somewhat similar to Figure 10, the model represents each major area (document, project, and company) as separate models with indexes in the document model that point to objects in the other two models. For example, an index in the document model points to an object in the project model, whereas a separate index in the document area points to an object in the company model. Readers should note that Hajjar and AbouRizk’s model focused on developing indexes for documents based on project or company data but not on establishing linkages between project and company data.

The researchers’ approach to developing EDDM was to consider not just the three main areas in Figure 10, but also to explicitly model the corresponding three many-to-many relationships. Figure 11 shows the corresponding high-level logical data model. A more formal definition of the three main entities follows:

- **PROJECT.** A PROJECT is a roadway project for which there is data in DCIS and other systems.
- **DOCUMENT.** A DOCUMENT is a tangible product in printed or electronic format. A document can have several versions based on date and/or author.
- **FEATURE.** A FEATURE is a real world or virtual phenomenon that exists in a spatial or spatiotemporal domain. The model uses points, lines, and polygons to represent features. Points represent features such as poles, signs, signals, and pedestals. Lines represent features such as centerlines, project limits, guardrails, barriers, and utility lines. Polygons represent features such as parcels, paved areas, bridges, and building footprints.

Notice in Figure 11 that entities have real world information system counterparts at TxDOT. The system counterpart for PROJECT is DCIS, the system counterpart for DOCUMENT is FileNet, and the system counterpart for FEATURE is GAIP. This characterization enables a direct mapping between EDDM and those systems, and facilitates the interpretation of the high-level diagram in Figure 10 as a set of system “place holders” for which EDDM provides the connecting framework.

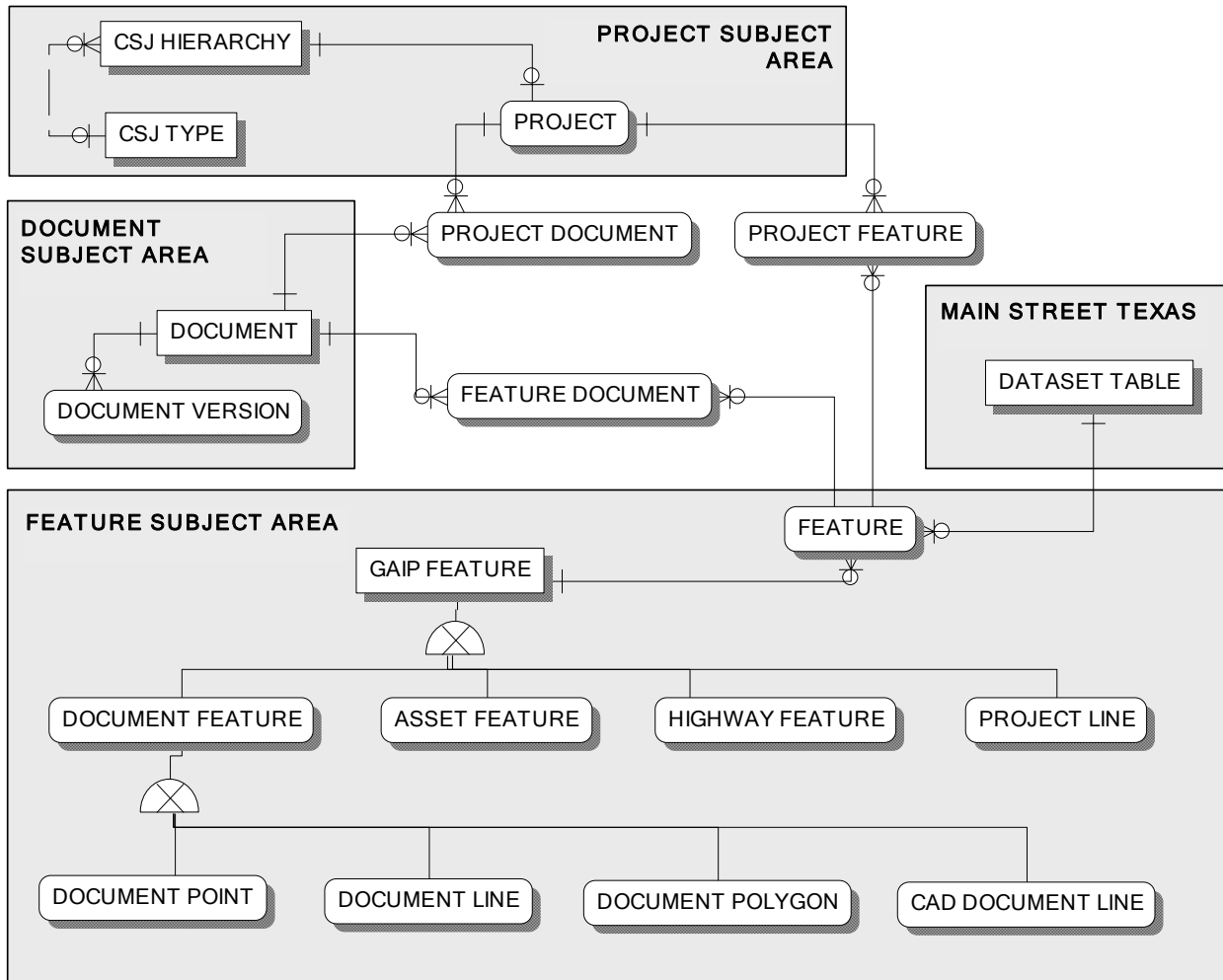


Figure 11. Engineering Design Data Model – High-Level Logical Data Model.

The researchers developed a formal data model for EDDM using Computer Associates' AllFusion ERwin[®] Data Modeler, which is a standard modeling tool at TxDOT (43). For clarity, the model includes three subject areas, one for each core entity in EDDM. To facilitate reading and understanding the model, Figure 12 shows an expanded view of the logical model in Figure 11, showing subject areas with entities without attributes. The following sections provide a description of the main entities and relationships in each subject area.

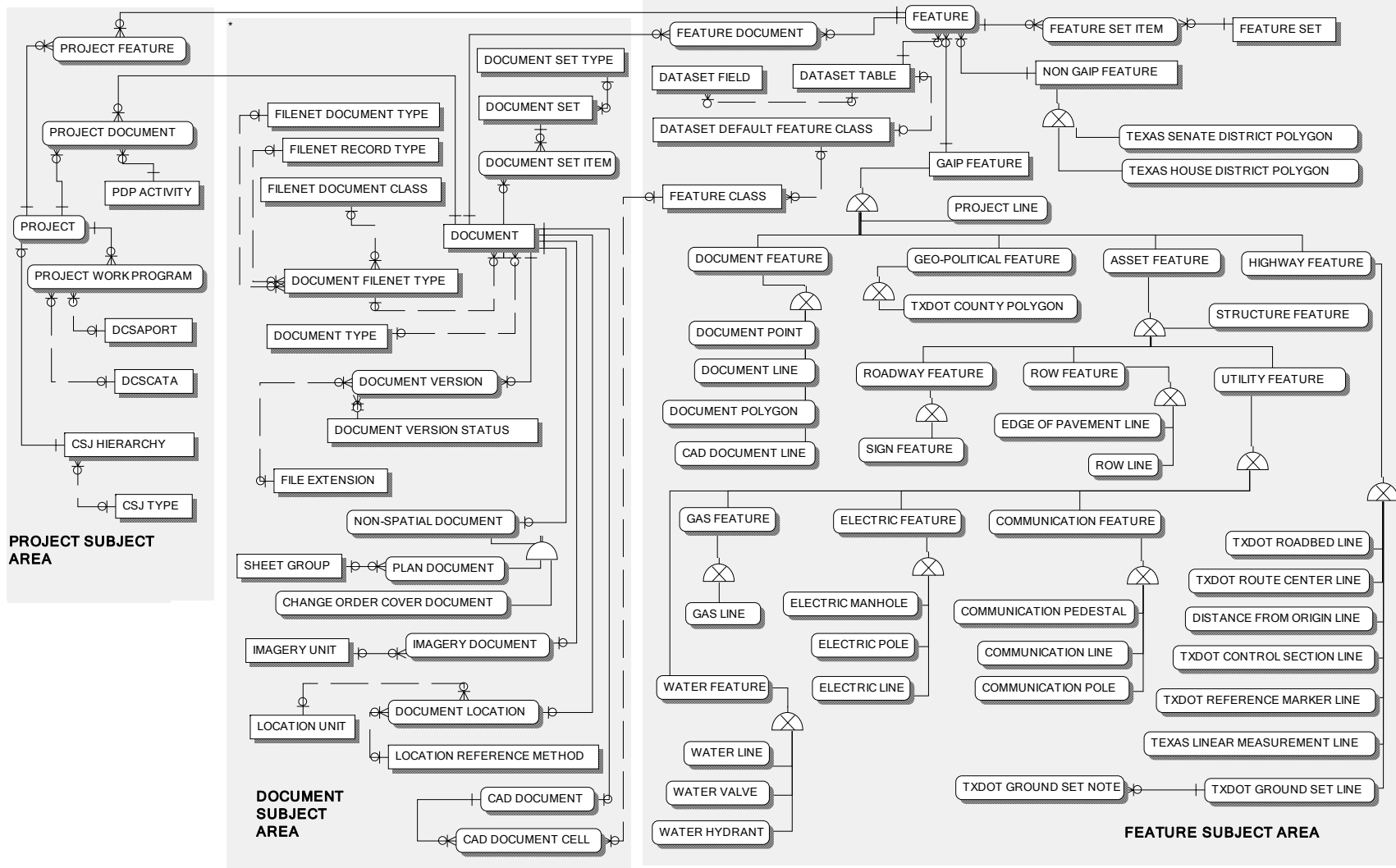


Figure 12. Logical Engineering Design Data Model – Entity Overview.

PROJECT Subject Area

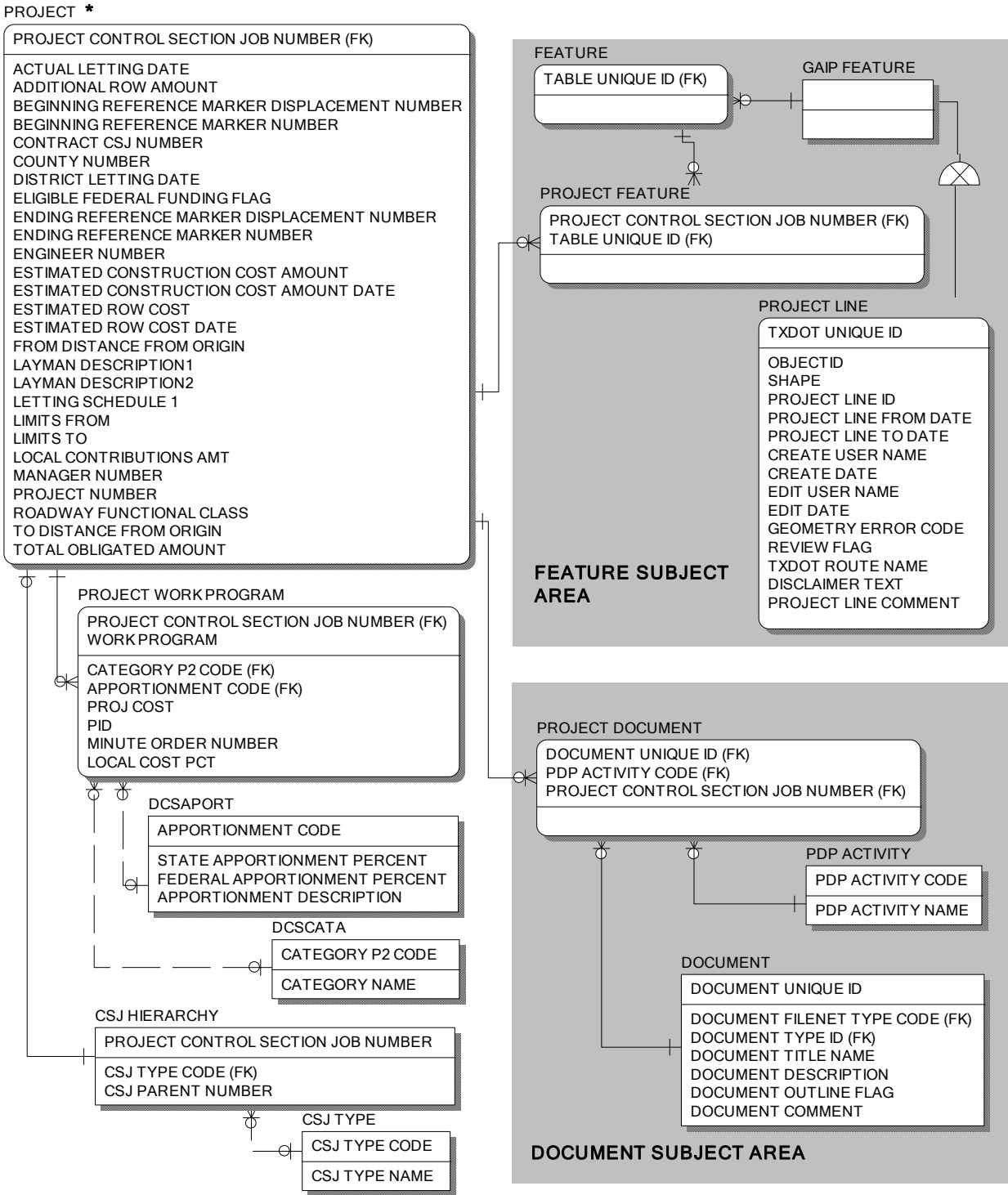
The PROJECT Subject Area consists of PROJECT, related lookup tables, and linkages to other entity subject areas (Figure 13, Table 20). PROJECT is a subset of DCIS File 121. To ensure compatibility with DCIS, PROJECT maintains the same structure as DCIS File 121. As a result, PROJECT does not follow TxDOT data architecture standards (43). Developing a standard-compliant version of PROJECT would have been possible but redundant, as TxDOT has already started the process to develop a standard-compliant version of DCIS.

DCIS File 121 contains a large number of attributes. For this research, only a few attributes were relevant to help characterize sample project data (other attributes, while important in DCIS, were not critical for this research). In general, attributes considered relevant were those that helped characterize projects according to key project identifiers, costs, critical dates, project description, funding, letting schedule, supervision, and geo-referencing. Table 21 shows the corresponding attribute groups.

The primary key of the PROJECT entity is PROJECT CONTROL SECTION JOB NUMBER. An alternate key is PROJECT NUMBER. Before TxDOT authorizes a construction project or a ROW project, that project may have a planning CSJ number, which functions as a temporary CSJ number. After authorization, TxDOT assigns a permanent CSJ number to the project. In addition, a project may have several “child” projects, each one having a separate CSJ number. CSJ HIERARCHY and CSJ TYPE model these relationships. CSJ HIERARCHY records the type, or function, of the CSJ number and an associated CSJ parent number. CSJ TYPE is a lookup table for CSJ HIERARCHY.

TxDOT funds highway improvement projects through one or more work programs. Each work program has a category, minute order, and apportionment percentages. PROJECT WORK PROGRAM models these relationships and uses DCIS TACS lookup tables DCSAPORT and DCSCATA. DCSAPORT lists project apportionment codes and default percentages for federal and state participation (e.g., 90 percent federal, 10 percent state for interstate projects). DCSCATA lists project category names (e.g., National Highway System – Mobility, Urban Corridor Projects).

PROJECT FEATURE identifies features associated with a given project (e.g., bridges, railroads, or centerlines). PROJECT FEATURE also handles many-to-many relationships between PROJECT and FEATURE. PROJECT DOCUMENT identifies documents associated with a given project (e.g., as-built plans, schematics, or environmental clearances). PROJECT DOCUMENT also handles many-to-many relationships between PROJECT and DOCUMENT. PDP ACTIVITY associates a specific PROJECT DOCUMENT with an activity identified in the TxDOT *Project Development Process Manual* (10) (e.g., 5540: Perform hydraulic design for culverts and storm drains). This relationship enables project task status queries (e.g., identify hydraulic design documents for a specific project).



Note:
 * PROJECT conceptually represents a condensed version of DCIS File 121, which contains project information and does not follow relational database design standards.

Figure 13. Logical Engineering Design Data Model – PROJECT Subject Area.

Table 20. PROJECT Subject Area Entities.

Entity Name	Entity Definition
CSJ HIERARCHY	A CSJ HIERARCHY is a mapping between a PROJECT CONTROL SECTION JOB NUMBER and a CSJ PARENT NUMBER, if the parent CSJ number exists.
CSJ TYPE	A CSJ TYPE is a property that categorizes the type of CSJ number. Examples include Construction, ROW, and Temporary.
DCSAPORT	DCSAPORT is a TACS table name associated with DCIS that lists project apportionment codes and default percentages for federal and state participation.
DCSCATA	DCSCATA is a TACS table name associated with DCIS that lists project category names. Examples include ROW (16R), Federal Demonstration Projects (15), and Interstate 4R Discretionary (1A).
PDP ACTIVITY	A PDP ACTIVITY is a task defined in the TxDOT <i>Project Development Process Manual (10)</i> .
PROJECT	A PROJECT is a roadway project for which there are data in DCIS and other systems. PROJECT conceptually represents a condensed version of DCIS File 121.
PROJECT DOCUMENT	A PROJECT DOCUMENT is a mapping that represents the many-to-many relationship between a PROJECT and a DOCUMENT. PROJECT DOCUMENT enables the identification of DOCUMENTS associated with a PROJECT and the identification of PROJECTS associated with a DOCUMENT.
PROJECT FEATURE	A PROJECT FEATURE is a mapping that represents the many-to-many relationship between a PROJECT and a FEATURE. PROJECT FEATURE enables the identification of FEATURES associated with a PROJECT and the identification of PROJECTS associated with a FEATURE.
PROJECT WORK PROGRAM	A PROJECT WORK PROGRAM is a group of similar types of projects selected, funded, and handled in a similar appropriate manner.

Table 21. PROJECT Entity Attributes and Grouping.

PROJECT Entity Attribute Name	PROJECT Entity Attribute Grouping
CONTRACT CSJ NUMBER PROJECT CONTROL SECTION JOB NUMBER PROJECT NUMBER	Identifiers
ADDITIONAL ROW AMOUNT ESTIMATED CONSTRUCTION COST AMOUNT ESTIMATED ROW COST TOTAL OBLIGATED AMOUNT	Costs
ACTUAL LETTING DATE DISTRICT LETTING DATE ESTIMATED CONSTRUCTION COST AMOUNT DATE ESTIMATED ROW COST DATE	Dates
COUNTY NUMBER LAYMAN DESCRIPTION 1 LAYMAN DESCRIPTION 2 ROADWAY FUNCTIONAL CLASS	Description
ELIGIBLE FEDERAL FUNDING FLAG LOCAL CONTRIBUTIONS AMOUNT	Funding
LETTING SCHEDULE 1	Letting
ENGINEER NUMBER MANAGER NUMBER	Supervision
BEGINNING REFERENCE MARKER DISPLACEMENT NUMBER BEGINNING REFERENCE MARKER NUMBER ENDING REFERENCE MARKER DISPLACEMENT NUMBER ENDING REFERENCE MARKER NUMBER FROM DISTANCE FROM ORIGIN LIMITS FROM LIMITS TO TO DISTANCE FROM ORIGIN	Referencing

DOCUMENT Subject Area

The DOCUMENT Subject Area consists of DOCUMENT, related lookup tables, and linkages to other subject areas (Figure 14, Table 22). In EDDM, DOCUMENT and several other entities within the DOCUMENT Subject Area are “place holders” for equivalent entities in the FileNet database structure. The researchers did not have access to the FileNet data model, and it was not possible to determine how closely the entities in the DOCUMENT Subject Area match the corresponding entities in FileNet. Therefore, during implementation, it may be necessary to modify some of the entities in this subject area, particularly at the physical level. This limitation is not likely to be critical because, at the logical level, the model in Figure 14 explicitly considers the main data elements necessary to characterize documents and document sets, as well as FileNet document classes, records types, and document types. For consistency with the rest of EDDM components, the entities in the DOCUMENT Subject Area comply with TxDOT data architecture standards, both in terms of content and entity and attribute naming conventions (43).

The primary key of the DOCUMENT entity is DOCUMENT UNIQUE ID. A DOCUMENT can have multiple versions through the DOCUMENT VERSION entity. Because a document can have multiple versions, each with a unique physical file name, DOCUMENT VERSION includes DOCUMENT VERSION LOGICAL NAME and DOCUMENT VERSION PHYSICAL NAME attributes. Several attributes in DOCUMENT and DOCUMENT VERSION originated from the TxDOT EDTIS Content Services Library Standards (36) and TxDOT’s *Data Architecture* (43). Attributes not based on the EDTIS standard include FILE EXTENSION, which indicates the document file extension (e.g., JPG, DOC, PDF), and DOCUMENT TYPE, which provides document categorization based on form (e.g., CAD, imagery, memorandum, Form 1002, checklist, request, notes, or analysis) rather than the FileNet library structure, which is based on document function.

DOCUMENT FILENET TYPE represents the TxDOT EDTIS library structure. The primary key for DOCUMENT FILENET TYPE is the DOCUMENT FILENET TYPE CODE attribute, which contains the FileNet File Code (Table 10). This attribute is a foreign key in DOCUMENT. DOCUMENT FILENET TYPE includes a DOCUMENT TYPE ADDED FLAG attribute to highlight document types the researchers added, which were not in the list of document types received from TxDOT. For convenience, the researchers added three entities (FILENET DOCUMENT CLASS, FILENET RECORD TYPE, and FILENET DOCUMENT TYPE) to generate a relational database-compliant index of document classes, record types, and document types. In the case of FILENET DOCUMENT CLASS, FILENET DOCUMENT CLASS ID matches the index of document classes in Table 9. In the case of FILENET RECORD TYPE and FILENET DOCUMENT TYPE, the corresponding ID fields are unique and do not correspond to the corresponding record type and document type codes in Table 10.

In EDDM, a DOCUMENT SET models documents that are combinations or aggregations of other documents, e.g., proposals and PS&E plan sets. In DOCUMENT SET, DOCUMENT SET NUMBER provides an optional index for document sets (e.g., change order 1, 2, 3). DOCUMENT SET ITEM represents the many-to-many relationship between DOCUMENT SET and DOCUMENT (i.e., a DOCUMENT can be associated with more than one DOCUMENT SET, and a DOCUMENT SET can be associated with more than one DOCUMENT). DOCUMENT SET TYPE is a lookup table that categorizes document sets.

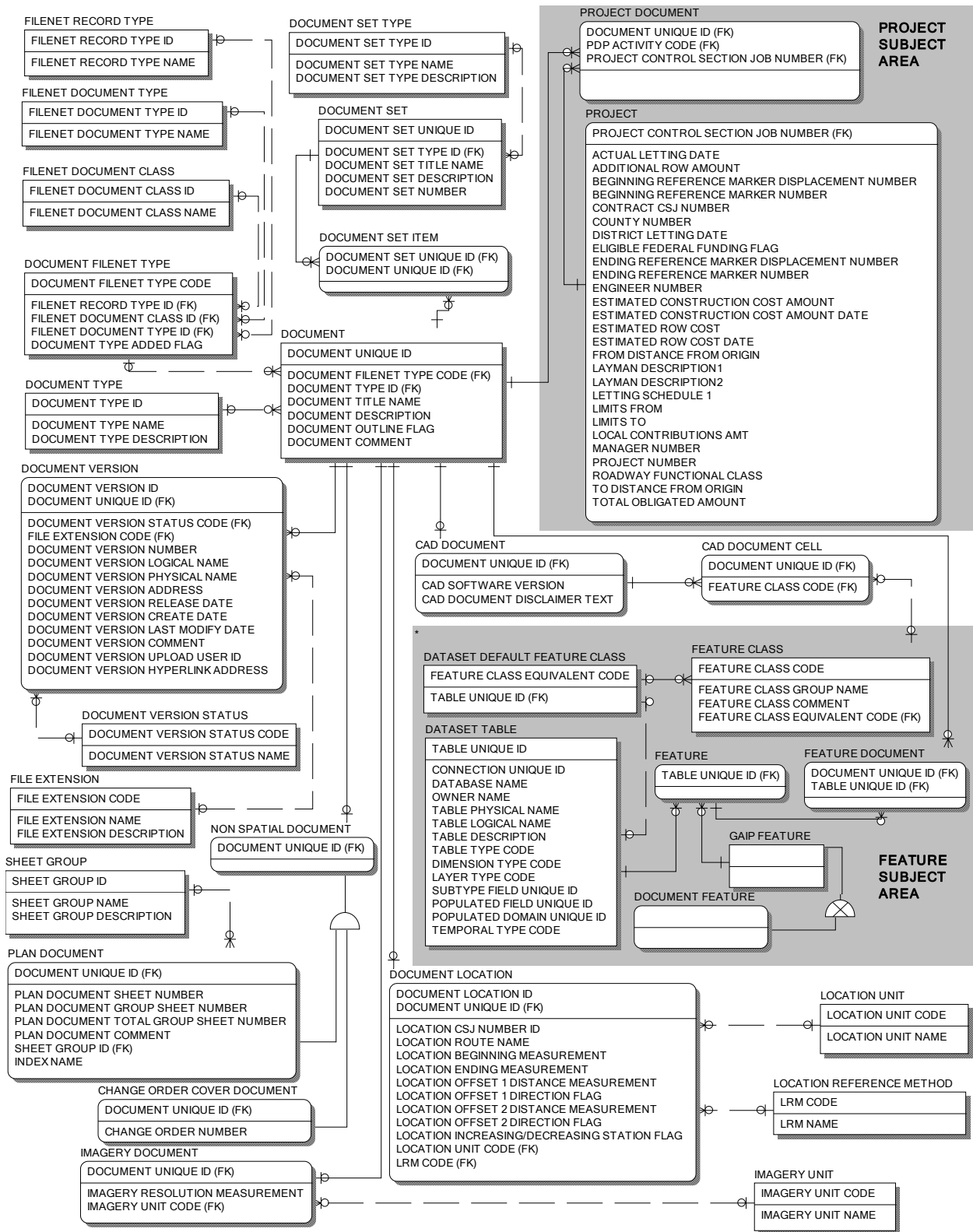


Figure 14. Logical Engineering Design Data Model – DOCUMENT Subject Area.

Table 22. DOCUMENT Subject Area Entities.

Entity Name	Entity Definition
CAD DOCUMENT	A CAD DOCUMENT is a document in electronic format that represents entities graphically using points, lines, or polygons generated in a CAD environment (e.g., MicroStation).
CAD DOCUMENT CELL	A CAD DOCUMENT CELL is the name of a CAD cell used in a CAD document. A CAD document could have zero, one, or many CAD DOCUMENT CELLS.
CHANGE ORDER COVER DOCUMENT	A CHANGE ORDER COVER DOCUMENT is a document generated as a cover letter for a set of documents associated with a change order.
DOCUMENT	A DOCUMENT is a tangible product in printed or electronic format. A document can have several versions based on date and/or author.
DOCUMENT FILENET TYPE	A DOCUMENT FILENET TYPE is a type of DOCUMENT according to TxDOT's EDTIS Project Content Services library standards.
DOCUMENT LOCATION	A DOCUMENT LOCATION is a spatial representation of a feature using a linear referencing method in terms of measurements along and perpendicular to a route centerline.
DOCUMENT SET	A DOCUMENT SET is a collection of documents. Examples include PS&E plan sets, proposals, and reports (provided several documents, e.g., chapters in separate files, make up the report; if a report is in a single file, the report is considered a document, not a document set).
DOCUMENT SET ITEM	A DOCUMENT SET ITEM is a document that is part of a DOCUMENT SET. Examples include each of the chapters that make up a report (if each chapter is a separate document) and each of the plan documents that make up a PS&E plan set.
DOCUMENT SET TYPE	A DOCUMENT SET TYPE is a word or phrase that characterizes document sets with similar attributes and characteristics. Examples include utility agreements, utility agreement assemblies, change orders, PS&E assemblies, and plan sets.
DOCUMENT TYPE	A DOCUMENT TYPE is a category of a DOCUMENT. Examples include CAD documents, plan documents, and schedule documents.
DOCUMENT VERSION	A DOCUMENT VERSION is an instance of a DOCUMENT. For example, for a chapter document, DOCUMENT VERSION represents each of the instances of that document, e.g., version 1, 2, or 3.
DOCUMENT VERSION STATUS	A DOCUMENT VERSION STATUS is a description of the production status of a DOCUMENT VERSION.
FEATURE DOCUMENT	A FEATURE DOCUMENT is a mapping that represents the many-to-many relationship between a FEATURE and a DOCUMENT. FEATURE DOCUMENT enables the identification of DOCUMENTS associated with a FEATURE and the identification of FEATURES associated with a DOCUMENT. Note: A FEATURE DOCUMENT is different from a DOCUMENT FEATURE. A DOCUMENT FEATURE (inside the FEATURE Subject Area) provides the actual spatial representation of a DOCUMENT
FILE EXTENSION	A FILE EXTENSION is the portion of a file name that indicates the file format or the application used to create the file.
FILENET DOCUMENT CLASS	A FILENET DOCUMENT CLASS is a category of documents that defines a specific FileNet library. In general, there is a one-to-one relationship between document classes and FileNet libraries. Examples include Administrative, Construction, Project Design, Right of Way, Traffic Operations, and Transportation Planning.
FILENET DOCUMENT TYPE	A FILENET DOCUMENT TYPE is a type of document within each FILENET RECORD TYPE. The combination between FILENET RECORD TYPE and FILENET DOCUMENT TYPE is unique within each FILENET DOCUMENT CLASS. For example, the FILENET DOCUMENT TYPE "Plan" is a type of document within the FILENET RECORD TYPE "Plans Specifications and Estimates." The combination between "Plans Specifications and Estimates" and "Plan" is unique within the FILENET DOCUMENT CLASS "Project Design."
FILENET RECORD TYPE	A FILENET RECORD TYPE is a document subclass within each FILENET DOCUMENT CLASS. For example, the FILENET RECORD TYPE "Plans Specifications and Estimates" is a document subclass within the FILENET DOCUMENT CLASS "Project Design."

Table 22. DOCUMENT Subject Area Entities (Continued).

Entity Name	Entity Definition
IMAGERY DOCUMENT	An IMAGERY DOCUMENT is a document that represents entities graphically using pixel structures.
IMAGERY UNIT	An IMAGERY UNIT is a measurement unit for imagery documents that provides an indication of the image resolution level (or pixel size). Examples include feet, inches, meters, miles, and kilometers.
LOCATION REFERENCE METHOD	A LOCATION REFERENCE METHOD is a descriptor of the linear reference method associated with a DOCUMENT LOCATION entity. Examples include Stationing, Control Section, and DFO.
LOCATION UNIT	A LOCATION UNIT is a measurement unit for a DOCUMENT LOCATION. Examples include feet, inches, meters, miles, kilometers, and yards.
NON-SPATIAL DOCUMENT	A NON-SPATIAL DOCUMENT is a document that does not have a spatial component.
PLAN DOCUMENT	A PLAN DOCUMENT is a document that contains one or more plan sheets. Plan documents normally include graphical elements that facilitate plan sheet printing for document submission purposes, such as title boxes, notes, and annotations.
PROJECT DOCUMENT	A PROJECT DOCUMENT is a mapping that represents the many-to-many relationship between a PROJECT and a DOCUMENT. PROJECT DOCUMENT enables the identification of DOCUMENTS associated with a PROJECT and the identification of PROJECTS associated with a DOCUMENT
SHEET GROUP	A SHEET GROUP is a PLAN DOCUMENT category that facilitates plan document grouping. Examples include typical sections, estimate and quantity sheets, plan and profile, and traffic control plans.

A DOCUMENT can be associated with multiple features through the FEATURE DOCUMENT entity. Notice that a DOCUMENT does not have to be associated with a FEATURE and a FEATURE does not have to be associated with a DOCUMENT. While FEATURE DOCUMENT represents the many-to-many relationship between DOCUMENT and FEATURE, DOCUMENT FEATURE (inside the FEATURE Subject Area) provides the actual spatial representation of a DOCUMENT.

In some cases, the spatial location of a document is not available, but a linear reference is. For example, an accident report may indicate the location of an accident by route and milepoint. DOCUMENT LOCATION stores the linear reference of a DOCUMENT as a set of distances, offsets, and linear referencing method. LOCATION UNIT indicates the units (e.g., feet, meters, or kilometers) associated with the location measurement attributes. LOCATION REFERENCE METHOD indicates the linear reference method used in DOCUMENT LOCATION.

EDDM handles document subtypes through the DOCUMENT TYPE ID attribute in the DOCUMENT entity. The researchers identified specific attributes for four document subtypes, which resulted in the addition of four corresponding entities: PLAN DOCUMENT, CHANGE ORDER COVER DOCUMENT, IMAGERY DOCUMENT, and CAD DOCUMENT.

PLAN DOCUMENT and CHANGE ORDER COVER DOCUMENT are two of 33 NON-SPATIAL DOCUMENT subtypes identified during the research (Table 23). PLAN DOCUMENT represents a view (e.g., plan or profile) of a highway improvement project in non-CAD format. PLAN DOCUMENT records are typically part of a PS&E plan set, as-built plan set, or a change order plan set. It may be worth noting that a PLAN DOCUMENT can have two

different titles associated with it (Figure 15) – a title placed in the title block of a plan document and a corresponding title on the plan sheet index. The DOCUMENT TITLE NAME attribute in DOCUMENT stores plan titles. However, often the titles in the plan title block do not match those in the plan sheet index. For example, sheet index titles can be shortened versions of plan titles, or they might use codes or abbreviations. SHEET GROUP stores sheet index titles.

Table 23. NON-SPATIAL DOCUMENT Subtypes.

Addendum Document	Agreement Document	Analysis Document
Assessment Document	Authorization Document	Certification Document
Change Order Cover Document	Checklist Document	Contract Document
Data Document	Design Document	Document
Estimate Document	Financial Document	Form Document
Legal Document	List Document	Memorandum Document
Methodology Document	Narrative Document	Notes Document
Notification Document	Permit Document	Plan Document
Proposal Document	Public Involvement Document	Report Document
Request Document	Schedule Document	Specification Document
Status Document	Work Order Document	Workplan Document

<p>Sheet Index Name: Traffic Control Plan & SW3P</p>	<p>Sheet Index Name: BC(1)-(12)-03</p>	<p>Sheet Index Name: Traffic Signal Layouts</p>																																																																			
<p style="text-align: center;">TRAFFIC CONTROL PLAN & SW3P PHASE 1B</p> <p style="text-align: center;">SHEET 3 OF 3</p> <p style="text-align: center;">© 2003 Texas Department of Transportation</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: small;"> <tr> <td>FED. NO. DIV. NO.</td> <td>FEDERAL AID PROJECT NO.</td> <td>SHEET NO.</td> </tr> <tr> <td>6</td> <td>C 291-12-1</td> <td>70</td> </tr> <tr> <td>STATE</td> <td>STATE DIST. NO.</td> <td>COUNTY</td> </tr> <tr> <td>TEXAS</td> <td>SAT</td> <td>BEXAR</td> </tr> <tr> <td>CONT.</td> <td>SECT.</td> <td>JOB</td> <td>HIGHWAY NO.</td> </tr> <tr> <td>0291</td> <td>12</td> <td>001</td> <td>SPUR 66</td> </tr> </table>	FED. NO. DIV. NO.	FEDERAL AID PROJECT NO.	SHEET NO.	6	C 291-12-1	70	STATE	STATE DIST. NO.	COUNTY	TEXAS	SAT	BEXAR	CONT.	SECT.	JOB	HIGHWAY NO.	0291	12	001	SPUR 66	<p>STANDARD PLANS Texas Department of Transportation <i>Traffic Operations Division</i></p> <p>BARRICADE AND CONSTRUCTION PLASTIC DRUM STANDARD</p> <p style="font-size: 2em; font-weight: bold;">7 of 12</p> <p style="font-size: 1.5em; font-weight: bold;">BC(7)-03</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <tr> <td>© TxDOT 11-4-02</td> <td>DN- BAS</td> <td>CE- GRB</td> <td>DN- FDN</td> <td>CE- CAL</td> </tr> <tr> <td>REVISED</td> <td>STATE DISTRICT</td> <td>FEDERAL REGION</td> <td>FEDERAL AID PROJECT</td> <td>SHEET</td> </tr> <tr> <td>4-03</td> <td>SAT</td> <td>G</td> <td>C 291-12-1</td> <td>99</td> </tr> <tr> <td></td> <td>COUNTY</td> <td>CONTROL</td> <td>SECTION</td> <td>JOB</td> <td>HIGHWAY</td> </tr> <tr> <td></td> <td>BEXAR</td> <td>0291</td> <td>12</td> <td>001</td> <td>SPUR 66</td> </tr> </table>	© TxDOT 11-4-02	DN- BAS	CE- GRB	DN- FDN	CE- CAL	REVISED	STATE DISTRICT	FEDERAL REGION	FEDERAL AID PROJECT	SHEET	4-03	SAT	G	C 291-12-1	99		COUNTY	CONTROL	SECTION	JOB	HIGHWAY		BEXAR	0291	12	001	SPUR 66	<p>SHEET 2 OF 3</p> <p>TRAFFIC SIGNAL INTERSECTION LAYOUT</p> <p>S. H. 16 AT SPUR 66 IN BEXAR COUNTY</p> <p style="text-align: right;">© 2003 Texas Department of Transportation</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <tr> <td>FED. NO. DIV. NO.</td> <td>FEDERAL AID PROJECT NO.</td> <td>SHEET NO.</td> </tr> <tr> <td>6</td> <td>C 291-12-1</td> <td>198</td> </tr> <tr> <td>STATE</td> <td>DIST.</td> <td>COUNTY</td> </tr> <tr> <td>TEXAS</td> <td>SAT</td> <td></td> </tr> <tr> <td>CONT.</td> <td>SECT.</td> <td>JOB</td> <td>HIGHWAY NO.</td> </tr> <tr> <td>0291</td> <td>12</td> <td>001</td> <td>SPUR 66</td> </tr> </table>	FED. NO. DIV. NO.	FEDERAL AID PROJECT NO.	SHEET NO.	6	C 291-12-1	198	STATE	DIST.	COUNTY	TEXAS	SAT		CONT.	SECT.	JOB	HIGHWAY NO.	0291	12	001	SPUR 66
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Figure 15. Sample PLAN DOCUMENT Title Blocks.

Modeling CAD documents in EDDM presented many challenges. The following section (FEATURE Subject Area) addresses challenges found while geo-referencing CAD documents. This section addresses the issue of compatibility and integration of CAD documents with other database components, in particular cell library lookup tables and MST tables. In EDDM, CAD DOCUMENT CELL provides a listing of all the MicroStation cell names that a CAD DOCUMENT contains. In most cases, MicroStation files use cells from the TxDOT cell library (89). However, a review of the sample project data used for the research (see Chapter 5) revealed cases where MicroStation documents used cells the TxDOT cell library did not include (such as “025” or “FIREHY” to represent fire hydrants – the TxDOT cell name is “FH”). This discrepancy meant it was not possible to use a lookup table listing the official TxDOT cell names and their corresponding description in conjunction with CAD DOCUMENT CELL, while at the same time enforcing a one-to-many constraint.

In addition, a review of the TxDOT cell library found many instances of cells that had different names but in reality referred to the same type of feature on the ground. For example, in addition to “POLE” (Pole), the cell library includes the following options to represent poles: “SUPP” (SUE Power Pole), “SPLE” (Service Pole Electric Point), “SUPPR” (SUE Power Pole with Riser), “PP” (Power Pole), “SUMP” (SUE Meter Pole), and “GPL” (Guy Pole Deadman). Using multiple cells to represent similar features on the ground (which might only exhibit relatively minor variations according to form or function) was probably justified when surveyors only had access to DOS-based data collectors and software that only provided rudimentary attribute data capturing capabilities. However, today’s survey data collectors and supporting software platforms support relational database and GIS-based structures. Under these conditions, it is possible to represent poles with just one feature class descriptor (e.g., “POLE”) and use attributes to handle specific situations that may affect poles (e.g., presence or absence of devices such as meters or riser structures, pole function [main, service, or guy], and so on). This characterization makes the use of multiple cells to represent the same type of feature on the ground redundant and therefore unnecessary.

At the same time, the MST data model stores a list of all the entities in the MST data model (DATASET TABLE entity in the FEATURE Subject Area). As mentioned previously, MST, which is the online implementation of GAIP, assumes that entities that represent objects on the ground have a corresponding feature class and GAIP-compliant attributes. Using the fire hydrant example above, for MST to properly model fire hydrants, there has to be a unique feature class with a unique feature class name and unique entry in DATASET TABLE. As a result, multiple references to the same feature class (e.g., “025,” “FIREHY,” or “FH”) require an additional entity to provide a mapping between those references and the feature class.

To address this situation, the researchers included an entity called FEATURE CLASS to provide a mapping between CAD DOCUMENT and DATASET TABLE. In FEATURE CLASS (Table 24), FEATURE CLASS CODE represents the feature code (or cell name) as identified in a MicroStation document (e.g., “025,” “FIREHY,” or “FH”), whereas FEATURE CLASS EQUIVALENT CODE represents a unique representation for the feature class on the ground (e.g., “WAT_FHYD”). Notice that FEATURE CLASS EQUIVALENT CODE is the primary key in DATASET DEFAULT FEATURE CLASS, which enables a one-to-one mapping between feature classes and entries in DATASET TABLE.

Table 24. FEATURE CLASS CODE Equivalence.

FEATURE CLASS CODE	FEATURE CLASS EQUIVALENT CODE
025	WAT_FHYD
FH	WAT_FHYD
FIREHY	WAT_FHYD
GPL	POLE
POLE	POLE
PP	POLE
SPLE	POLE
SUMP	POLE
SUPP	POLE
SUPPR	POLE

FEATURE Subject Area

The FEATURE Subject Area consists of FEATURE, related lookup tables, and linkages to other subject areas (Figure 16, Table 25). A FEATURE is a real world or virtual phenomenon that exists in space and time. There are two general types of features: GAIP features and non-GAIP features. A GAIP FEATURE is a GAIP-compliant feature. A NON-GAIP FEATURE is a non-GAIP-compliant feature, typically associated with features that TxDOT does not maintain.

At the lowest level, the primary key for GAIP features and non-GAIP features is a TXDOT UNIQUE ID attribute. TXDOT UNIQUE ID is unique within each feature class, but not necessarily across features classes, i.e., different feature entities could share the same TXDOT UNIQUE ID values. For example, potential TXDOT UNIQUE ID values within the TXDOT CONTROL SECTION LINE feature are 1, 2, 3, and 4. These values are also potential TXDOT UNIQUE ID values within the TXDOT ROADBED LINE feature.

Readers should note that all subtype entities between the FEATURE entity level and the actual feature entity level (i.e., GAIP FEATURE, NON-GAIP FEATURE, GEOPOLITICAL FEATURE, HIGHWAY FEATURE, and DOCUMENT FEATURE) are “conceptual” subtype/supertype entities that need to be “collapsed” prior to the generation of the physical data model. After collapsing those intermediate entities, the result is that the TXDOT UNIQUE ID attribute becomes one of the FEATURE entity primary key components. The other primary key component is the TABLE UNIQUE ID attribute, which is a foreign key to DATASET TABLE. DATASET TABLE includes a listing of all the entity logical names and table physical names in the database. DATASET FIELD includes a listing of all the entity attribute names and table field names in the database. Both DATASET TABLE and DATASET FIELD are MST entities.

The combination of TABLE UNIQUE ID and TXDOT UNIQUE ID makes FEATURE a comprehensive index of features in the database, facilitating query transactions that involve other subject areas. In a typical situation, the analyst would first select the specific feature of interest (e.g., DISTANCE FROM ORIGIN LINE in Figure 16) manually, using a GIS interface, or using a pre-defined query form. A direct query would enable the retrieval of any specific records of interest in DISTANCE FROM ORIGIN LINE. Through DATASET TABLE, the system provides the corresponding TABLE UNIQUE ID value, which the analyst would use to retrieve the corresponding records in FEATURE. With the selected records in FEATURE, the analyst could retrieve records in PROJECT FEATURE and/or DOCUMENT FEATURE, which in turn would enable the retrieval of data from relevant tables in the PROJECT and DOCUMENT Subject Areas. The structure of the database is flexible, facilitating other types of database transactions, e.g., in situations where the analyst already knows a specific project or document of interest and it is necessary to retrieve the corresponding feature records. In this case, FEATURE provides the necessary bridge between the PROJECT and/or DOCUMENT Subject Areas and the corresponding feature of interest.

Certain types of features are combinations of other features. For example, a bridge can include features such as deck, guardrail, abutments, piers, and markings. In EDDM, a FEATURE SET entity describes the main characteristics of a feature set. FEATURE SET ITEM contains a list of features that make up a FEATURE SET.

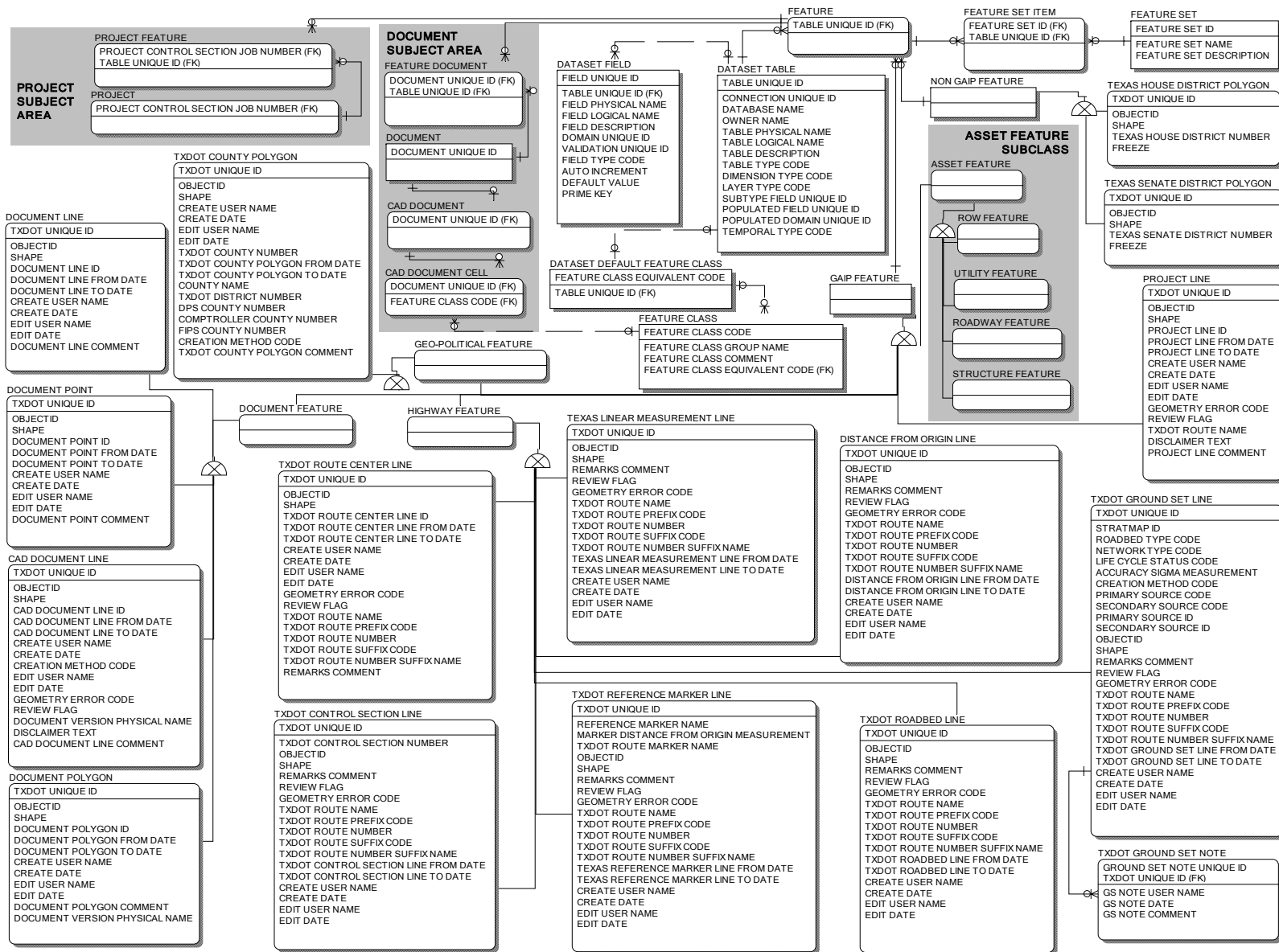


Figure 16. Logical Engineering Design Data Model – FEATURE Subject Area.

Table 25. FEATURE Subject Area Entities.

Entity	Description
ASSET FEATURE	An ASSET FEATURE is a real world object that agencies include in their inventories for asset management purposes. Examples include bridges, recreation facilities, utilities, water systems, waste management, public facilities, rest areas, canals, and signs.
CAD DOCUMENT CELL	A CAD DOCUMENT CELL is the name of a CAD cell used in a CAD document. A CAD document could have zero, one, or many CAD DOCUMENT CELLS.
CAD DOCUMENT LINE	A CAD DOCUMENT LINE is a representation of a geo-referenced CAD document as a set of multilines. In the database, a CAD DOCUMENT LINE represents an entire CAD document.
DATASET DEFAULT FEATURE CLASS	A DATASET DEFAULT FEATURE CLASS is the default feature class code associated with a DATASET TABLE. For example, in the database the default feature class code for a fire hydrant is "WAT_FHYD." This feature class code is associated with the DATASET TABLE logical name "WATER HYDRANT."
DATASET FIELD	A DATASET FIELD is a table that stores field information for tables identified in the DATASET TABLE. Source: MST documentation (90)
DATASET TABLE	A DATASET TABLE is a table that lists accessible tables in the enterprise. Source: MST documentation (90)
DISTANCE FROM ORIGIN LINE	A DISTANCE FROM ORIGIN LINE is a spatial representation that follows roadway centerlines, under TxDOT jurisdiction, and models statewide routes from a statewide view. It is mainly used for cartographic purposes. Source: <i>TxDOT Graphic Data Standard (49)</i>
DOCUMENT FEATURE	A DOCUMENT FEATURE is a simplified spatial representation of a DOCUMENT. In the data model, DOCUMENT FEATURE exists as a logical supertype entity that includes the following subtypes: DOCUMENT LINE, DOCUMENT POINT, and DOCUMENT POLYGON. Note: A DOCUMENT FEATURE is different from a FEATURE DOCUMENT. A FEATURE DOCUMENT identifies the DOCUMENTS associated with a FEATURE.
DOCUMENT LINE	A DOCUMENT LINE is a simplified spatial representation of a DOCUMENT as a linear feature. The purpose of a DOCUMENT LINE is to serve as a spatial pointer to a DOCUMENT such as a cross section or a profile.
DOCUMENT POINT	A DOCUMENT POINT is a simplified spatial representation of a DOCUMENT as a point feature. The purpose of a DOCUMENT POINT is to serve as a spatial pointer to a DOCUMENT such as a photograph, a boring location, or a benchmark.
DOCUMENT POLYGON	A DOCUMENT POLYGON is a simplified spatial representation of a DOCUMENT as a polygon feature. The purpose of a DOCUMENT POLYGON is to serve as a spatial pointer to a DOCUMENT such as a plan, a schematic, or a layout.
FEATURE	A FEATURE is a real world or virtual phenomenon that exists in a spatial or spatiotemporal domain. In the database, it provides a listing of all spatial or spatiotemporal features regardless of feature code. Source: NCHRP Report 460 (91).
FEATURE CLASS	A FEATURE CLASS is a group of features that share common properties and definitions. In the database, FEATURE CLASS provides TxDOT feature codes, which include surveying and MicroStation cells (e.g., BL, EP, MON, and MP), as well as new feature class codes developed to standardize existing feature codes and to support GIS applications.
FEATURE DOCUMENT	A FEATURE DOCUMENT is a mapping that represents the many-to-many relationship between a FEATURE and a DOCUMENT. FEATURE DOCUMENT enables the identification of DOCUMENTS associated with a FEATURE and the identification of FEATURES associated with a DOCUMENT. Note: A FEATURE DOCUMENT is different from a DOCUMENT FEATURE. A DOCUMENT FEATURE (inside the FEATURE Subject Area) provides the actual spatial representation of a DOCUMENT
FEATURE SET	A FEATURE SET is a collection of features. Examples include signposts with multiple signs or poles with multiple utility features.
FEATURE SET ITEM	A FEATURE SET ITEM is a feature that is part of a FEATURE SET. Examples include each of the utilities on a utility pole and each of the signs on a signpost.

Table 25. FEATURE Subject Area Entities (Continued).

Entity	Description
GAIP FEATURE	A GAIP FEATURE is a real world or virtual phenomenon that exists in a spatial or spatiotemporal domain modeled in accordance with the TxDOT GAIP standard.
GEO-POLITICAL FEATURE	A GEO-POLITICAL FEATURE is a spatial boundary defined by a jurisdictional agency. Examples include counties, districts, and cities. In the data model, GEO-POLITICAL FEATURE exists as a logical supertype entity that includes the TXDOT COUNTY POLYGON subtype.
HIGHWAY FEATURE	A HIGHWAY FEATURE is a spatial representation of a roadbed or roadway centerline. In the data model, HIGHWAY FEATURE exists as a logical supertype entity that includes the following subtypes: TXDOT ROUTE CENTER LINE, TXDOT CONTROL SECTION LINE, TEXAS LINEAR MEASUREMENT LINE, TXDOT REFERENCE MARKER LINE, DISTANCE FROM ORIGIN LINE, TXDOT ROADBED LINE, and TXDOT GROUND SET LINE.
NON-GAIP FEATURE	A NON-GAIP FEATURE is a real world or virtual phenomenon that exists in a spatial or spatiotemporal domain that is not modeled in accordance with the TxDOT GAIP standard.
PROJECT FEATURE	A PROJECT FEATURE is a mapping that represents the many-to-many relationship between a FEATURE and a PROJECT. PROJECT FEATURE enables the identification of FEATURES that are associated with a PROJECT and the identification of PROJECTS associated with a FEATURE.
PROJECT LINE	A PROJECT LINE is a spatial representation of a highway improvement project represented as a roadway centerline segment bounded by project limits.
TEXAS HOUSE DISTRICT POLYGON	A TEXAS HOUSE DISTRICT POLYGON is a spatial representation of a Texas House of Representatives district as a polygon feature.
TEXAS LINEAR MEASUREMENT LINE	A TEXAS LINEAR MEASUREMENT LINE is a spatial representation of a roadbed centerline. Source: <i>TxDOT Graphic Data Standard (49)</i> .
TEXAS SENATE DISTRICT POLYGON	A TEXAS SENATE DISTRICT POLYGON is spatial representation of a Texas House of Representatives district as a polygon feature.
TXDOT CONTROL SECTION LINE	A TXDOT CONTROL SECTION LINE is a spatial representation of a TxDOT control section that follows roadway centerlines under TxDOT jurisdiction. Source: <i>TxDOT Graphic Data Standard (49)</i> . A TxDOT control section is a 6 digit number, where the first 4 digits represent a portion of a highway with well-defined termini (i.e., “control”) and the last 2 digits represent a “section” of that “control.” Source: TxDOT Production GIS Data (48)
TXDOT COUNTY POLYGON	A TXDOT COUNTY POLYGON is a spatial representation of the “largest politically bounded geographic area defined to serve a local government within the state of Texas” (48). Examples of counties include Bexar, Travis, Harris, and Dallas.
TXDOT GROUND SET LINE	A TXDOT GROUND SET LINE is a spatial representation of a Texas traveled route roadbed centerline used for subset collections. Source: <i>TxDOT Graphic Data Standard (49)</i> .
TXDOT GROUND SET NOTE	A TXDOT GROUND SET NOTE is a note or comment associated with TXDOT GROUND SET LINE.
TXDOT REFERENCE MARKER LINE	A TXDOT REFERENCE MARKER LINE is a spatial representation of the section of roadbed centerline between adjacent highway reference markers. Source: <i>TxDOT Graphic Data Standard (49)</i> .
TXDOT ROADBED LINE	A TXDOT ROADBED LINE is a spatial representation that follows roadbed centerlines under TxDOT jurisdiction.
TXDOT ROUTE CENTER LINE	A TXDOT ROUTE CENTER LINE is a spatial representation that follows roadway centerlines of TxDOT routes. Source: TxDOT Production GIS Data (48)

GAIP features of special relevance to this research are GEO-POLITICAL FEATURE, PROJECT LINE, DOCUMENT FEATURE, ASSET FEATURE, and HIGHWAY FEATURE. GEO-POLITICAL FEATURE represents the spatial boundaries of political or administrative jurisdictions as TxDOT districts, states, cities, and counties. TXDOT COUNTY POLYGON is worth mentioning since it includes unique county identifiers in use by state and federal agencies: TxDOT County Number, County Name, Texas Department of Public Safety (DPS) County Number, Comptroller County Number, and Federal Information Processing Standards (FIPS) County Number. In a GIS environment, it is possible to overlay TXDOT COUNTY POLYGON and PROJECT LINE, producing county identifiers for project features “on the fly,” rendering use of the DCIS TACS COUNTY-L table, which also contains county identifiers, unnecessary.

PROJECT LINE represents project limits as linear features. PROJECT LINE is associated with a specific project through the PROJECT FEATURE entity. In EDDM, PROJECT LINE also provides a spatial “linkage” to document entities that are normally associated with projects but do not normally have geographic location data associated with them (e.g., Design Conference Form, Form 1002, and State Letter of Authority).

DOCUMENT FEATURE provides geographic representations for a variety of document types. EDDM includes three DOCUMENT FEATURE types: DOCUMENT POINT, DOCUMENT LINE, and DOCUMENT POLYGON. An example of a DOCUMENT POINT is the geographic location associated with a digital picture. DOCUMENT LINE and DOCUMENT POLYGON enable the use of spatial outlines to represent the spatial extent of a document. An example of a DOCUMENT LINE is a highway cross section or the limits of a highway cross section sheet. An example of a DOCUMENT POLYGON is the outside border of an engineering design sheet, an aerial photograph, or a scanned plan. Document polygons are particularly useful in situations where it is preferable to see an outline of a geo-referenced document on the screen instead of the entire document. For completeness, EDDM includes a fourth DOCUMENT FEATURE type called CAD DOCUMENT LINE, which represents a geo-referenced CAD document as a set of multilines. While loading CAD documents in their native format in a GIS environment is possible, loading rates can become a performance issue. Under these circumstances, it may be preferable to load a “view” of the CAD document instead of the original document.

ASSET FEATURE provides geographic representations of assets located within the ROW. ASSET FEATURE includes four subtypes: ROW FEATURE, UTILITY FEATURE, ROADWAY FEATURE, and STRUCTURE FEATURES. [Figure 17](#) shows examples of ASSET FEATURE classes the researchers used to test the feasibility of the data model. [Table 26](#) shows the corresponding entity definitions. Readers should note that the asset features listed in [Figure 17](#) and [Table 26](#) represent a very small sample. A comprehensive inventory of asset features would include a much larger number of feature classes.

HIGHWAY FEATURE provides geographic representations of roadway centerlines or roadbeds according to the *TxDOT Graphic Data Standard* (49). Following [Table 19](#), EDDM includes the following HIGHWAY FEATURE entities: TXDOT GROUND SET LINE, TEXAS LINEAR MEASUREMENT LINE, DISTANCE FROM ORIGIN LINE, TXDOT CONTROL SECTION LINE, TXDOT REFERENCE MARKER LINE, TXDOT ROUTE CENTERLINE, and TXDOT ROADBED LINE.

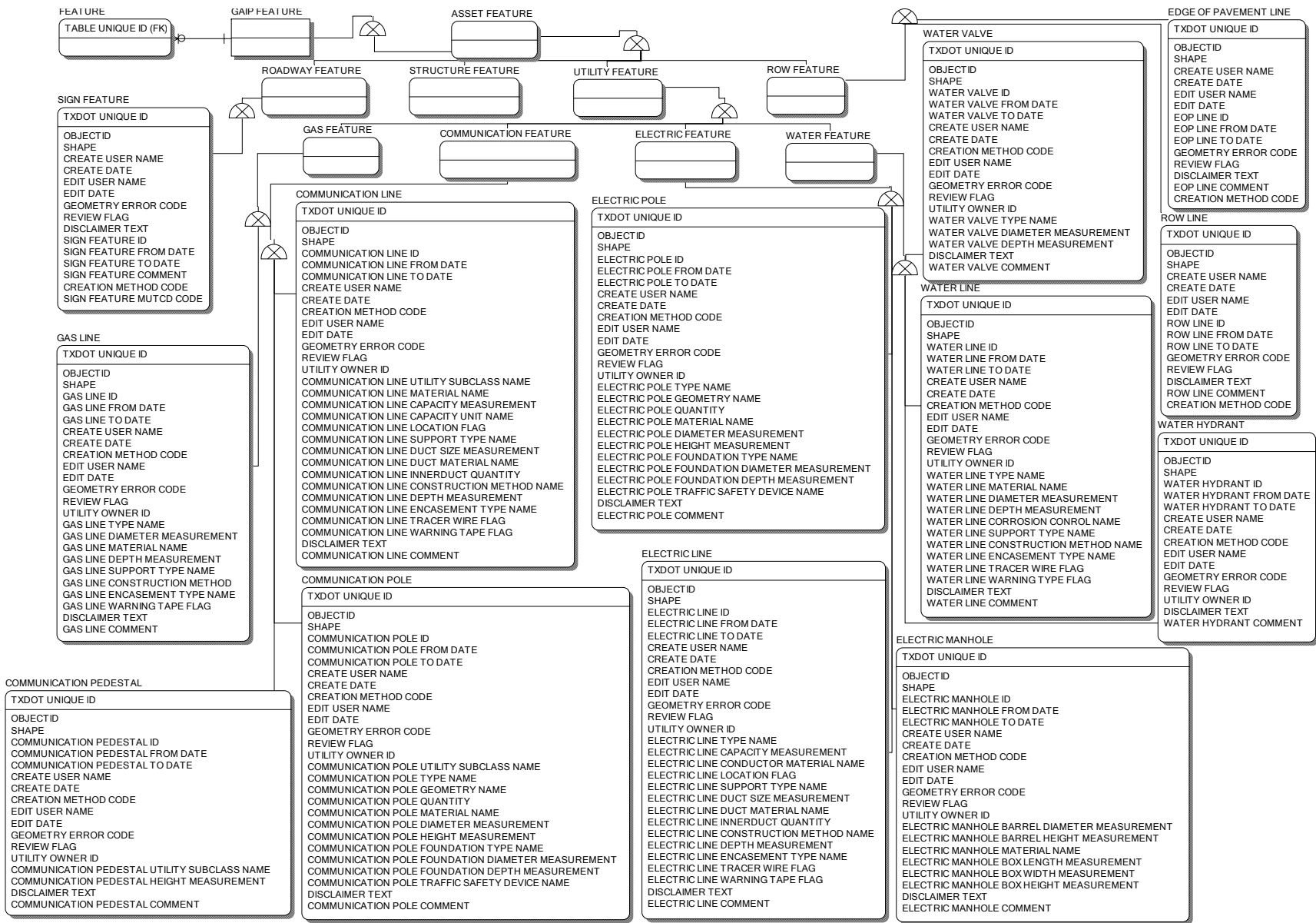


Figure 17. Logical Engineering Design Data Model – ASSET FEATURE Subclass Entities.

Table 26. ASSET FEATURE Subclass Entities.

Entity	Description
ASSET FEATURE	An ASSET FEATURE is a real world object that agencies include in their inventories for asset management purposes. Examples include bridges, recreation facilities, utilities, water systems, waste management, public facilities, rest areas, canals, and signs.
COMMUNICATION FEATURE	A COMMUNICATION FEATURE is a component of a communication network. Examples include telephone lines, poles, and pedestals.
COMMUNICATION LINE	A COMMUNICATION LINE is a line that can carry data, voice (telephone), or video (including television) signals. Depending on the carrier technology and other factors, communication lines can include optical fiber, coaxial cable, or twisted pair copper.
COMMUNICATION PEDESTAL	A COMMUNICATION PEDESTAL is typically a narrow, tall enclosure that protrudes from the ground and that houses communication circuit connections.
COMMUNICATION POLE	A COMMUNICATION POLE is a support structure for overhead communication lines and/or equipment. For simplicity (and for consistency with the naming convention for electric support structures), a pole is treated as a generic term that includes traditional poles, A-frame towers (sometimes called A-frame poles), H-frame towers (sometimes called H-frame poles), lattice towers, and tube towers (sometimes called tube poles).
EDGE OF PAVEMENT LINE	An EDGE OF PAVEMENT LINE is a line that represents the visible edge of the pavement structure.
ELECTRIC FEATURE	An ELECTRIC FEATURE is a component of an electric transmission or distribution network. Examples include electric lines, manholes, and poles.
ELECTRIC LINE	An ELECTRIC LINE is a line that carries electricity.
ELECTRIC MANHOLE	An ELECTRIC MANHOLE is a hole with a flush cover that enables access to an underground electric utility.
ELECTRIC POLE	An ELECTRIC POLE is a support structure for overhead electric lines and/or equipment. For simplicity, a pole is treated as a generic term that includes traditional poles, A-frame towers (sometimes called A-frame poles), H-frame towers (sometimes called H-frame poles), lattice towers, and tube towers (sometimes called tube poles).
GAS FEATURE	A GAS FEATURE is a component of a natural gas generation or distribution network. Examples include gas lines and valves.
GAS LINE	A GAS LINE is a pipeline that carries natural gas.
ROADWAY FEATURE	A ROADWAY FEATURE is a real world object within the boundaries of a roadway. Examples include signs, barriers, and guard rail.
ROW FEATURE	A ROW FEATURE is a spatial representation of a ROW feature. In the data model, ROW FEATURE exists as a logical supertype entity that includes the following subtypes: ROW LINE and EDGE OF PAVEMENT LINE.
ROW LINE	A ROW LINE is a line that represents the boundary of the road right of way.
SIGN FEATURE	A SIGN FEATURE is a sign with an associated support structure located on the ROW.
STRUCTURE FEATURE	A STRUCTURE FEATURE is a spatial representation of a feature that bears and transmits roadway-related stresses through a foundation to the ground. In the data model, STRUCTURE FEATURE exists as a logical supertype entity. Examples include bridges, piers, abutments, and retaining walls.
UTILITY FEATURE	A UTILITY FEATURE is a real world object associated with a utility installation. Examples include communication feature, electric feature, and water line.
WATER FEATURE	A WATER FEATURE is a component of a drinkable water network. Examples include water hydrants, lines, and valves.
WATER HYDRANT	A WATER HYDRANT is a device that allows direct, controlled discharges from a water main. This feature is typically an upright metal device that protrudes from the ground.
WATER LINE	A WATER LINE is a pipe that carries drinkable water.
WATER VALVE	A WATER VALVE is a device for closing or modifying the passage of drinkable water through a pipe.

PHYSICAL DATA MODEL DEVELOPMENT

With the logical data model described in the previous sections, the researchers developed a physical data model for implementation in a database environment. One challenge in developing the physical data model was the conversion of subcategories into tables. The EDDM logical data model has several subcategories indicating subtype and supertypes. For example, the Sign Feature subtype entity is a subcategory of the Roadway Feature supertype entity. In ERwin, Data Modeler subcategories typically contain no attributes or foreign keys, which would translate into empty tables in the physical data model. To address this situation, the researchers “collapsed” the subcategories using ERwin Data Modeler supertype-subtype rollup and rolldown tools. To comply with physical data model naming standards (43), the researchers also used an ERwin Data Modeler macro that uses a TxDOT-provided logical/physical name equivalence table to generate physical model table and field names from logical model entity and attribute names.

The result of this effort was a physical data model for EDDM compliant with TxDOT standards. Research Product 0-5246-P1 includes this data model.

After developing the physical data model, the researchers checked the model for errors and generated scripts that contained SQL statements to create tables, columns, indexes, triggers, views, integrity constraints, and other items in Oracle. The next step involved checking datatypes and running the scripts using Oracle SQL Plus™ to generate an Oracle schema for the PROJECT and DOCUMENT Subject Areas. Finally, the researchers created an ESRI geodatabase in Oracle using ArcSDE for the FEATURE Subject Area.

DATA DICTIONARY

The researchers also generated a data dictionary for EDDM that included definitions for individual entities and attributes. Typically, the definitions included name, purpose, format, valid values, and examples (43). As appropriate, the definitions included the source. Research Product 0-5246-P1 includes the data dictionary, both within the ERwin Data Modeler file and as a standalone document.

CHAPTER 5. PROTOTYPE DATABASE IMPLEMENTATION

INTRODUCTION

This chapter summarizes the steps involved in the population of a prototype database using the data model developed in [Chapter 4](#), including a review of the sample project data used to populate the database, development of a document inventory, mapping the document inventory to TxDOT’s EDTIS library structure, and development of document outlines and feature datasets.

SAMPLE PROJECT DATA

TxDOT provided sample data associated with four highway construction projects. [Table 27](#) summarizes the data provided for each project and the general results obtained while using the sample data to populate the prototype database. Of the 8816 documents received, the researchers used 7784 documents (or 88 percent) for the prototype platform. Most of the documents used were MicroStation files (2850 or 37 percent) or as-built plans (2392 or 31 percent).

Table 27. Summary of Project Documents.

Documents	Spur 66		Interstate Highway (IH) 410 @ Ingram	IH 410 @ Nacagodches	IH 20 @ JBS	Total	
	CSJ 029112001	CSJ 029112002	CSJ 052104190	CSJ 052104187	CSJ 000513043		
Documents Provided:							
Districts	1768	294	2954	186	861	6063	69%
Plans Online	719	43	1734	2	255	2753	31%
Total	2487	337	4688	188	1116	8816	100%
Documents Used:							
MicroStation Files	581	65	2106	2	96	2850	37%
AutoCAD™ Files	12	5	0	0	0	17	<1%
Word Processing Files	107	29	99	113	9	357	5%
Photographs	103	0	182	0	626	911	12%
Project Plan Files	393	41	1731	0	227	2392	31%
Spreadsheets	87	4	62	8	6	167	2%
Schedule Files	369	163	140	0	0	672	9%
PDF Files	28	3	77	20	2	130	2%
Subtotal	1680	310	4397	143	966	7496	96%
Other Files Used:							
Primavera™ Files	Y	Y				Y	
Databases				Y		Y	
Presentations	Y		Y			Y	
GEOPAK™ Setting Files	Y		Y		Y	Y	
CaiCE™ Setting Files	Y					Y	
Illustrations	Y		Y			Y	
Total	1763	325	4442	182	1072	7784	100%

Spur 66 Widening/Reconstruction (CSJ 029112001 and 029112002)

This project was a fast track project in south San Antonio (Figure 18). CSJ 029112002 was the landscaping component of this project. The San Antonio District completed the design internally and used FMS to store and monitor all project documentation. Driven by the construction of a new truck assembly plant, this new location/retrofitting project took five months from project selection to final design review. Letting took place in August 2003. As Table 27 shows, of the 2824 documents TxDOT provided, the researchers used 2088 documents to populate the database. Many of the unused files were miscellaneous working files and CaiCE, GEOPAK, and Primavera user preference files. Other unused files included duplicate transmittal data and plan sets. Probably because TxDOT completed the project internally, the document dataset contained the greatest variety of document types of the four sample projects used.

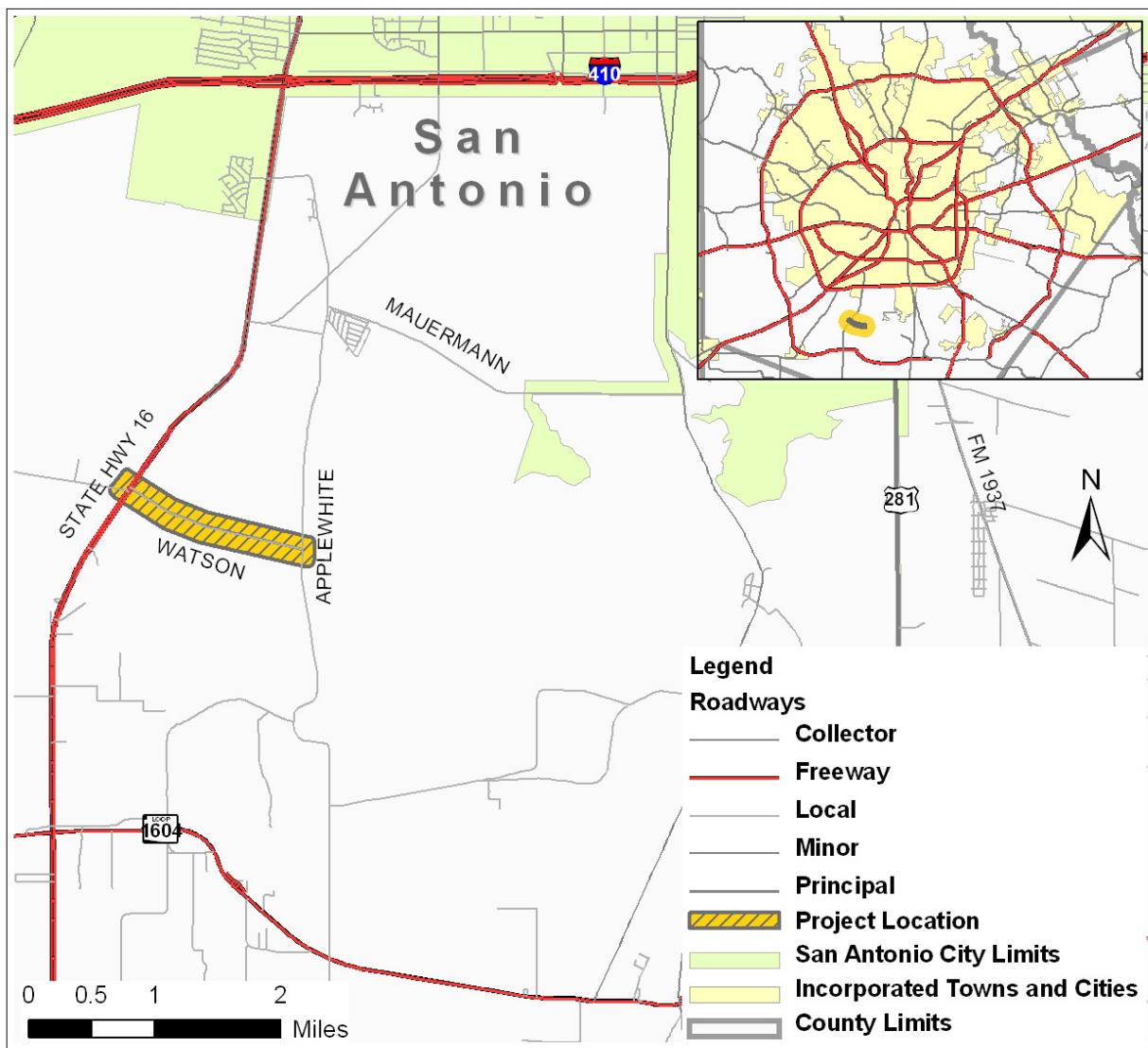


Figure 18. Spur 66 Widening/Reconstruction Project (San Antonio, Texas).

IH 410 Reconstruction/Widening from Ingram Road to Callaghan Road (CSJ 052104190)

This project in northwest San Antonio is currently under construction (Figure 19). Except for bridge design, which the San Antonio District conducted internally, project design and documentation involved five different consultants. Letting took place in February 2005. After letting, there were several change orders to correct items such as cross sections, vertical alignments, bridge and pier elevations, and underground infrastructure. Due to the various change orders and consultant turnover issues, electronic project documentation was inconsistent. Although required, the design consultants did not use the FMS standard and only provided printed documentation after creating the electronic files. The change orders for this project are still not complete. Frontage roads are currently undergoing a redesign to accommodate driveway slopes, which the original design did not consider. As Table 27 shows, of the 4688 documents TxDOT provided, the researchers used 4442 documents to populate the database. Unused documents included miscellaneous working files and GEOPAK user files. The document dataset contained the most documents of the four sample projects used.

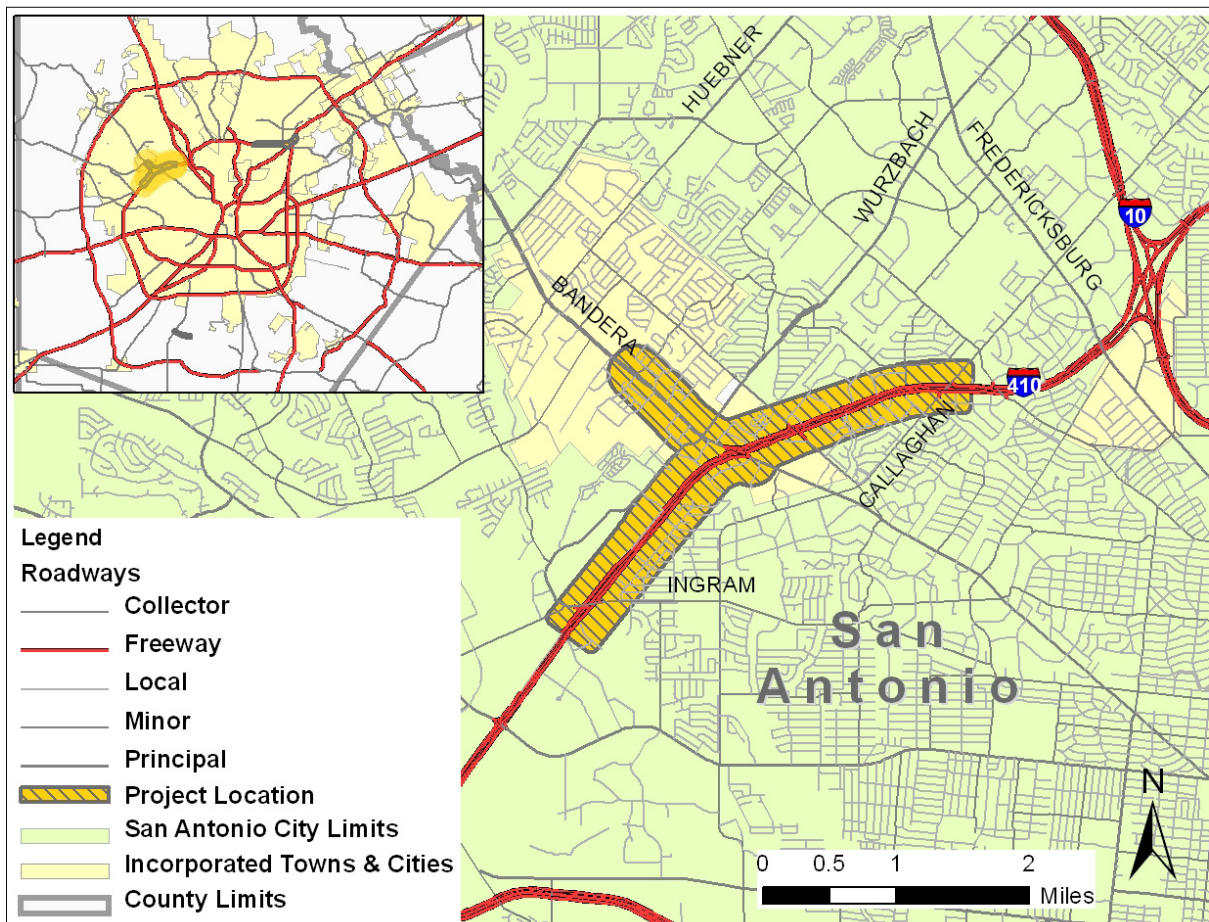


Figure 19. IH 410 Reconstruction/Widening from Ingram Road to Callaghan Road Project (San Antonio, Texas).

IH 410 Reconstruction/Widening from Nacogdoches Road to Austin Highway (CSJ 052104187)

This project in northeast San Antonio is currently under construction (Figure 20). Letting took place in 2006. As Table 27 shows, of the 188 documents TxDOT provided, the researchers used 182 documents to populate the database. It may be worth noting that when TxDOT provided the document dataset, letting had not taken place yet. As a result, proposals, bid tabs, and plan sets were not available, and the San Antonio District could not release any internal files. As a result, documents provided for this project included primarily correspondence. The San Antonio District is using FMS to store and monitor all project documentation.

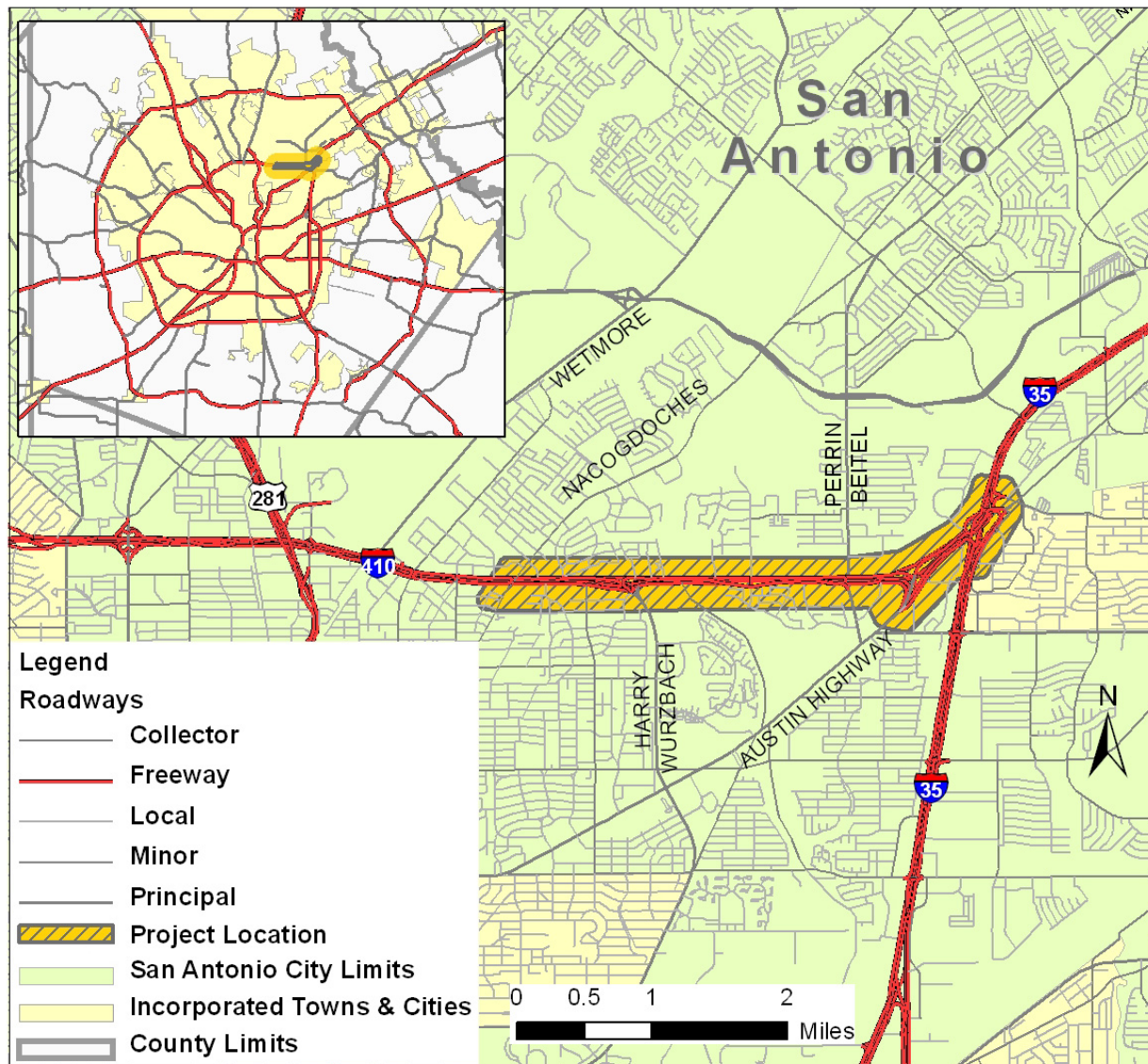


Figure 20. IH 410 Reconstruction/Widening from Nacogdoches Road to Austin Highway Project (San Antonio, Texas).

IH 20 New Location/Reconstruction with JBS Parkway (CSJ 000513043)

This project in Odessa is currently under construction (Figure 21). Driven by local concerns and new warehouse development, the project involves a new location freeway with two interchanges connecting JBS Parkway to IH 20. Except for bridge design, which consultants completed, the Odessa District performed all design internally. As Table 27 shows, of the 1116 documents TxDOT provided, the researchers used 1072 documents to populate the database. Most documents provided were district photographs and as-built plans of the current project.

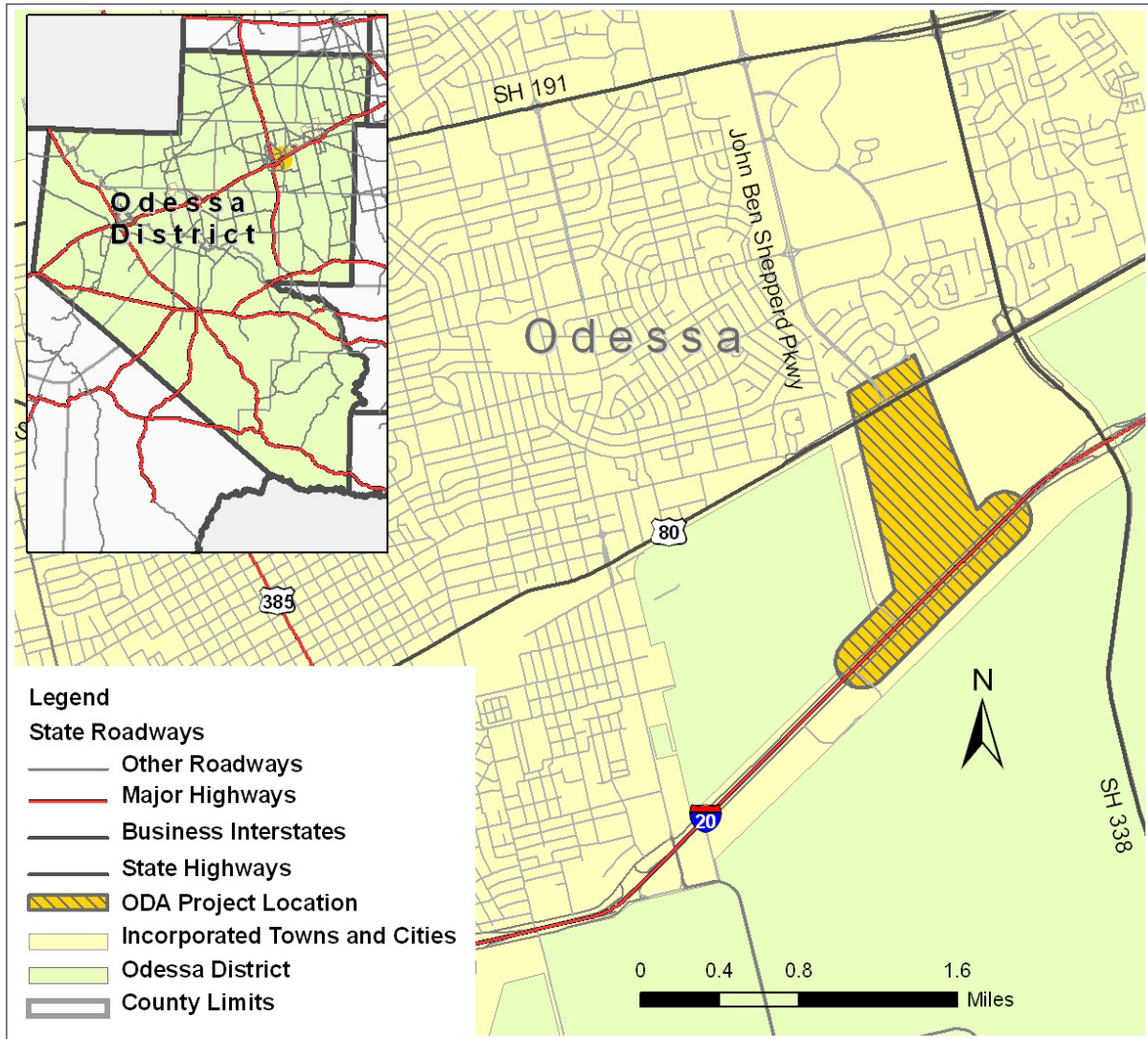


Figure 21. IH 20 New Location/Reconstruction with JBS Parkway (Odessa, Texas).

PROJECT DOCUMENT PROCESSING METHODOLOGY

Processing the sample project documents and associated data involved a number of activities:

- integrate project data in the database;
- develop a physical file structure to simulate the FileNet file structure;
- develop an inventory of PDP document categories;
- map PDP document categories to the FileNet-compatible file structure;
- integrate document data in the prototype;
- integrate spatial document data in the database;
- integrate feature data in the database; and
- link project, document, and feature data in the database.

The rest of the chapter describes the procedure followed to complete these activities.

INTEGRATING PROJECT DATA IN THE DATABASE

TxDOT provided basic DCIS project data for the four projects analyzed. With the data provided, the researchers populated the PROJ and CSJ_HIERARCHY tables. [Table 28](#) shows the data used to populate the PROJ table.

DEVELOPMENT OF PHYSICAL FILE STRUCTURE TO SIMULATE THE FILENET FILE STRUCTURE

As mentioned previously in [Chapter 4](#), the researchers did not have access to the FileNet data model. Further, the researchers did not have access to the FileNet physical file structure at TxDOT. For populating and testing the EDDM prototype, the researchers developed a physical folder structure that mimics the Austin District FileNet library structure ([36, 37](#)), under the assumption that this structure will likely provide the foundation for FileNet implementations at the district level throughout the state. [Figure 22](#) shows a screenshot of the file structure created for the prototype.

Table 28. Basic Project Attribute Data.

DCIS Project Attribute	Spur 66		IH 410 @ Ingram	IH 410 @ Nacogdoches	IH 20 @ JBS
	CSJ 029112001	CSJ 029112002	CSJ 052104190	CSJ 052104187	CSJ 000513043
PROJ CSJ NBR	029112001	029112002	052104190	052104187	000513043
ELIG FED FUND FLAG	S	S	F	F	F
EST CONST COST	9523242.91	219300	55401560.62	67350000	9752202.79
DT EST COST					
LMT_FROM	0.27 MI WEST OF SH 16	SH 16	IH 410 FROM E OF INGRAM RD	IH 410 0.2 MI EAST OF BROADWAY	AT JBS PARKWAY IN ODESSA
LMT_TO	APPLEWHITE ROAD	APPLEWHITE ROAD	CALLAGHAN RD	BEITEL CREEK WEST OF LP 368	
LAYMAN_DSCR1	CONSTRUCT SPUR TO REPLACE WATSON ROAD	LAND- SCAPING	EXPAND TO 10 LANE FRWY & TMS	EXPAND TO 10 LANE FRWY & TMS	NEW INTER- CHANGE
LAYMAN_DSCR2			FREEWAY REHAB- ILITATION	FREEWAY REHAB- ILITATION	
CNTRCT CSJ					
DIST LET DT	01-Oct-03	01-Jan-05	01-Jan-05		01-Aug-05
ACTL LET DT	01-Oct-03	01-Jan-05	01-Jan-05		01-Aug-05
EST ROW COST					
DT EST ROW					
PROJ NBR	C 291-12-1	C 291-12-2	NH 2005(136)		NH 2005(863)
TOT OBG AMT					
RDWY FUNCT CLS					
ADDL ROW					
ENGR NBR				59	
LET SCH 1	2004	2005	2005	2006	2005
BEG REF MRKR NBR			0012		0119
BEG REF MRKR DISP			0.424		0.315
END REF MRKR NBR			0014X		0120
END REF MRKR DISP			0.618		0.338
LOC CONTRIB AMT					
TO DFO					
FROM DFO					
MGR NBR					
CNTY NBR					

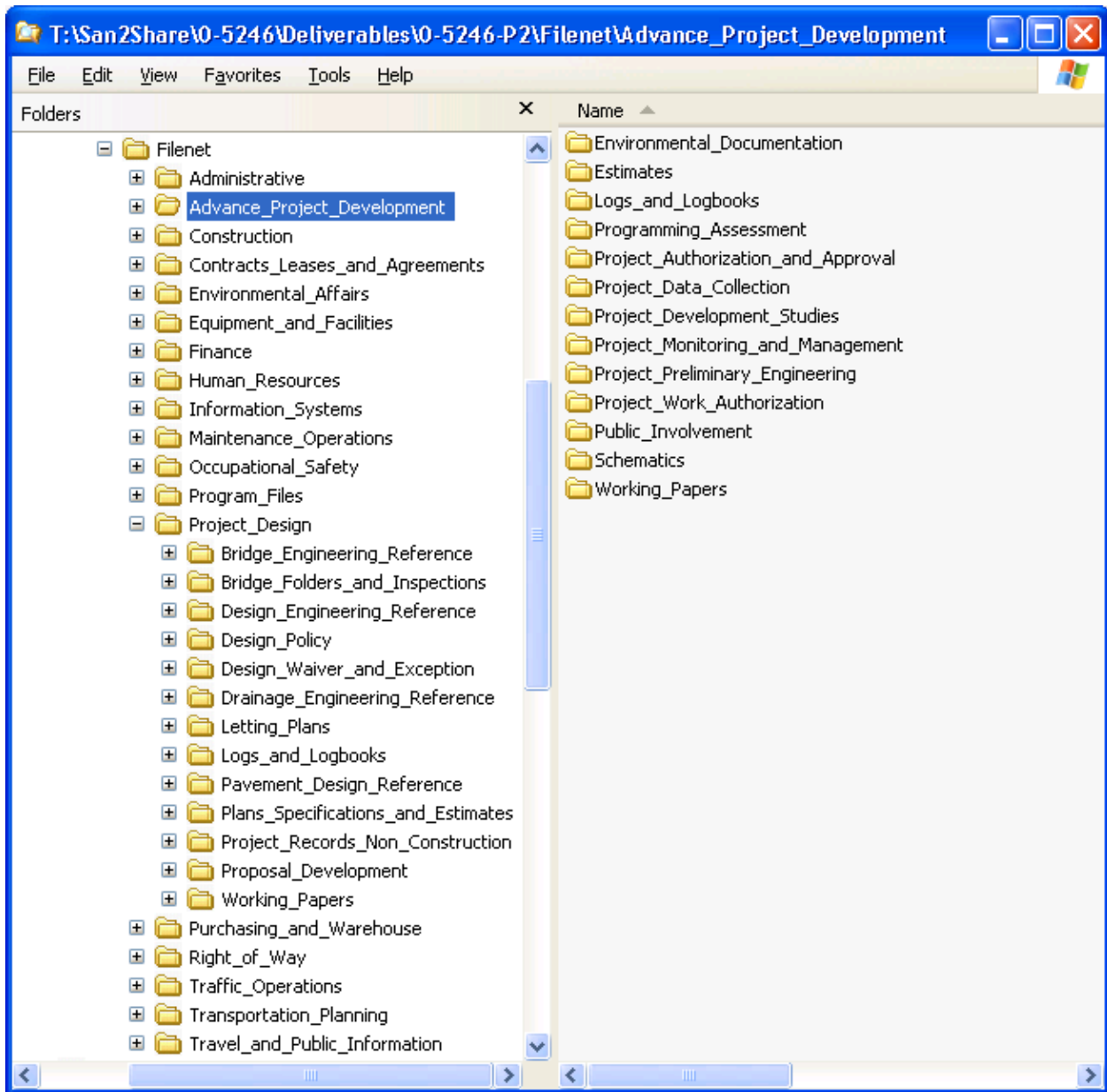


Figure 22. Prototype File Structure View.

DEVELOPMENT OF PDP DOCUMENT CATEGORIES

As [Chapter 2](#) documented, a variety of project document management approaches have evolved at TxDOT districts over the years. A common denominator of those approaches is that the resulting document file structures tend to follow the process that districts use to plan, design, and build projects. During the process of transferring documents from the sample project dataset to the prototype EDDM FileNet-compatible file structure, the researchers realized that mapping from individual project-based file structures to the FileNet file structure was not straightforward. In order to facilitate and standardize the document mapping process, the researchers decided to

analyze project-based file structures using standard document development specifications and requirements at TxDOT. To conduct the analysis, the researchers reviewed a number of documents, including the following:

- *Project Development Process Manual (10)*,
- *PS&E Preparation Manual (12)*,
- Design Summary Report (13),
- TxDOT's Form 1002 (14),
- San Antonio District Standards and Forms (15),
- San Antonio District PDP Milestones (16),
- TxDOT – Odessa District Standard Operating Procedure No. TP 07-01 (19),
- TxDOT – Odessa District Standard Operating Procedure No. TP 01-02 (20),
- Odessa District's Design Conference Form (21), and
- *Project Delivery and Project Management for TxDOT Projects (92)*.

In addition, the researchers reviewed the sample project data to identify potential gaps in the PDP document category inventory. The result of this effort was a summary of document categories that are typically associated with standard PDP activities. Research Product 0-5246-P1 includes the summary.

MAPPING PDP DOCUMENT CATEGORIES TO THE FILENET FILE STRUCTURE

Mapping TxDOT design document categories to the TxDOT FileNet library structure was a major effort. In general, the researchers found four types of matches between TxDOT design document categories and FileNet document types: direct matches, multiple matches, partial matches, and no matches. This section describes the characteristics of each type of match. The [appendix](#) includes a listing of the corresponding FileNet document types.

- **Direct matches.** Direct matches occurred when mapping from TxDOT design document categories to FileNet document types was positive and straightforward. For example, the Design Summary Report identified in the *Project Development Process Manual (10)* matched the Design Conference document type (FileNet Code 2.8.2).
- **Multiple matches.** Multiple matches occurred when a single TxDOT design document category could potential match multiple FileNet document types. For example, the environmental clearance document category identified in the TxDOT *PS&E Preparation Manual (12)* had at least six possible matching FileNet document types:
 - Environmental Clearance or Permit (12.8.4)
 - Environmental Clearance (2.1.2)
 - Environmental Clearance (5.2.3)
 - Environmental Clearance (5.5.3)
 - Environmental Clearance (16.8.1)
 - Environmental Clearance (16.9.1)

In this case, the researchers selected Environmental Clearance or Permit (12.8.4) as the matching FileNet document type.

- **Partial matches.** Partial matches occurred when the correspondence between TxDOT design document category and FileNet document type was not necessarily straightforward or intuitively clear, which during implementation could result in confusion and/or mapping errors. For example, there were not FileNet document types for ROW status data sheets, utility status data sheets, or ROW advance acquisition parcel lists, but there was a FileNet Working Paper (14.21.1) document type (Right of Way document class), which the researchers used. Likewise, there was not a FileNet document type for value engineering studies, but there was a FileNet Design Study (12.8.5) document type (Project Design document class), which the researchers used. In both of these cases, the correspondence between TxDOT design document category and FileNet document type could leave considerable room for interpretation.
- **No matches.** No matches occurred when it was not possible to match TxDOT design document categories to FileNet document types. In most cases, the researchers generated additional FileNet document types. For example, FileNet did not have document types for erosion control design documents. As a result, the researchers added an Erosion Control (5.5.11) document type (Project Environmental record type, Environmental Affairs document class). In other cases, it was necessary to rename or move document types. In total, the researchers added 73 document types to the FileNet library structure. Of the 228 FileNet document types used in the research (out of 1279 types in the FileNet library structure), the researchers renamed or moved 42 document types. [Table 29](#) lists the document types added, renamed, or moved.

Table 29. Additional, Renamed, or Moved FileNet Document Types.

Document Class	Record Type	Document Type	File Code
Administrative	Public Hearings	Certification	1.22.5
	Public Hearings	Summary	1.22.6
	Public Hearings	Supporting Documentation	1.22.7
	Schedules	Construction	1.28.4
	Schedules	Contract	1.28.5
	Schedules	Project	1.28.6
	Schedules	Submission	1.28.7
	Schedules	Utility Adjustment	1.28.8
Advance Project Development	Project Data Collection	Site Photographs or Video	2.13.1
	Project Data Collection	Aerial Photography	2.13.2
	Project Data Collection	Planimetrics	2.13.3
	Project Data Collection	Elevation Points and Models	2.13.4
	Project Data Collection	Survey Control	2.13.5
	Project Data Collection	Field Surveying	2.13.6
Contracts Leases and Agreements	Agreements	Escrow Agreement	4.1.14
Environmental Affairs	Project Environmental	Erosion Control	5.5.11
	Project Environmental	Commitments and Resources	5.5.12
	Project Environmental	Noise Analysis	5.5.13
	Project Environmental	Water Quality	5.5.14
	Project Environmental	Alternatives Study	5.5.15
	Project Environmental	Plan Sheet	5.5.16
	Project Environmental	Wetlands Report	5.5.17
	Project Environmental	Floodplain Encroachment	5.5.18
Project Environmental	Map, Diagram, or Sketch	5.5.19	
Maintenance Operations	Maintenance Traffic Control Plans	Contract Provision	10.13.1
	Maintenance Traffic Control Plans	Detour	10.13.2
	Maintenance Traffic Control Plans	Marking	10.13.3
	Maintenance Traffic Control Plans	Plan Review	10.13.4
	Maintenance Traffic Control Plans	Schematic	10.13.5
	Maintenance Traffic Control Plans	Sequence of Construction	10.13.6
	Maintenance Traffic Control Plans	Signs	10.13.7
	Maintenance Traffic Control Plans	Standard Sheets	10.13.8
Project Design	Bridge Engineering Reference	Retaining Wall Notes, Calculations, and Plans	12.1.12
	Bridge Engineering Reference	Culvert Notes, Calculations, and Plans	12.1.13
	Bridge Engineering Reference	Stream Hydrology Notes, Calculations, and Plans	12.1.14
	Bridge Engineering Reference	Bridge Detail	12.1.15
	Design Engineering Reference	Staking and Alignment Coordinates	12.3.9
	Design Engineering Reference	Earthwork	12.3.10
	Design Engineering Reference	Alignment Plan and Profile	12.3.11
	Design Engineering Reference	Design Detail	12.3.12
	Design Engineering Reference	Design Standard	12.3.13
	Plans Specifications and Estimates	Estimate and Quantities	12.8.6
	Plans Specifications and Estimates	Landscaping and Irrigation	12.8.15
	Plans Specifications and Estimates	Removal	12.8.16
	Plans Specifications and Estimates	General Plan	12.8.17
	Plans Specifications and Estimates	Submittal	12.8.18
	Plans Specifications and Estimates	Review	12.8.19
	Plans Specifications and Estimates	Meeting Notice	12.8.20
	Plans Specifications and Estimates	Design Checklist	12.8.21
	Plans Specifications and Estimates	PS&E Submission Checklist	12.8.22
	Plans Specifications and Estimates	PS&E Review Checklist	12.8.23
	Plans Specifications and Estimates	Product Checklist	12.8.24
Drainage Engineering Reference	Hydrology Notes, Calculations, and Plans	12.12.1	
Drainage Engineering Reference	Drainage Facility Notes, Calculations, and Plans	12.12.2	
Right of Way	ROW Project Files	Requests, Notices, and Access Permissions	14.12.10
	ROW Determination	Acreage Estimate	14.18.1
	ROW Determination	Cost Estimate	14.18.2
	ROW Determination	Map	14.18.3
	ROW Determination	Schematic	14.18.4

Table 29. Additional, Renamed, or Moved FileNet Document Types (Continued).

Document Class	Record Type	Document Type	File Code
	Subsurface Utility Engineering	Correspondence	14.19.1
	Subsurface Utility Engineering	Deliverable	14.19.2
	Subsurface Utility Engineering	Media Information Form	14.19.3
	Subsurface Utility Engineering	Meeting Minutes and Notes	14.19.4
	Subsurface Utility Engineering	Statement	14.19.5
	Subsurface Utility Engineering	Work Authorization	14.19.6
	Utility Relocation	Adjustment	14.20.1
	Utility Relocation	Affidavit	14.20.2
	Utility Relocation	Billing	14.20.3
	Utility Relocation	Compensable Interest Certificate	14.20.4
	Utility Relocation	Consultant Contract Review	14.20.5
	Utility Relocation	Cost Estimate	14.20.6
	Utility Relocation	Date of Eligibility Request	14.20.7
	Utility Relocation	Determination of Eligibility	14.20.8
	Utility Relocation	Funding	14.20.9
	Utility Relocation	Indemnity Agreement	14.20.10
	Utility Relocation	Joint Use Agreement	14.20.11
	Utility Relocation	Letter of Authority	14.20.12
	Utility Relocation	Meeting Minutes and Notes	14.20.13
	Utility Relocation	Notice	14.20.14
	Utility Relocation	Notice of Proposed Installation	14.20.15
	Utility Relocation	Payment	14.20.16
	Utility Relocation	Plan	14.20.17
	Utility Relocation	Relocation	14.20.18
	Utility Relocation	Schematic	14.20.19
	Utility Relocation	Specification	14.20.20
	Utility Relocation	Survey	14.20.21
	Utility Relocation	Utility Agreement	14.20.22
	Utility Relocation	Utility Easement	14.20.23
Traffic Operations	Railroad (RR) Replanking & Warning Devices	Details	15.3.20
	Traffic Data	Local Traffic Forecasts and Existing Counts	15.9.1
	Traffic Data	Intersection/Interchange Geometrics and Control Data	15.9.2
	Traffic Data	Intersection Vehicle Count/Turning Volume Data	15.9.3
	Traffic Data	Traffic Signal Operations, Control, and Maintenance Data	15.9.4
	Traffic Data	Traffic Detector Data	15.9.5
	Traffic Data	Traffic Management/Control Data	15.9.6
	Traffic Data	Traffic Simulation Model Data	15.9.7
	Traffic Data	Origin-Destination Data	15.9.8
	Traffic Data	Modal Operations Data	15.9.9
	Traffic Data	Crash Data	15.9.10
	Traffic Control Device Inventory	Markings	15.10.1
	Traffic Control Device Inventory	Signs	15.10.2
	Traffic Control Device Inventory	Signals	15.10.3
	Traffic Control Device Inventory	ITS	15.10.4
	Construction Traffic Control Plans	Contract Provision	15.11.1
	Construction Traffic Control Plans	Detour	15.11.2
	Construction Traffic Control Plans	Marking	15.11.3
	Construction Traffic Control Plans	Plan Review	15.11.4
	Construction Traffic Control Plans	Schematic	15.11.5
	Construction Traffic Control Plans	Sequence of Construction	15.11.6
	Construction Traffic Control Plans	Signs	15.11.7
	Construction Traffic Control Plans	Standard Sheets	15.11.8
	Construction Traffic Control Plans	Temporary Illumination and Traffic Signals	15.11.9
	Construction Traffic Control Plans	Electrical and Lighting Design and Plans	15.11.10
	Construction Traffic Control Plans	Signal Design and Plans	15.11.11
	Construction Traffic Control Plans	Traffic Management System Plans	15.11.12

INTEGRATING DOCUMENT DATA IN THE PROTOTYPE

The researchers used the mapping of TxDOT design document categories to FileNet document types to populate prototype database records with sample project data. As Table 30 shows, the researchers mapped 7784 files to eight document classes.

Table 30. Project Files Mapped to FileNet Document Classes.

Document Class	Spur 66		IH 410 @ Ingram	IH 410 @ Nacagodches	IH 20 @ JBS	Total	
	CSJ 029112001	CSJ 029112002	CSJ 052104190	CSJ 052104187	CSJ 000513043		
Administrative	409	171	160	2		742	10%
Advance Project Development	150	1	234		632	1017	13%
Construction	7					7	<1%
Contracts Leases and Agreements	25	4	31	22	1	83	1%
Environmental Affairs	13	6	76	8	2	105	1%
Project Design	851	96	2772	116	427	4262	55%
Right of Way	100	28	266	31	7	432	6%
Traffic Operations	208	19	903	3	3	1136	15%
Total	1763	325	4442	182	1072	7784	100%

In addition to the challenges described in the previous sections, project datasets frequently contained multiple instances of files with the same name in different folders (either within the same project or across projects). For example, in the dataset for project CSJ 052104190, file 0030ill.dgn, an electrical layout plan, was in the following folders:

- \052104190\Correspondence\Carter Burgess\
- \052104190\Correspondence\Carter Burgess\C-B SAT\Illum\
- \052104190\ReferenceFiles\

In this particular example, the researchers mapped the file to the Electrical and Lighting Design and Plans (15.11.10) document type (Construction Traffic Control Plans record type, Traffic Operations document class).

In general, examining files in the dataset to determine if they were duplicate files or file versions was quite time consuming. Readers should note that the purpose of the research was to document processes and procedures as well as build and test a prototype (rather than to conduct activities that would be part of a routine project application). For this reason, after examining a number of files that appeared to be duplicate files or file versions, the researchers decided to assume that duplicate files with the same file names but different dates were document versions. As a result, it became necessary to develop a file logical and physical naming convention, where the file logical name was the same (e.g., 0030ill.dgn) but the physical names had project and version suffixes to differentiate the various instances of the file (e.g., 0030ill_190_1.dgn, 0030ill_190_2.dgn, and 0030ill_190_3.dgn).

Certain document types had special challenges. For example, in the case of CAD documents, the database included attribute data contained in plans, layouts, elevations, and detailed views, such as sheet number (e.g., 253), group sheet number (e.g., sheet two of four), and sheet index titles. For the prototype database, the researchers extracted these data manually from as-built plans that Plans Online provided for all projects, except CSJ 052104187 where as-built plans were not available. In total, the researchers registered 2394 as-built plans in the database. It may be worth noting that during implementation, extracting the data manually would not be necessary. As mentioned previously, Plans Online uses OCR software to assist in the process of extracting attribute data from as-built plans.

As described in [Chapter 4](#), certain types of documents are combinations of other documents, such as a proposal and a PS&E plan set. For the prototype database, the researchers assembled 51 document sets from all projects except for CSJ 052104187, where data were not available. Document sets were either project PS&E packages or change order sets.

INTEGRATING SPATIAL DOCUMENT DATA IN THE PROTOTYPE

It is possible to overlay a wide range of documents in a GIS environment ([Table 31](#)). In general, there are two types of spatial documents: (a) documents that contain all the necessary data (either embedded in the file or stored in a companion file) and are, therefore, geo-referenced; and (b) documents for which the spatial data component is missing, incomplete, or incorrect, and it becomes necessary to apply a procedure to geo-reference the files.

Many spatial documents, e.g., CAD files, are not native GIS applications, and displaying those files in a GIS environment can degrade interface performance quite significantly. Other spatial documents, e.g., large aerial photographs, can also degrade performance because of the time it takes to render the images on the screen. In addition, overlying many spatial documents at once can be confusing to users. To address these issues, the researchers generated geo-referenced outlines that represented the spatial boundary of those documents and provided links to enable users to access the documents on an as-needed basis. In general, the procedure to generate the spatial outlines was to geo-reference the documents first and then extract the corresponding spatial boundaries.

Other issues included the presence of “ghosts,” where certain extraneous graphical elements were visible when displaying a MicroStation file in the GIS but were not present when displaying the file in MicroStation. Upon further examination, the researchers realized that “compressing” CAD documents in MicroStation eliminated the “ghosts.” As a result, the researchers compressed all sample project CAD documents in MicroStation before geo-referencing those files in the GIS.

Table 31. Spatial Document Categories.

Aerial photography	Annual district traffic maps
As-built construction plans	County road/urban saturation count maps
Geometric design schematic	Planimetric maps
Preliminary geometric design schematic	Barricade layout sheets
Bicycle/pedestrian final facility design plans	Bicycle/pedestrian preliminary facility design plans
Bicycle/pedestrian preliminary facility layouts	Braided ramp bridge layout sheets
Bridge layout sheets	Bridge plan and profile sheets
Channel improvement layout sheets	Construction staging plans
Cross drainage structure layout sheets	Culvert cross sections, layout, and detail sheets
Detour layout sheets	Drainage area maps
Drainage plan and profile sheets	Electrical and illumination layout sheets
Environmental mitigation plan sheets	Environmental mitigation plan sheets for historic structures
Existing layout sheets	Existing structure layout sheets
Existing utilities plan and profile layout sheets	Geometric with ROW and easements schematic
Hazardous materials remediation plan	Interchange layout sheets
ITS plan sheets	Landscaping/irrigation layout sheets
Miscellaneous structures plan sheets	Overall drainage area boundaries
Parcel plats	Pavement contours sheets
Pavement markings and markers layout sheets	Permanent illumination layout sheets
Preliminary construction staging plans	Preliminary drainage plans
Project layout sheet	Proposed layout sheets
Proposed utilities plan and profile layout sheets	Pump station outfall plan and profile sheets
Railroad bridge layout sheet	Railroad grade crossing layout sheets
Railroad plan and profile sheets	Removal sheets

Geo-referencing Spatial Documents

CAD Documents with a Known Coordinate System

The prototype geodatabase used a State Plane Texas South Central coordinate system and a Lambert Conformal Conic projection (Table 32). Most San Antonio District CAD documents had the same coordinate system and projection as the prototype geodatabase, except the CAD documents were in “surface” coordinates. As a result, it was necessary to apply a scale transformation using a combined scale factor (CSF) to convert all “surface” level documents so they could display correctly in the GIS (52). Unfortunately, the actual CSF values used for the sample projects in San Antonio were not available. As a result, the researchers calculated default CSF values for each of the projects (52) and then, as needed, adjusted the CSF values by trial and error until achieving satisfactory matching results using reference features that were visible in the GIS. It may be worth noting that during implementation, analysts would need to rely on actual project-specific CSF values provided by district surveyors.

Table 32. Prototype Geodatabase versus CAD Document Spatial Data Characteristics.

Coordinate System	Format	Basic Metadata	
		Parameter	Description
State Plane	Geodatabase	Source	Texas Transportation Institute
		Coordinate system	State Plane Texas South Central
		Projection	Lambert Conformal Conic
		Ellipsoid	Geodetic Reference System 80
		Surface adjustment	None; referenced to ellipsoid
		Datum	North American Datum 1983 (NAD 83)
		Longitude of origin	-99.000000
		Latitude of origin	27.833333
		Standard parallel # 1	28.383333
		Standard parallel # 2	30.283333
		False easting	1,968,500 feet
		False northing	13,123,333.333333 feet
Unit of measure	Survey feet		
State Plane	MicroStation	Source	San Antonio District Office
		Coordinate system	State Plane Texas South Central
		Projection	Lambert Conformal Conic
		Ellipsoid	Geodetic Reference System 80
		Surface adjustment	Depends on project
		Datum	North American Datum 1983
		Longitude of origin	-99.000000
		Latitude of origin	27.833333
		Standard parallel # 1	28.383333
		Standard parallel # 2	30.283333
		False easting	1,968,500 feet
		False northing	13,123,333.333333 feet
Unit of measure	Survey feet		

To apply the transformation using the CSF values, the researchers created companion world files with the same name as the corresponding files processed, except the world files had a .wld extension. Each world file contained the following information (93):

$$\begin{matrix}
 X_{1a}, Y_{1a} & X_{1b}, Y_{1b} \\
 X_{2a}, Y_{2a} & X_{2b}, Y_{2b}
 \end{matrix}$$

where

$$\begin{matrix}
 X_{1a}, Y_{1a} = \text{point No. 1 coordinates ("surface")}, \\
 X_{1b}, Y_{1b} = \text{point No. 1 coordinates ("ellipsoid")}, \\
 X_{2a}, Y_{1a} = \text{point No. 2 coordinates ("surface")}, \text{ and} \\
 X_{2b}, Y_{2b} = \text{point No. 2 coordinates ("ellipsoid")}.
 \end{matrix}$$

The researchers normalized the process by creating generic world files that contained the following information:

$$\begin{matrix}
 0,0 & 0,0 \\
 1,1 & \langle \text{CSF} \rangle, \langle \text{CSF} \rangle
 \end{matrix}$$

The CSF value for the reconstruction project on IH 410 from Ingram Road to Callaghan Road (CSJ 052104190) was 0.999830. For the Spur 66 Widening/Reconstruction (CSJ 029112001 and 029112002) project, where there were also a substantial number of CAD documents, the CSF value was 0.999840.

It may be worth noting that any transformed CAD document was still in its native format (e.g., MicroStation) and that the world file provided the necessary scale transformation data for ArcGIS to overlay the CAD document correctly.

CAD Documents with an Unknown Coordinate System

The coordinate system associated with all CAD documents from the Odessa District sample project (CSJ 000513043), as well as some CAD documents from San Antonio District sample projects, was arbitrary. The only parameter known for those files was that the distance units were in feet. ESRI's ArcGIS 9.2 geo-referencing tool supports geo-referencing CAD files. ArcGIS 9.1, which the researchers used for development of the prototype, did not have this functionality. However, a CAD transformation tool was available for download (94). This tool enabled the rotation, scaling, and translation of MicroStation files within the GIS and the corresponding generation of companion world files. Unfortunately, there were not adequate control points within the GIS environment to conduct the transformation. This situation made it necessary to use 1:24,000 scale datasets (available through TNRIS [95]) as reference within the GIS to provide approximate control point locations with which to apply the transformation.

In general, the procedure to geo-reference CAD documents with an unknown coordinate system was as follows:

- determine the approximate correct location of the CAD document in relation to the reference 1:24,000 scale datasets;
- use the CAD transformation tool to insert control points and rotate, fit to display, and scale the CAD file to ensure a correct display in the GIS environment; and
- save the world file.

This procedure created a generic world file that contained the following information:

```
1675855.67,10638913.458 932964.645092752,14595740.8246705  
1685853.788,10652066.593 943079.547511649,14608786.4965148
```

Strictly speaking, this process did not geo-reference files. What it did was to produce world files that enabled a linear transformation of the data – made possible because the files were already projected to a rectangular grid to begin with – that, in turn, enabled the correct display of the MicroStation data in the GIS (93).

Raster Documents with an Unknown Coordinate System

In general, raster documents in the sample dataset did not have a defined coordinate system. To geo-reference these documents, the researchers used a standard geo-referencing tool in ArcGIS. Geo-referencing involved translating, scaling, rotating, and/or “rubbersheeting” raster documents to their correct location using the 1:24,000 scale datasets described in the previous section as reference. The geo-referencing tool produced world files for geo-referenced raster documents.

Extracting Spatial Document Outlines

CAD Document Outlines

In general, the extent of a CAD document is a property that defines the limits of a spatial document as a rectangular box that uses maximum and minimum x and y coordinates. While adequate in some situations, using the extent to define the document outline can easily misrepresent the actual contents of the document, particularly in situations where the general spatial orientation of the document is not in the north-south or east-west direction (Figure 23).

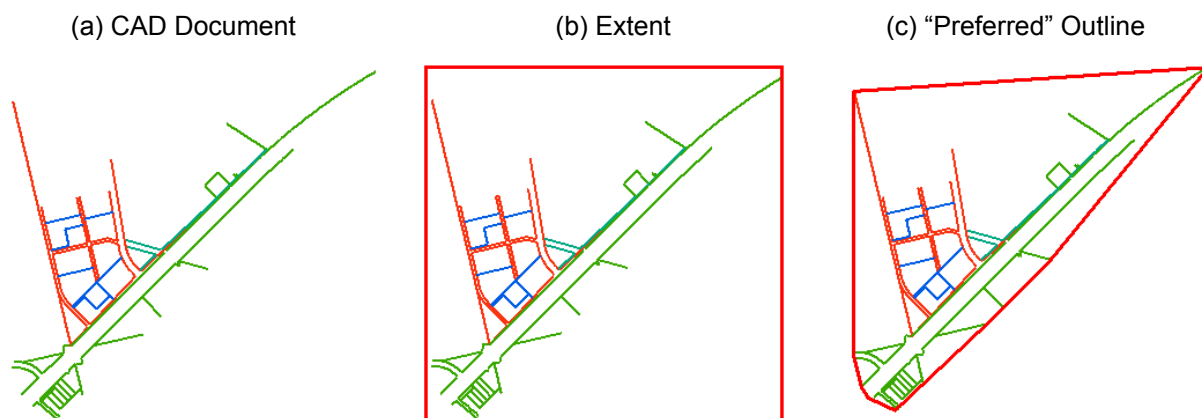


Figure 23. Geo-referenced CAD Document with Extent and “Preferred” Outline.

ArcGIS does not have a standard tool to generate outlines from vector feature classes. In some cases, the researchers traced the boundaries of geo-referenced CAD documents. To automate the process, the researchers developed a script in ArcGIS ModelBuilder that completed the following tasks (Figure 24):

- define a reference coordinate system for the CAD document,
- generate a triangulated irregular network (TIN) from the CAD document polylines, and
- convert the TIN to triangles (polygons) and dissolve the triangles to create one polygon.

The researchers geo-referenced 88 CAD documents and stored spatial outlines for each document in the DCMNT_POLY geodatabase feature table (Table 33). The researchers also updated the DCMNT_OUTLN_FLG attribute in the DCMNT table for these CAD documents.

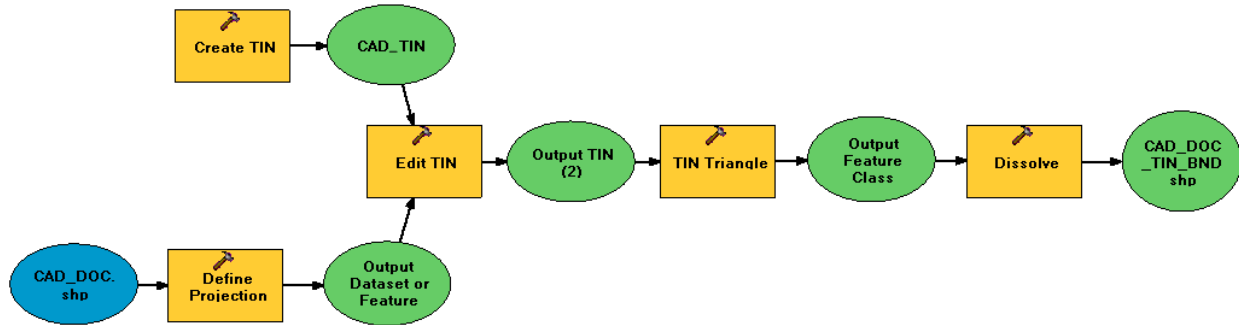


Figure 24. Automated Extraction of CAD Document Outlines Using ArcGIS ModelBuilder.

Table 33. Spatial Documents with Outlines.

Spatial Documents	Spur 66		IH 410 @ Ingram	IH 410 @ Nacagodches	IH 20 @ JBS	Total	
	CSJ 029112001	CSJ 029112002	CSJ 052104190	CSJ 052104187	CSJ 000513043		
CAD Documents	24	8	42	0	14	88	26%
Raster Documents	85	10	129	0	32	256	74%
Total	109	18	171	0	46	344	100%

Challenges experienced while extracting CAD document boundaries included the following:

- **Large detailed CAD files.** For small CAD documents, the ModelBuilder script worked well, which enabled its use in batch mode. However, for large detailed CAD files, the script took a significant amount of time or resulted in non-defined boundaries. In these situations, the researchers either removed features that did not help to define the boundary and re-ran the script or traced the boundary of the CAD document manually.
- **Integrating CAD document outlines.** Generating CAD document outlines manually was relatively straightforward. In ArcGIS, the researchers created features in the DCMNT_POLY geodatabase feature class, defined the boundaries of the CAD documents, and populated the rest of the attribute data. By comparison, the automated script produced individual outlines as shape files, which the researchers had to import into the DCMNT_POLY geodatabase feature class. Further automation may be possible in the ModelBuilder script to accomplish this task.

Raster Document Outlines

As in the case of CAD documents, using the extent of a raster document to define the document outline can misrepresent the actual contents of the document (Figure 25).

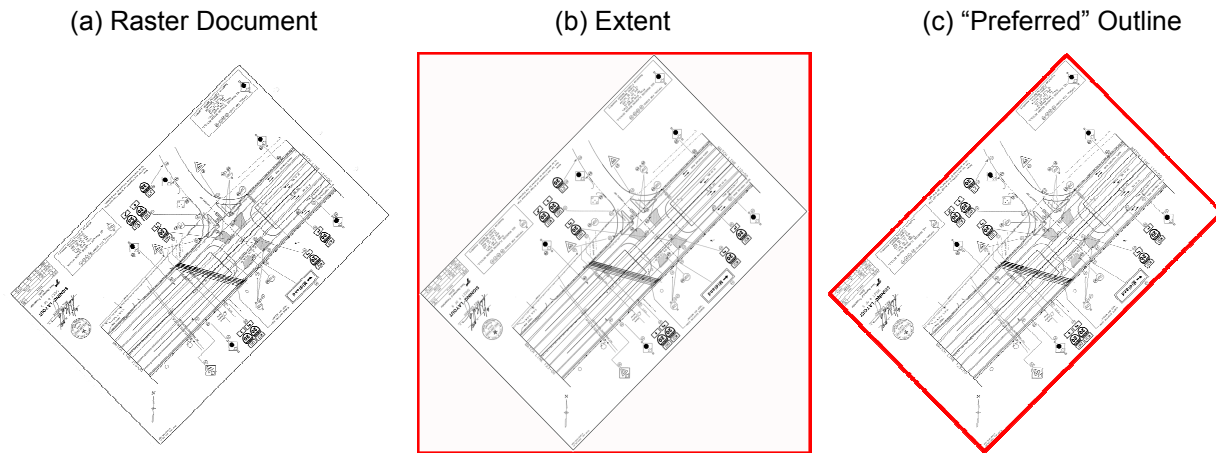


Figure 25. Geo-referenced Raster Document with Extent and “Preferred” Outline.

In some cases, the researchers traced the boundaries of geo-referenced raster documents. To automate the process, the researchers developed a script in ArcGIS ModelBuilder that completed the following tasks (Figure 26):

- convert the raster document to a polygon feature class;
- calculate the areas of each polygon feature and select the polygon with the maximum area;
- dissolve and simplify the polygon to remove multipart features and jagged boundaries, resulting in an extent rectangular polygon with a portion of the interior removed;
- using the original polygon feature class, dissolve the polygons to create an extent rectangular polygon; and
- perform a subtraction of the two polygon feature classes.

The researchers geo-referenced 256 raster documents and stored spatial outlines for each document in the DCMNT_POLY geodatabase feature table (Table 33). The researchers also updated the DCMNT_OUTLN_FLG attribute in the DCMNT table for these raster documents.

Challenges experienced while extracting raster document boundaries included the following:

- **Raster files not to scale.** Not all as-built plans were to scale. Some plans distort segment lengths when it is not critical to show the locations of features on a to-scale basis, e.g., in the case of barrier layouts and sign placement. In these situations, while the raster document shows station and offset data, overlaying the raster document in the GIS may not produce a reliable spatial representation of the feature being depicted.
- **Multiple road segments.** As-built plans typically cover several road sections per sheet to save space. Also typical is to show road sections with breaks in stationing (e.g., not showing station 1001+25 to 1002+75) when showing that part of the road is not relevant. For as-built plans with multiple road sections, the researchers created a copy of the as-built plan for each road section, geo-referenced each as-built plan copy to the road

section, generated a separate outline for each as-built plan copy, and created a union of the outlines.

- System resources.** Running the ModelBuilder script repeatedly within the same session tended to cause a significant degradation in script performance. Restarting the computer appeared to help. However, during periods of severe performance degradation, it became necessary to digitize the raster document boundary manually. It is not clear at this point whether using a more powerful computer would resolve the issue or whether the performance degradation is a structural ArcGIS problem.
- Integrating raster document outlines.** As in the case of CAD documents, generating raster document outlines manually was a relatively straightforward geodatabase activity. However, the automated script produced individual outlines as shape files, which the researchers had to import into the DCMNT_POLY geodatabase feature class. Further automation may be possible in the ModelBuilder script to accomplish this task.

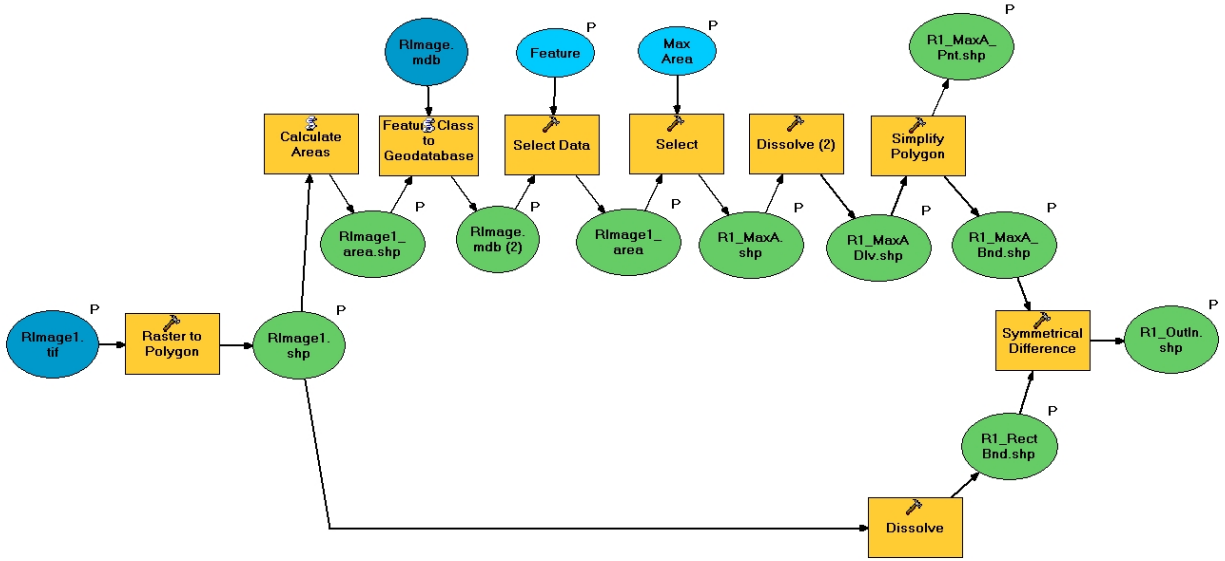


Figure 26. Raster Image Outline Procedure Model.

INTEGRATING FEATURE DATA IN THE DATABASE

Developing a comprehensive inventory of features included in the sample project documents was not practical. To illustrate the general methodology, the researchers generated records for 15 sample feature classes within the following categories (as described in Chapter 4): project lines, document features, asset features, highway features, and geo-political features. Table 34 lists those feature classes along with the corresponding number of records per table. Of the 15 feature classes, three classes were highway features or geo-political features the researchers imported from TxDOT-provided datasets.

Table 34. FEATURE Subclass Records in the Prototype Database.

Feature Class	Spur 66		IH 410 @ Ingram	IH 410 @ Nacagodches	IH 20 @ JBS	Total	
	CSJ	CSJ	CSJ	CSJ	CSJ		
	029112001	029112002	052104190	052104187	000513043		
PROJ_LN	1	1	1	1	1	5	<1%
CAD_DCMNT_LN	11	2	19		5	37	<1%
DCMNT_POLY	133	22	151		48	354 ¹	2%
COMNCT_LN	2765	718	383		37	3903	19%
COMNCT_PEDESTAL	576	108			21	705	3%
COMNCT_POLE	323	83	1170		344	1920	10%
ELEC_LN	2027	516	564		18	3125	15%
GAS_LN	388	138	192		9	727	4%
SIGN_FEAT	412	50	1067		355	1884	9%
WATR_HYDNT	384	81	720		10	1195	6%
WATR_LN	3979	782	505		24	5290	26%
WATR_VALV	659	120	250		19	1048	5%
Total	11658	2621	5022	1	891	20193	100%
TXDOT_CNTY_POLY						254	
TXDOT_CTRL_SECT_LN						10042	
TXDOT_RTE_CNTR_LN						4518	
Total						14814	

¹ This total includes additional document outlines for as-built plans with multiple road segments.

Project Lines

In theory, it would have been ideal to generate project line features (PROJ_LN table) from beginning and ending highway reference marker displacement data. As shown in Table 35, in reality, reference marker displacement data are not always available, e.g., in the case of new corridors (e.g., 029112001 and 029112001), where highway reference markers do not exist yet, or where project limits are not known (e.g., 052104187 and 052104190).

Table 35. Prototype Project Limits.

Project CSJ	Control Section	Route Number	Beginning Limits ¹	Ending Limits ¹
029112001 / 029112002	029112	SP66	TRM 486 -0.019 ²	TRM 486 +1.761 ²
052104190	052104	IH410	TRM 12 +0.424 ³	TRM 14 +0.618 ³
052104190	029110	SH16	TRM 588 +1.316 ²	TRM 590 +0.280 ²
052104187	052104	IH410	TRM 23 +0.263 ²	TRM 26 +0.577 ²
000513043	000513	IH020	TRM 119 +0.315 ³	TRM 120 +0.338 ³

¹ Reference marker number (e.g., TRM 486) and displacement in miles with respect to the reference marker location (e.g., -0.019 represents a negative displacement of 0.019 miles from TRM 486 along SP66)

² Source: Measured offsets from digitized project limits to the 2006 reference marker GIS dataset

³ Source: DCIS data

In recent years, TxDOT has started to document project limits by using geographic coordinates (e.g., from GPS readings in the field). Unfortunately, these data were not available for the

sample projects used in this research. In general, generating project limit features from this type of data in a GIS environment is straightforward and involves the following steps:

- overlay the project limit coordinate data on the TXDOT_CTRL_SECT_LN dataset (for existing projects);
- use a GIS function to map each project limit data point to the closest control section and retrieve the corresponding cumulative distance of the mapped point along the control section selected;
- generate a route event table for the beginning and ending points using the TXDOT_CTRL_SECT_LN table as the route (because this dataset is a polyline M dataset with measures); and
- using the route event table, generate a new record in the PROJ_LN table.

For new projects, the most effective way to generate new records in the PROJ_LN table is by overlaying geo-referenced CAD documents that include project centerlines and importing these centerlines into PROJ_LN table features.

Because the availability of beginning and ending highway reference marker displacement data for the sample projects varied, the researchers had to follow different procedures to generate PROJ_LN table features, as follows:

- **CSJ 029112001 and 029112002.** The TXDOT_CTRL_SECT_LN table did not include a record for control section 029112 because the project was a new construction project. Although it was possible to geo-reference CAD documents for this project, there were nonetheless questions regarding the accuracy of the combined surface factor. This situation made it necessary to use aerial photography to digitize the project limits.
- **CSJ 052104190.** Highway reference marker displacement data were not available for the SH 16 component of the project. As a result, the researchers extracted control section features from the TXDOT_CTRL_SECT_LN table and edited these features based on as-built plans, CAD files, and aerial imagery. The researchers also merged the two linear features (on IH 410 and SH 16) into one multipart feature to generate one record in the PROJ_LN table.
- **CSJ 052104187.** Highway reference marker displacement data were not available for this project. As a result, the researchers extracted control section features from the TXDOT_CTRL_SECT_LN table and edited these features based on known project limit intersections.
- **CSJ 00513043.** The researchers created a linear event table using the beginning and ending project reference marker displacement data and the TXDOT_RTE_CNTR_LN table as the route. However, the generated project limit linear feature did not match other geo-referenced datasets available such as aerial photography or CAD documents. As a result, it was necessary to edit the project line to match existing geo-referenced sources.

Document Features

As mentioned previously, EDDM includes point, line, and polygon feature classes to represent different types of documents spatially. A previous section in this chapter described the process to generate CAD document outlines (which table DCMNT_POLY stores). This section summarizes the process to generate CAD_DCMNT_LN table records, which represent geo-referenced CAD documents as a set of multilines:

- convert each CAD file into a polyline feature class using the ArcGIS “CAD to Feature Class” script;
- remove non-essential attributes, except for document physical name, from the feature class;
- dissolve the features into one polyline feature;
- merge the polyline features for all CAD documents;
- add GAIP attribute fields; and
- add and populate field CAD_DCMNT_LN_ID.

Asset Features

As [Table 34](#) shows, the researchers generated records for nine asset features: COMNCT_LN, COMNCT_PEDESTAL, COMNCT_POLE, ELEC_LN, GAS_LN, SIGN_FEAT, WATR_HYDNT, WATR_LN, and WATR_VALV. These asset features were common across the sample CAD files from all the projects. Eight of the nine asset features were utility point or line features. It may be worth noting that the utility-related feature classes were features developed as part of a prototype GIS model for utility installation inventories in the state ROW ([96](#)). In general, the procedure to generate asset feature records involved using MicroStation cells as a mechanism to extract point features from MicroStation files and using MicroStation levels to extract linear features (the sample files did not use cells to define utility lines).

Steps to extract asset features and add records to corresponding asset feature classes included:

- For each project:
 - For CAD files containing utility cells and sign cells, record the cell names used and update the FEAT_CLASS table.
 - For CAD files containing utility lines, record the corresponding MicroStation level number.
 - Convert each CAD file into point and line shape files.
 - Merge the point and line shape files into one point and one line shape file for each project.
 - Remove non-essential attributes from the shape files, except for document physical name, entity, level, and reference name attributes.

- Add and populate the temporary attribute field CSJ_NUMBER to each shape file (this step makes populating the PROJ_FEAT table easier).
- Add and populate temporary attribute field DCMNT_UID to each shape file. DCMNT_UID values result from a SQL script that includes the DCMNT_VERS table and the point and line shape files for each project (this step makes populating the FEAT_DCMNT table easier).
- For the point shape file of each project :
 - Filter the shape file by selecting records where “Entity” is a “cell.”
 - Run an SQL query that groups document name, document unique ID, and associated cell names. Use the results of this query to populate the CAD_DCMNT_CELL table.
 - Using the list of cell names created earlier, select records from the point shape file where “RefName” is a listed cell name (e.g., FH), and create a new asset feature point shape file.
- For the line shape file of each project, filter the shape file by removing records where “Entity” is a “cell,” a “LineString,” a “Closed Shape,” or a “Circle.” Then using the list of level names created earlier, select records where “Level” is a listed level number and create a new asset feature line shape file.
- Merge the point and line shape files for all projects to generate asset feature point and asset feature line shape files.
- Add GAIP attribute fields to each asset feature shape file.
- Add temporary attribute TABL_UID for each asset feature shape file. Populate values for this attribute using the TABL_UID attribute in the DSET_TABL table based on the name of the asset feature shape file. This step also makes populating the FEAT_DCMNT table easier.
- Remove the temporary attributes.

LINKING PROJECT, DOCUMENT, AND FEATURE DATA IN THE DATABASE

The last step in the database population effort was the population of the tables that define the many-to-many relationships between projects, documents, and features, i.e., PROJ_DCMNT, PROJ_FEAT, and FEAT_DCMNT. In general, the process involved adding records to the main anchor tables first (i.e., PROJ, DCMNT, and FEAT) and then running SQL scripts to extract relevant data and populate PROJ_DCMNT, PROJ_FEAT, and FEAT_DCMNT.

CHAPTER 6. PROTOTYPE TESTING

INTRODUCTION

[Chapter 5](#) described the process to populate the prototype EDDM database with sample project data. This chapter describes three testing environments for the prototype database and summarizes feedback received from TxDOT officials.

TESTING ENVIRONMENTS

As mentioned in [Chapter 4](#), the researchers translated the physical model into an Oracle database. To simulate separate TxDOT systems (e.g., DCIS, FileNet, and MST), the researchers used separate Oracle workspaces for the Project, Document, and FEATURE Subject Area tables. The FEATURE Subject Area Oracle workspace was an ESRI ArcSDE geodatabase. In order to test the EDDM database design, examine potential implementation and integration issues with other systems, and demonstrate the EDDM model to a variety of audiences, the researchers used three different environments: Microsoft Access, ESRI ArcGIS, and Microsoft Internet Explorer. Readers should note that, in line with the scope of the research, the testing effort focused on the EDDM architecture rather than the user interfaces (although, by necessity, the researchers designed and built the testing user interfaces in a way that could support the testing effort efficiently). Design and testing of user interfaces for implementation purposes would need to undergo a formal process that identifies comprehensive user interface needs and relies on actual links to systems such as DCIS, FileNet, and MST.

Each testing environment fulfilled a role in the testing process. The Microsoft Access and ESRI ArcGIS testing environments focused on basic database design and relationship testing using a variety of “ready-made” tools that expedited the testing process. For portability, the researchers exported the data from the three Oracle workspaces to an ESRI personal geodatabase (in Microsoft Access format). This portable configuration enabled the demonstration of EDDM to audiences in situations where online access was not possible.

The Microsoft Internet Explorer testing environment focused on the examination of potential implementation and integration issues with other systems and as a tool to demonstrate how EDDM could potentially function in a web-based environment (which proved useful during discussions with TxDOT officials when issues such as EDDM implementation, portability, and functionality were raised). As mentioned before, several TxDOT systems, e.g., TxDocsOnline, Plans Online, and MST, use web-based protocols. During the research, it was therefore important to develop an understanding of the degree to which EDDM could support those protocols and for the formulation of potential recommendations for implementation.

Access Testing Environment

Access testing involved the development of a number of queries and forms to test items such as database design and compliance with database integrity constraints. For example, [Figure 27](#) through [Figure 30](#) show the design view of the following queries:

- **ProjectInfo.** This query retrieves data associated with a project.
- **ProjectFeature.** This query retrieves features associated with a project.
- **ProjectDocuments.** This query retrieves documents and document versions associated with a project.
- **FeatureDocument.** This query retrieves features associated with each document version.

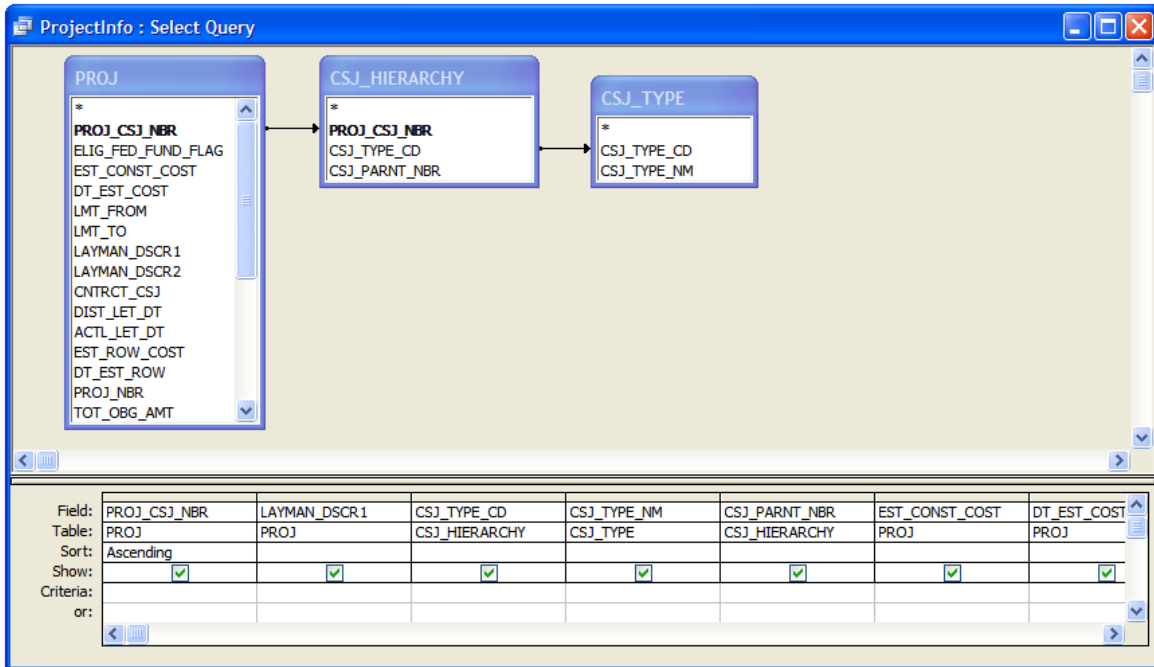


Figure 27. ProjectInfo Query Design View.

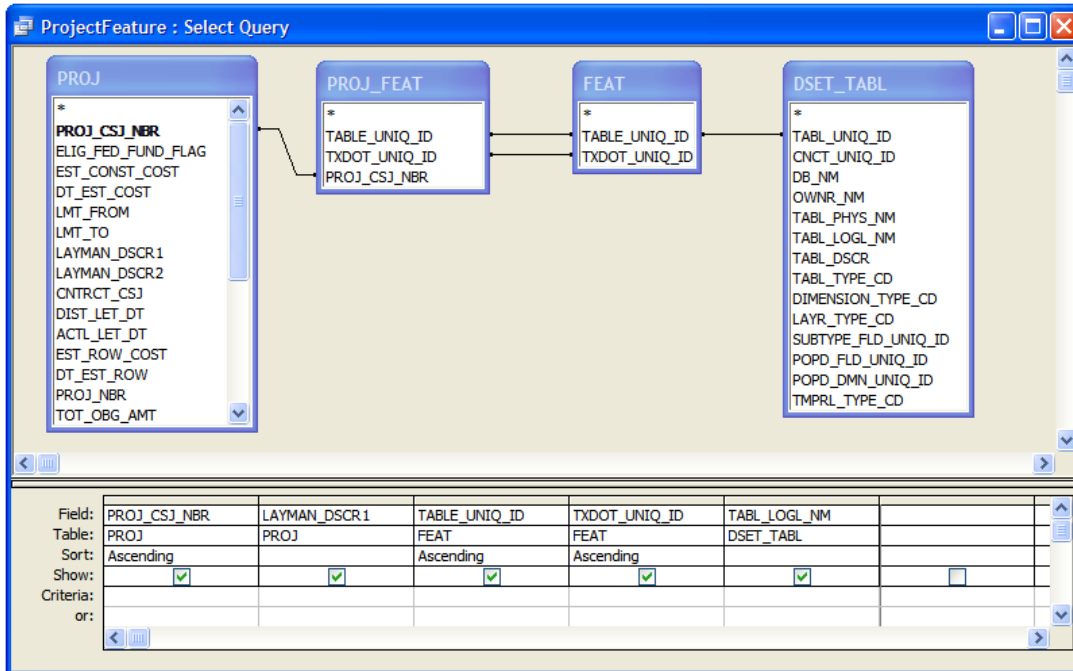


Figure 28. ProjectFeature Query Design View.

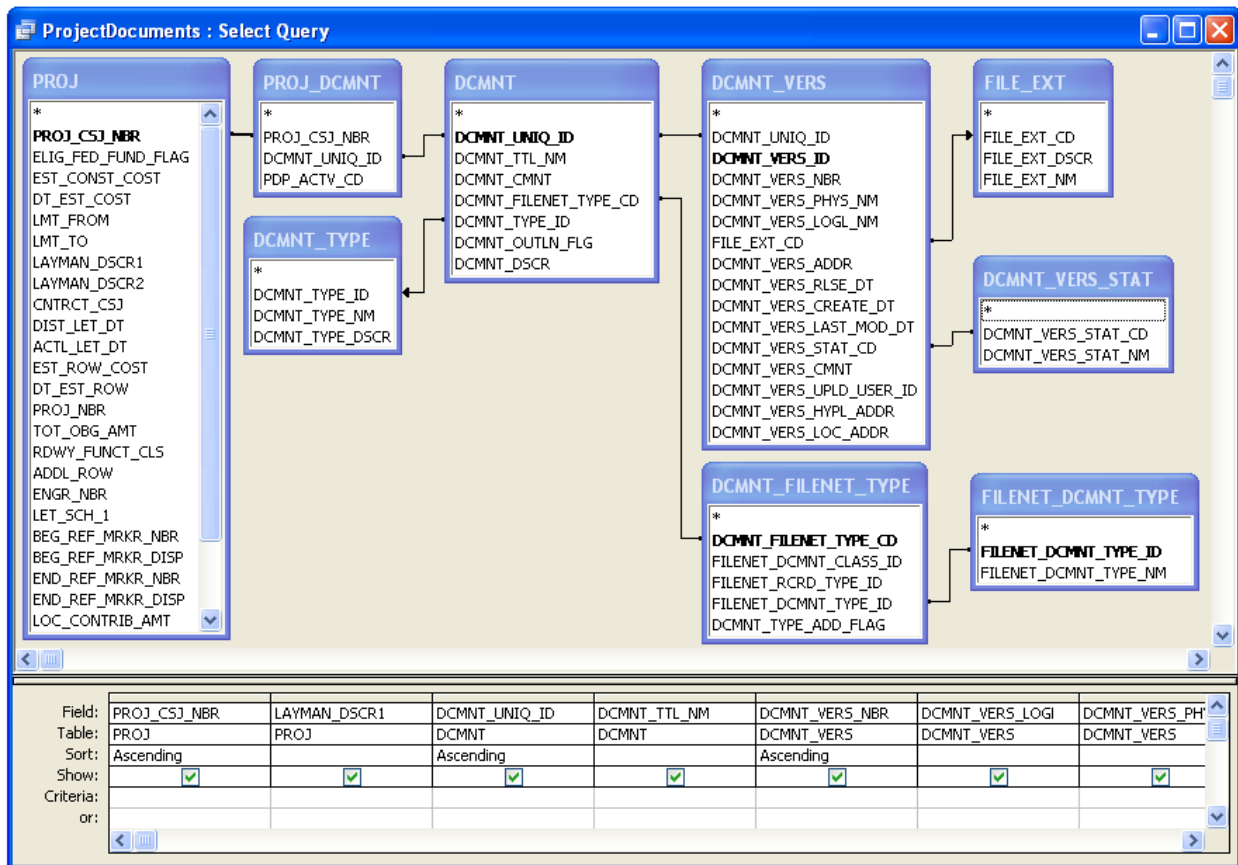


Figure 29. ProjectDocuments Query Design View.

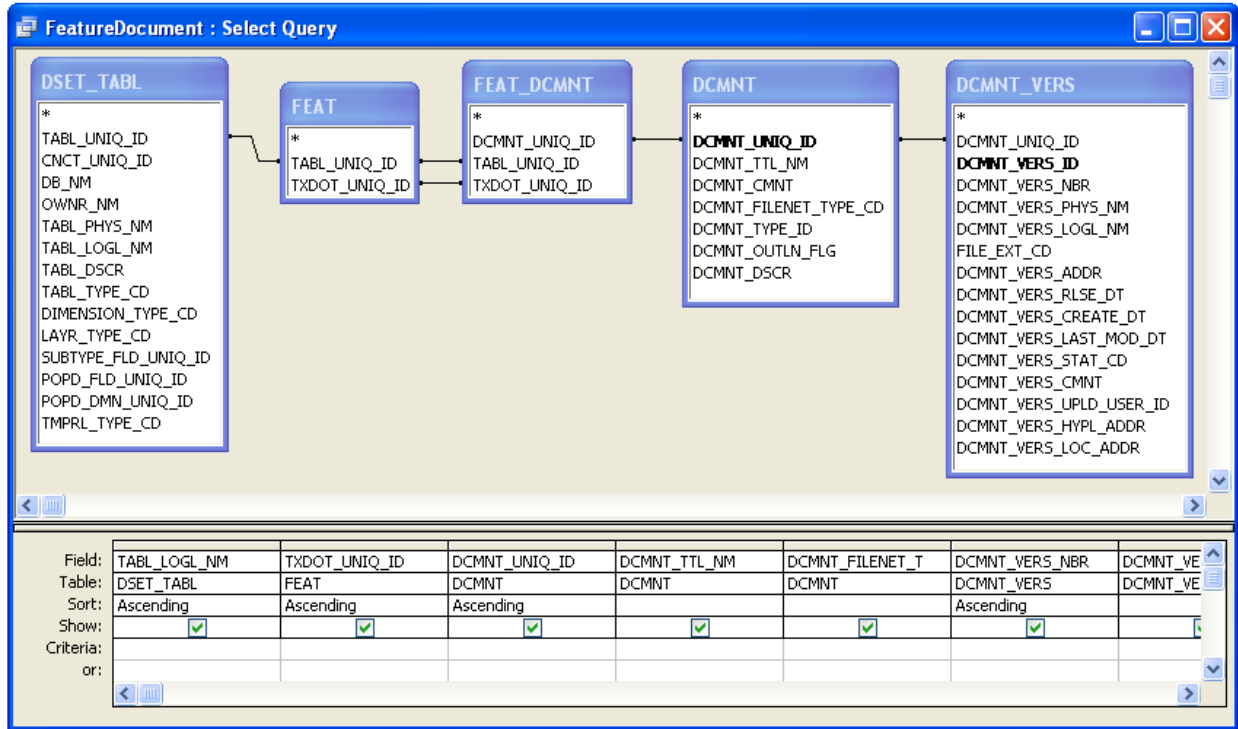


Figure 30. FeatureDocument Query Design View.

Figure 31 and Figure 32 show views of a form that includes one main form (ProjectInfo) and two subforms (ProjectFeature and ProjectDocuments) that show results from the ProjectInfo, ProjectFeature, and ProjectDocuments queries. Notice the hyperlink attribute in Figure 32 (i.e., DCMNT_VERS_ADDR), which enables opening and viewing documents in their native applications and/or a suitable viewer on the client computer.

ProjectInfo

PROJ_CSJ_NBR: 029112001 CSJ_PARENT_NBR: 029112900 CNTRCT_CSJ:
 LAYMAN_DSCR1: CONSTRUCT SPUR TO REPLACE WATSON ROAD PROJ_NBR: C 291-12-1
 CSJ_TYPE_CD: C CSJ_TYPE_NM: Construction
 LMT_FROM: 0.27 MI WEST OF SH 16 LMT_TO: APPLEWHITE ROAD
 BEG_REF_MRKR_NBR: BEG_REF_MRKR_DISP: 0
 END_REF_MRKR_NBR: END_REF_MRKR_DISP: 0
 LET_SCH_1: 2004 EST_CONST_COST: \$9,523,242.91 DT_EST_COST:
 DIST_LET_DT: 10/1/2003 ACTL_LET_DT: 10/1/2003

PROJECT FEATURES

PROJ_CSJ_NBR	TABL_LOGL_NM	TABLE_UNIQ_ID	TXDOT_UNIQ_ID
029112001	WATER LINE	1071	1
029112001	SIGN FEATURE	1087	1
029112001	ELECTRIC LINE	1021	1
029112001	WATER VALVE	1073	1
029112001	WATER HYDRANT	1070	1
029112001	COMMUNICATION LINE	1007	1

Record: 1 of 11658

PROJECT DOCUMENTS

PROJ_CSJ_NBR	DCMNT_UNIQ	DCMNT_TTL_NM	DCMNT_VERS_NO	DCMNT_VERS_LOGL_NM	DCMNT_VERS_PHYS_NM
029112001	5982	Title Page	1	0291-12-001-0001.tif	0291-12-001-0001.tif
029112001	5983	Spur 66 Change Orders	1	0291-12-001-0001a.tif	0291-12-001-0001a.tif
029112001	5985	Spur 66 Project Layout	1	0291-12-001-0003.tif	0291-12-001-0003.tif
029112001	5986	Traffic Control and Warning Devices	1	0291-12-001-0004.tif	0291-12-001-0004.tif
029112001	5987	Traffic Control and Warning Devices	1	0291-12-001-0005.tif	0291-12-001-0005.tif
029112001	5988	Traffic Control and Warning Devices	1	0291-12-001-0006.tif	0291-12-001-0006.tif
029112001	5989	Traffic Control and Warning Devices	1	0291-12-001-0007.tif	0291-12-001-0007.tif
029112001	5990	Horizontal Control Data	1	0291-12-001-0008.tif	0291-12-001-0008.tif
029112001	5991	Horizontal Control Data	1	0291-12-001-0009.tif	0291-12-001-0009.tif
029112001	5992	Spur 66 Horizontal Control Data	1	0291-12-001-0010.tif	0291-12-001-0010.tif

Record: 1 of 1763

Record: 2 of 6

Figure 31. ProjectInfo Form with Project CSJ 029112001 Data.

ProjectInfo

PROJ_CSJ_NBR	000513043	CSJ_PARNT_NBR	000513917	
LAYMAN_DSCR1	NEW INTERCHANGE			
CSJ_TYPE_CD	C	CSJ_TYPE_NM	Construction	
LMT_FROM	AT JBS PARKWAY IN ODESSA		LMT_TO	
BEG_REF_MRKR_NBR	0119	BEG_REF_MRKR_DISP		
END_REF_MRKR_NBR	0120	END_REF_MRKR_DISP		
LET_SCH_1	2005	EST_CONST_COST	\$9,752,202.7	
DIST_LET_DT	8/1/2005	ACTL_LET_DT	8/1/2005	

PROJECT FEATURES

PROJ_CSJ_NBR	TABL_LOGL_NM	TABLE_UNIQ_ID
000513043	GAS LINE	1034
000513043	PROJECT LINE	1074
000513043	DOCUMENT OUTLINE POLYGON	1080
000513043	DOCUMENT OUTLINE POLYGON	1080
000513043	DOCUMENT OUTLINE POLYGON	1080
000513043	DOCUMENT OUTLINE POLYGON	1080

Record: 1 of 891

PROJECT DOCUMENTS

DCMNT_VERS_ADDR	DCMNT_VE	DCMNT_VI	DCMNT_VE	FILE #	DCMNT	FILENET_DCM	DCMNT_TY
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0001.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0002.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0003.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0004.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0005.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0006.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0007.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0008.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0009.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur
C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0005-13-043-0010.tif	9/25/2006	6/20/2005	Reference	TIF	12.6.1	Letting Plan	Plan Docur

Record: 1 of 6

STATE OF TEXAS
DEPARTMENT OF TRANSPORTATION

PLANS OF PROPOSED STATE HIGHWAY IMPROVEMENT
ECTOR COUNTY
IH 20

NET LENGTH OF PROJECT: 6,400.00 FT + 1,820.00 FT
LIMITS: AT JBS PARKWAY

FOR THE CONSTRUCTION OF NEW INTERCHANGE CONSISTING OF GRADING, STRUCTURES, FLEX BASE, 2-COURSE SURFACE TREATMENT, HOT MIX CURB-F, RETAINING WALLS, PAVEMENT MARKINGS, SIGNS, AND ILLUMINATION

INDEX OF SHEETS
SHEET NO. DESCRIPTION
SEE SHEET NO. 1A

SCALE: 1" = 310'

2004 by Texas Department of Transportation
All Rights Reserved

TXDOT PROJECT: 005-13-043
124-88-00-00
REF MTR 120-0-338 MTR

TXDOT PROJECT: 005-13-043
124-88-00-00
REF MTR 120-0-338 MTR

EXCEPTIONS NONE
OMISSIONS NONE

APPROVED FOR LETTING: [Signature]
APPROVED FOR LETTING: [Signature]
APPROVED FOR LETTING: [Signature]

Figure 32. ProjectInfo Form with Project CSJ 000513043 Data.

ArcGIS Testing Environment

While the purpose of the Access testing environment was to test non-spatial relationships, the purpose of the ArcGIS testing environment was to test spatial relationships in an offline, portable environment. ArcGIS testing involved developing “joins” between GIS feature classes and non-spatial tables such as PROJ, PROJ_DCMNT, and DCMNT_VERS in order to retrieve project and document data when querying features using the GIS user interface.

Without extensions, custom code, or the use of ESRI relationship classes, ArcGIS has limited joining table capabilities. When joining tables, ArcGIS appends the fields of one table to those of another through their common field. If the common field of one table has duplicate values, the join function appends the attribute values of the first matching record. Because the purpose of the ArcGIS testing environment was to retrieve project and document data when selecting a feature using the GIS interface, for simplicity, the researchers joined feature-specific pre-joined tables to feature class tables. Specifically, for each feature class, the researchers created joins with the PROJ, PROJ_DCMNT, and DCMNT_VERS tables.

Figure 33 shows a view of the ArcGIS testing environment. For readability, the name associated with each layer added to the interface is the same as the feature class logical name. Using the Identify tool to query a feature opens a separate window that shows all the attribute values associated with that feature along with attribute values associated with any joined table. For example, Figure 33 shows the result of querying the IH 410 (Ingram Road to Callaghan Road) project line. Notice the DCMNT_VERS_LOC_ADDR field is a hyperlink that enables opening and viewing documents in their native applications and/or a suitable viewer on the client computer. Because of the limitations of the join function in ArcGIS, as described above, the query only produced one document associated with the IH 410 project line record. To retrieve all the documents associated with that project using the GIS interface, it would be necessary to write code to customize the Identify tool and/or use ESRI relationship class constructs.

0-5246 project 2007-06-30 - ArcMap - ArcInfo

File Edit View Insert Selection Tools Window Help

1:15,909

Layers

- PROJECT LINE
- DOCUMENT POLYGON
- SIGN FEATURE
- WATER HYDRANT
- WATER VALVE
- WATER LINE
- COMMUNICATION POLE
- COMMUNICATION PEDESTAL
- COMMUNICATION LINE
- ELECTRIC LINE
- GAS LINE
- CAD DOCUMENT LINE
- TXDOT CONTROL SECTION LINE
- TXDOT ROUTE CENTER LINE
- TXDOT DISTRICT POLYGON
- TXDOT COUNTY POLYGON

Identify

Identify from: <Top-most layer>

PROJECT LINE
IH0410

Location: 2,098,507.060 13,724,353.850 Feet

Field	Value
PROJ_LN_CSJ_NUM	052104190
PROJ_EST_CONST_COST	55401560.62
PROJ_LMT_FROM	IH 410 FROM E OF INGRAM RD
PROJ_LMT_TO	CALLAGHAN RD
PROJ_LAYMAN_DSCR1	EXPAND TO 10 LANE FRWY & TMS
PROJ_LAYMAN_DSCR2	FREEWAY REHABILITATION
PROJ_DIST_LET_DT	1/1/2005
PROJ_ACTL_LET_DT	1/1/2005
PROJ_PROJ_NBR	NH 2005(136)
PROJ_LET_SCH_1	2005
PROJ_BEG_REF_MRKR_NBR	0012
PROJ_BEG_REF_MRKR_DISP	0.424
PROJ_END_REF_MRKR_NBR	0014X
PROJ_END_REF_MRKR_DISP	0.618
DCMNT_VERS.DCMNT_VERS_PHYS_NM	0521-04-190-1043.tif
DCMNT_VERS.DCMNT_VERS_CREATE_DT	9/25/2006
DCMNT_VERS.DCMNT_VERS_LAST_MOD_DT	12/2/2004
DCMNT_VERS.DCMNT_VERS_STAT_CD	Reference
DCMNT_VERS.DCMNT_VERS_LOC_ADDR	C:\Filenet\Project_Design\Letting_Plans\Letting_Plan\0521-04-190-

Identified 1 feature

0521-04-190-1043 - Microsoft Office Document Imaging

File Edit View Page Tools Window Help

Page: 1 of 1

Zoom: Entire Page

Ready

2103687.56 13723697.56 Feet

OCR Language: English

Figure 33. ArcGIS Testing Environment Showing Identify Tool Results on Project Line.

Internet Explorer Testing Environment

Internet Explorer testing involved the development of a customized web application that enables the retrieval of project-related documents using tabular and/or map views. To the extent possible, the web application used web forms and source code the researchers had already developed for other TxDOT research projects. In some cases, it was necessary to develop and/or customize forms and functions. However, the level of customization was kept to a minimum.

The web application includes a data query and exploration component and a mapping component. The data query and exploration component enables users to select and explore project folders and view selected documents within those folders. The component functions use active server pages (ASP), SQL scripts, and hypertext markup language (HTML) tags. The mapping component provides a navigable map that enables users to identify and query features. The mapping component uses an ESRI ArcIMS map server and customized code to retrieve feature-related data when querying the feature using the map interface.

The web application includes five main modules, of which Data Query and Spatial Data Query are currently functional (Figure 34). A summarized description of these two modules follows.

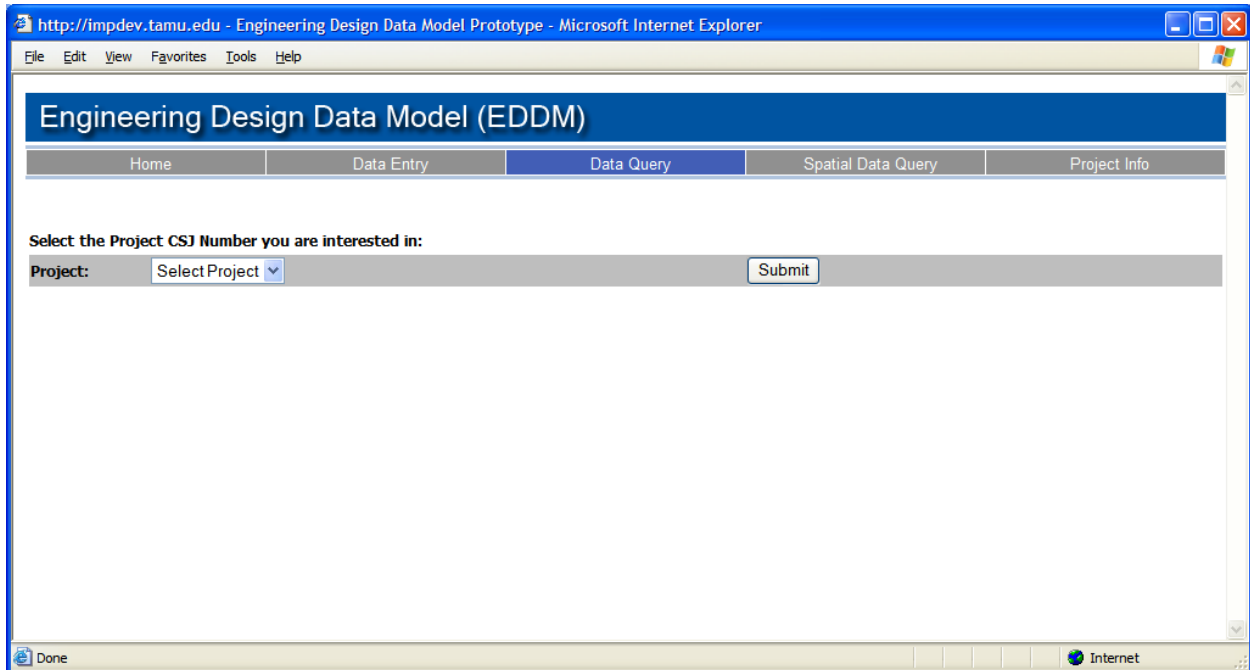


Figure 34. EDDM Web Application Modules.

Data Query

After a user selects a project (Figure 34), the interface displays a View Project Data screen that displays summary project data (Figure 35). At the bottom of the screen, there are three viewing options: View Project Data (default option when selecting a project), View Project Documents,

and View Map of Project. The View Project Documents screen (Figure 36) displays an expandable list of project folders that follows the FileNet file structure and a list of documents within each folder. In the current version, the screen provides the following functionality:

- **Open and view documents.** Clicking a document name enables opening and viewing of the document in its native application and/or a suitable viewer on the client computer. Clicking the “+” icon to the left of certain documents expands the view to provide a clickable list of available document versions.
- **Metadata.** Clicking the metadata icon opens a window that displays basic metadata associated with the document (Figure 37).
- **Map.** Checking one or more boxes under the Map column and clicking the Select button at the bottom of the screen opens a map that displays the outlines of the corresponding documents (Figure 38).

The View Map of Project screen produces a map that shows the project limits, which is essentially the same map as in Figure 38.

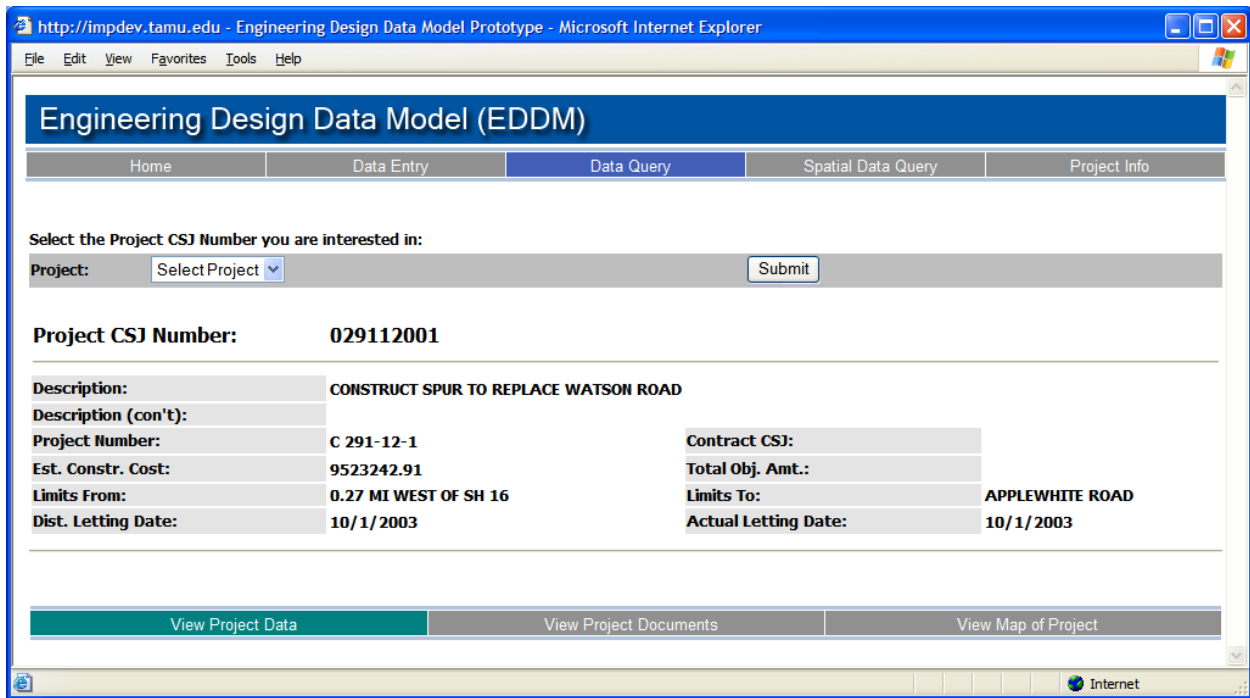


Figure 35. Data Query View Project Data Screen.

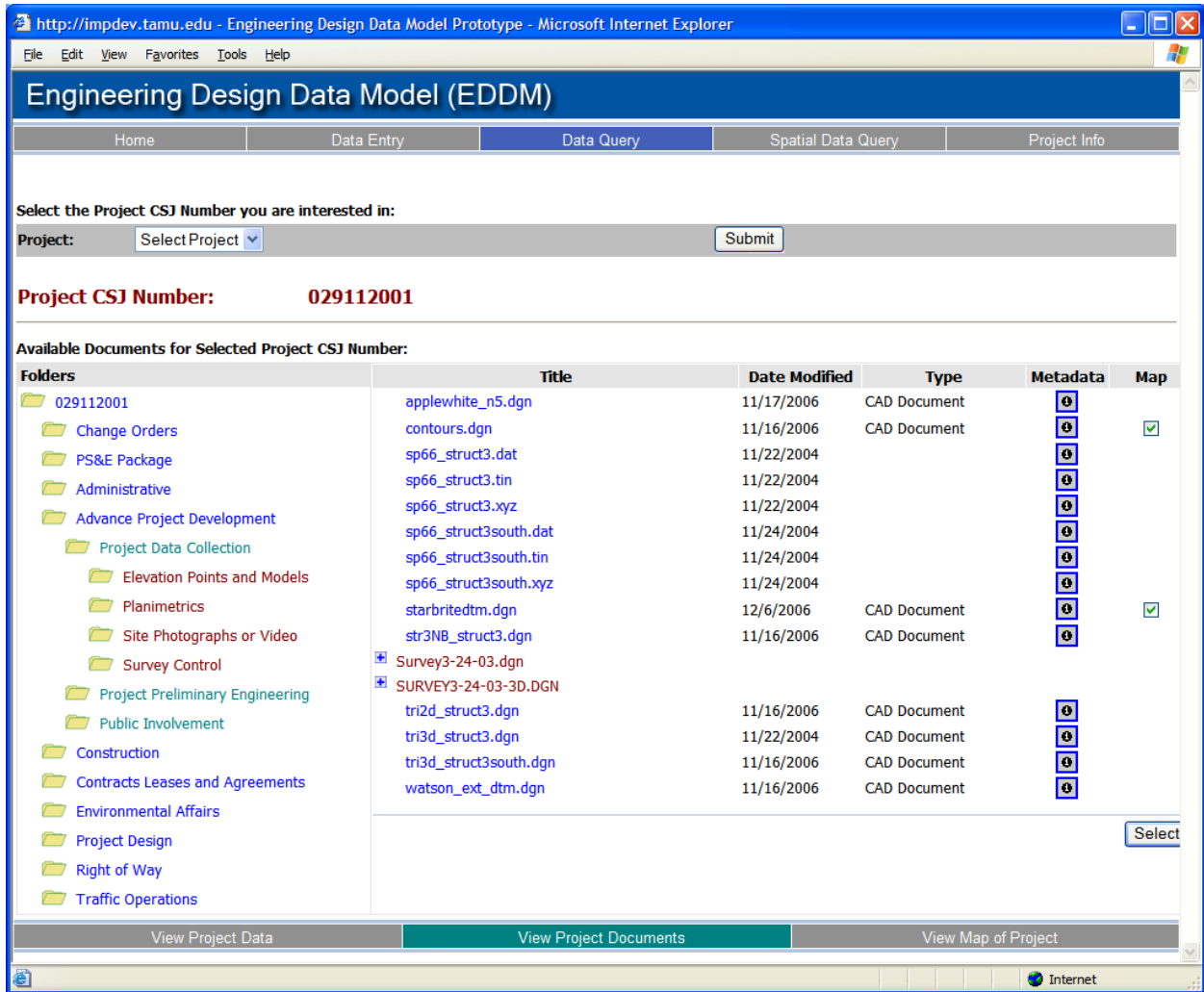


Figure 36. Data Query View Project Documents Screen.

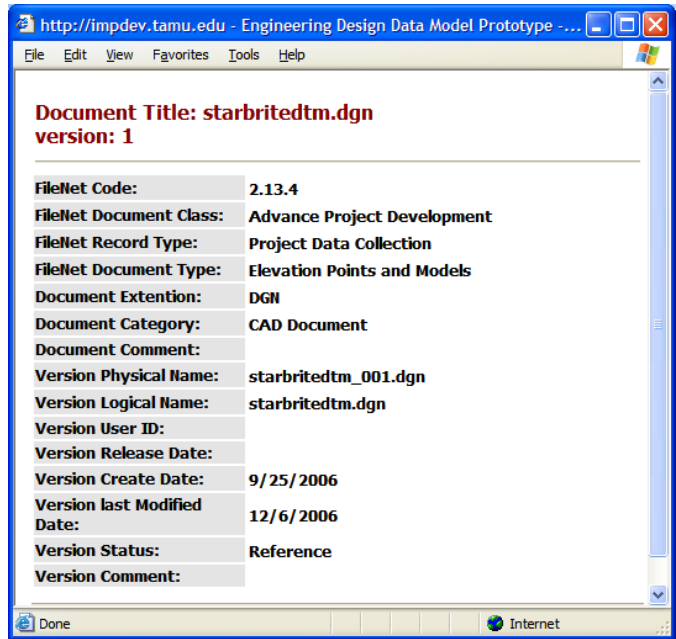


Figure 37. Data Query View Project Documents Screen – Metadata View.

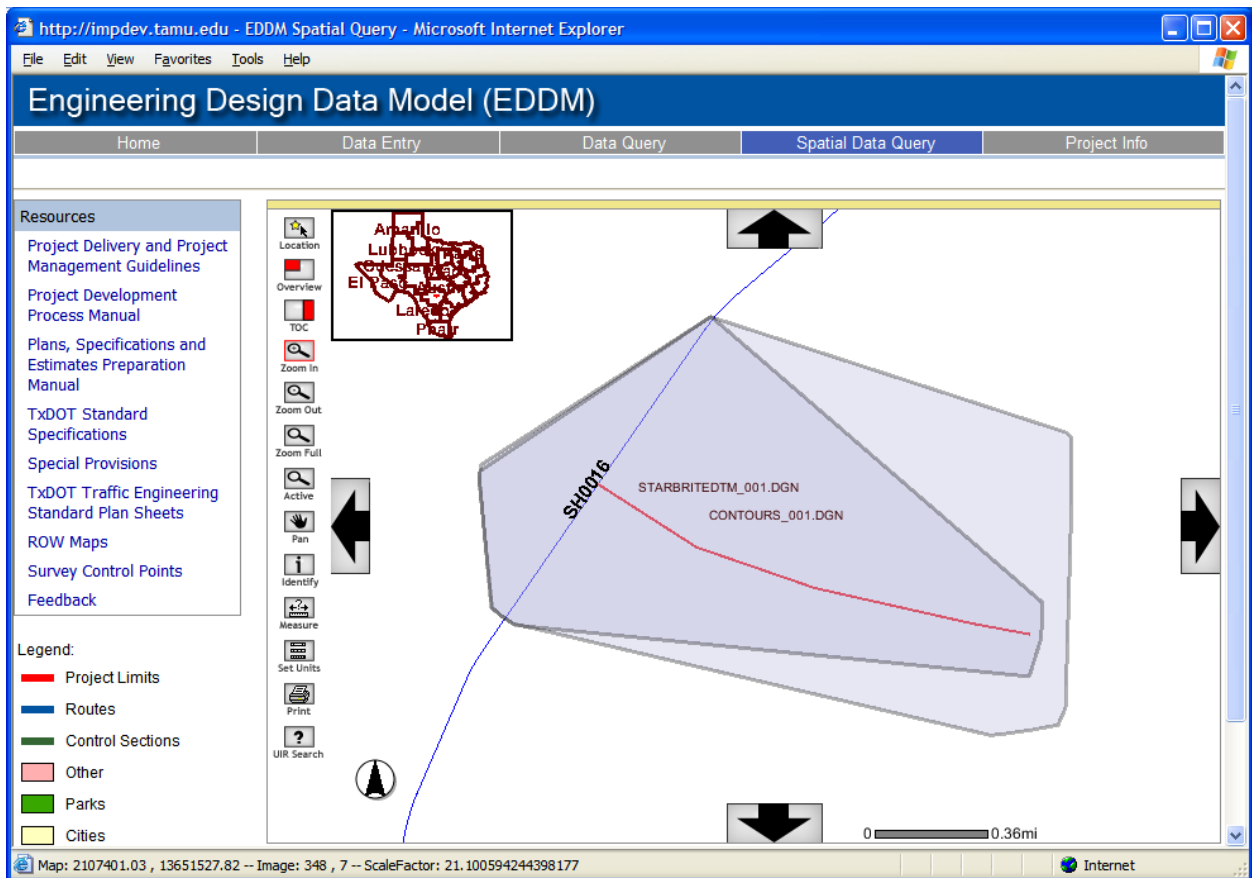


Figure 38. Data Query View Project Documents Screen – Map View.

Spatial Data Query

Clicking Spatial Data Query on the web application (Figure 34) opens an interactive map window. One of the layers accessible on the map is the project line layer. As an illustration, Figure 39 shows the project lines for the three sample projects in San Antonio (in red). Selecting the Identify tool and then highlighting a project line feature opens a window that displays project data for all the projects located near the point selected (Figure 40).

Similar to the Data Query View Project Documents tool (Figure 36), selecting the View Project Documents tool from the open window provides an expandable list of document folders and document names for the selected project (Figure 41). Clicking the document name opens the file in its native application and/or suitable viewer on the client computer. It is also possible to retrieve metadata for individual documents.

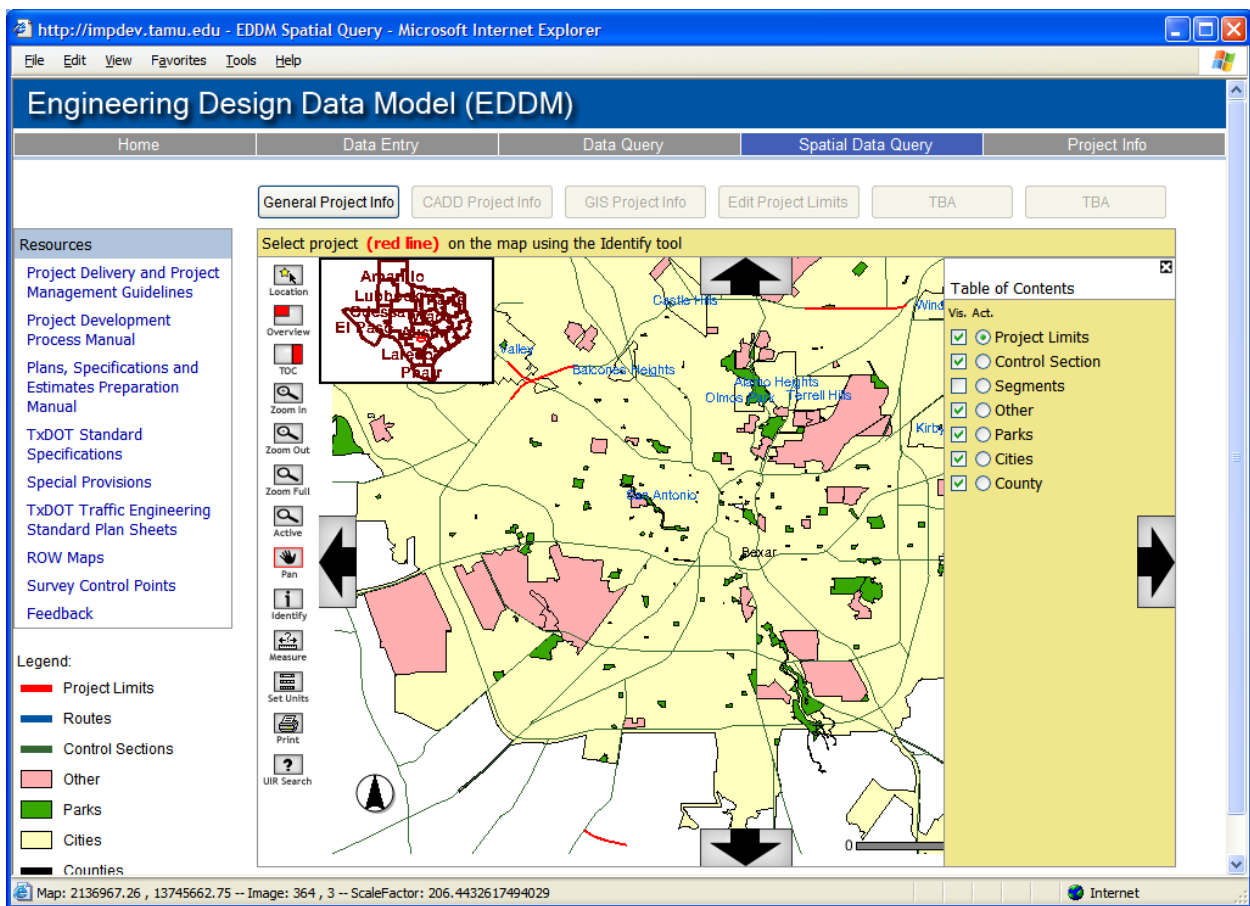


Figure 39. Spatial Data Query Screen.

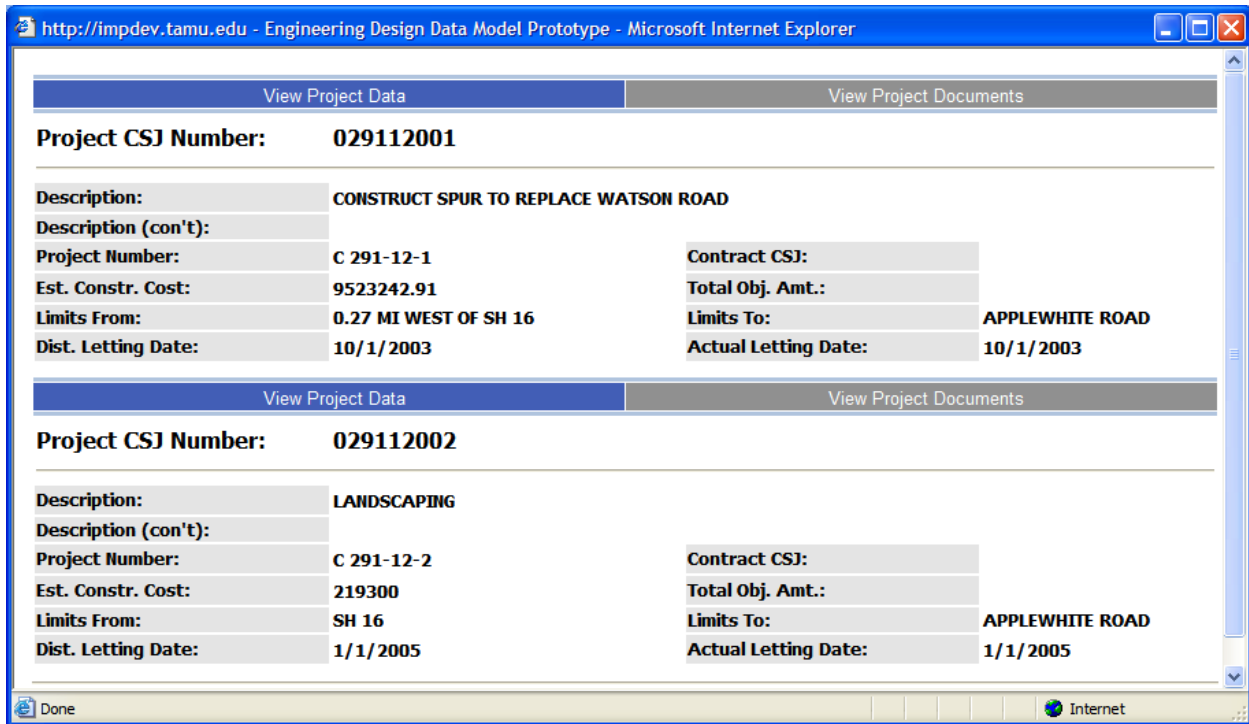


Figure 40. Spatial Data Query Screen – Project Feature Query Results.

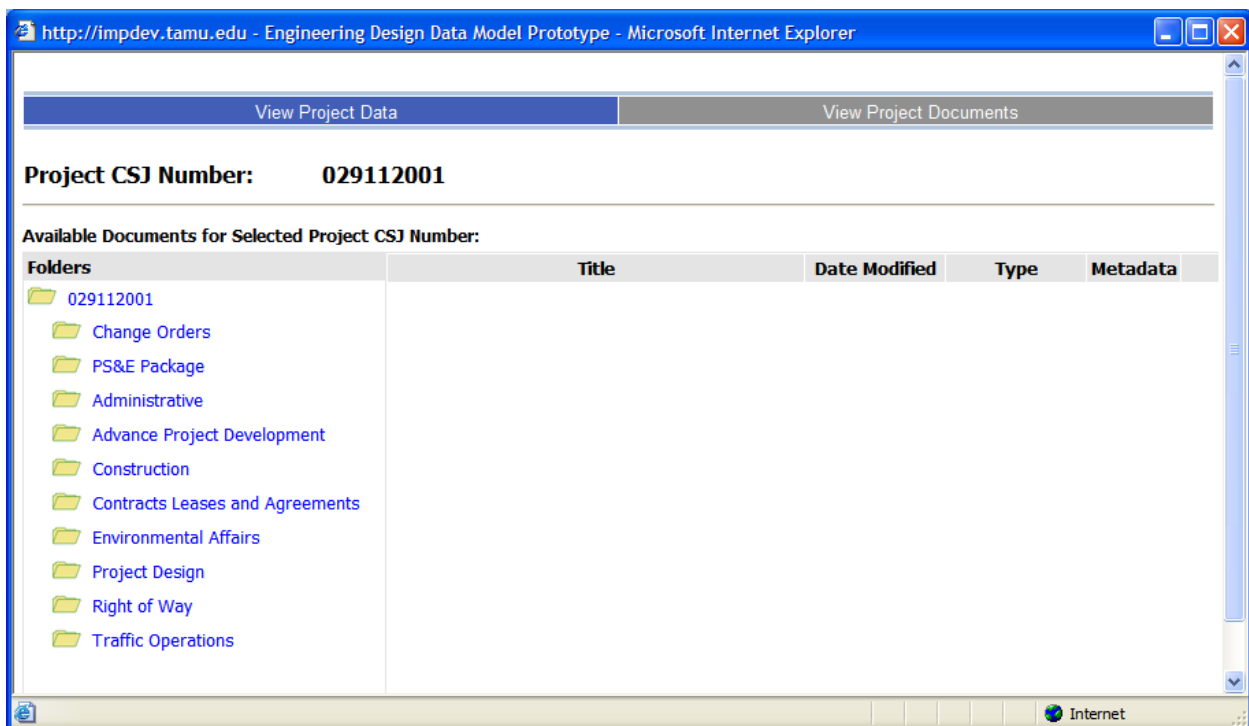


Figure 41. Spatial Data Query Screen – Project Document View.

In addition to project lines, the spatial data query screen includes a variety of document outlines, CAD files, and project-related asset features (e.g., signs, water hydrants, and electric lines). For example, [Figure 42](#) shows all the document outlines for Project CSJ 052104190. [Figure 43](#) shows signs and CAD file linework for the same project. In general, selecting the Identify tool and highlighting a feature opens a window that displays attribute data associated with that feature.

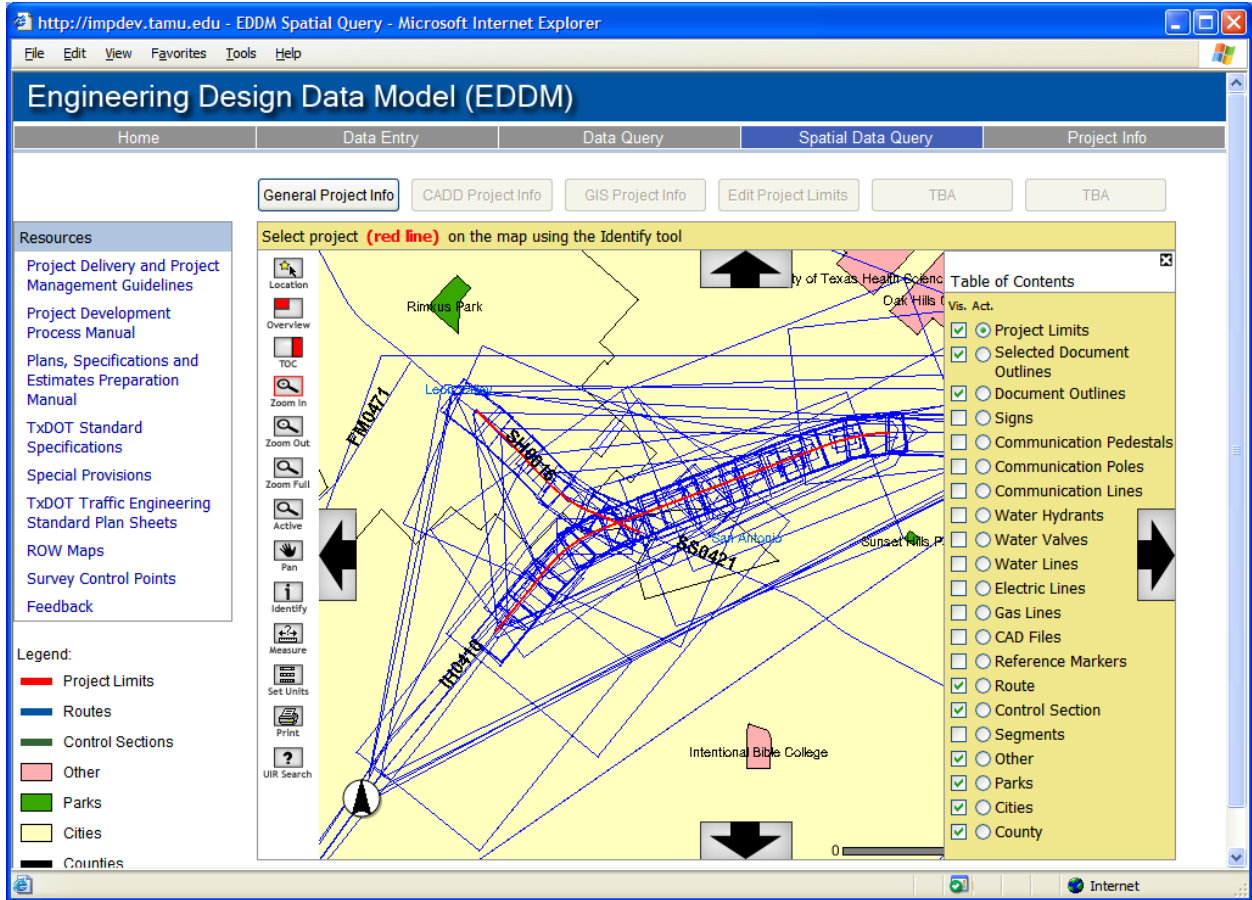


Figure 42. Spatial Data Query Screen – Document Outline View.

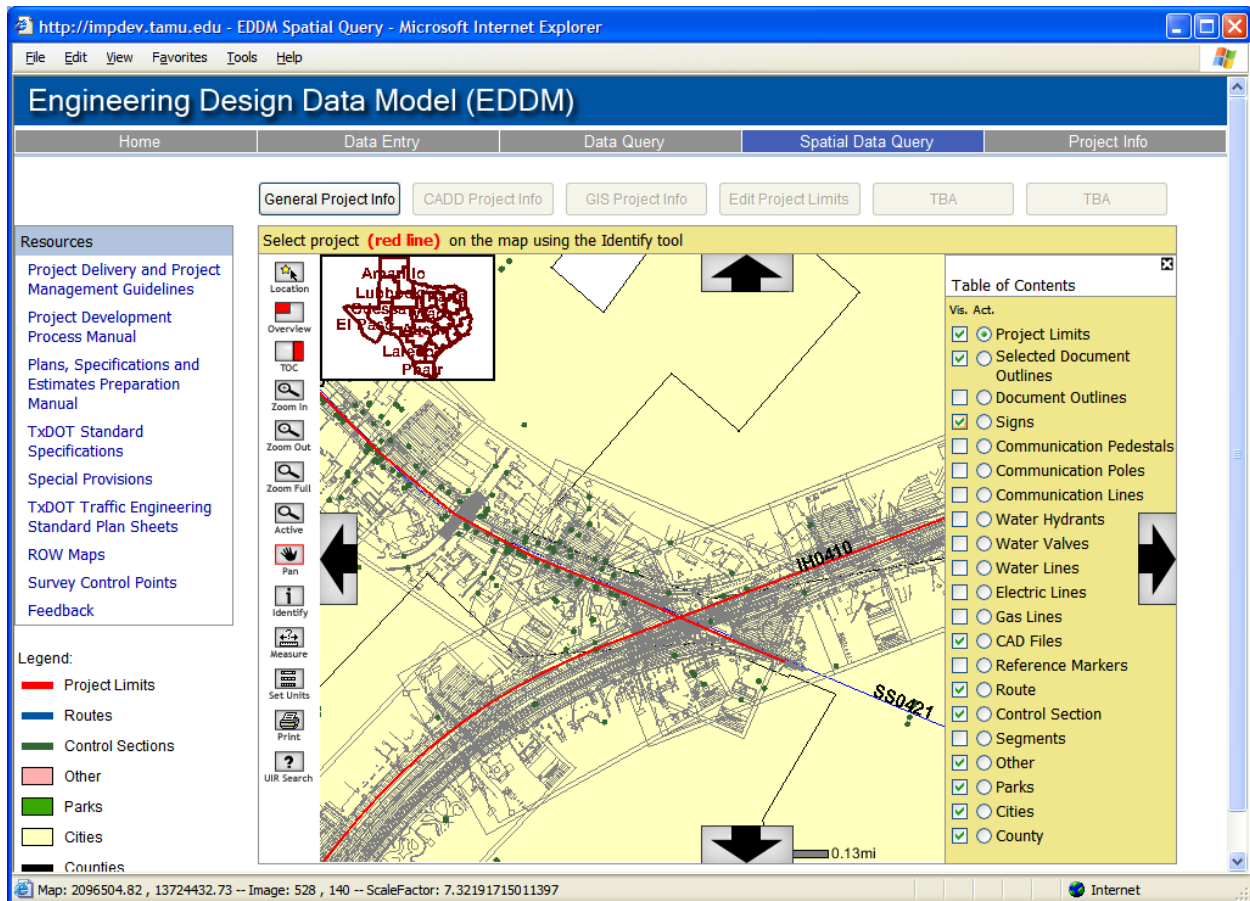


Figure 43. Spatial Data Query Screen – Sign and CAD File View.

USER FEEDBACK

The researchers met with Odessa District, San Antonio District, and General Services Division officials to gather feedback regarding EDDM, develop additional understanding about engineering documentation management practices and plans at TxDOT, and discuss potential mechanisms for integration of EDDM into existing business processes at TxDOT. Several recommendations from TxDOT officials resulted in changes to the prototype database and user interfaces, which previous sections in this report have already described. In other cases, where changes were not feasible during the research (either because of research scope limitations or because the proposed changes would be more appropriate for an implementation phase), the researchers compiled and structured the comments into potential implementation recommendations.

A summary of some of the relevant issues discussed with TxDOT officials during the feedback phase follows:

- **Coordinate systems.** It is straightforward to display and process geo-referenced CAD files (e.g., files that use the state plane coordinate system) in a GIS environment. The

difficulty arises when CAD files use an arbitrary coordinate system, which happens frequently particularly in the case of small projects, where using arbitrary coordinate systems is simpler and less cumbersome. At the same time, district officials would like to continue the practice of identifying project limits using reference marker displacements. Although the GIS environment supports this functionality, using reference marker displacements can produce inaccurate project limit definitions. In general, it is preferable to use absolute coordinates (e.g., by using GPS receiver readings) to identify project limits in the field and use GIS functions to automatically determine the linear feature that defines the project.

- **FileNet/TxDocsOnline implementation.** As mentioned previously, TxDOT is implementing functional area-based district FileNet libraries. Although one of the document indexing fields is CSJ number, district officials noted that associating documents with their CSJ number correctly is a critical challenge. District officials also noted that adequate FileNet training (not limited to an initial introductory phase) is a key element to ensure long-term implementation success. In general, districts envision FileNet implementations focusing on final document archival, not necessarily as a mechanism to manage “partial” documents produced during the PDP.

Discussions with TxDOT officials about the FileNet library structure highlighted a number of deficiencies in the library record type and document type structure (see [Chapter 5](#)). From those discussions, TxDOT introduced a series of proposed modifications to the FileNet library structure (38). Unfortunately, because of the timing of activities at the end of the research project, it was not possible to incorporate those proposed changes in the EDDM prototype. Including those changes in EDDM would need to be completed in a subsequent phase.

- **Data access and security.** Sensitive information in CAD files (e.g., an engineer’s electronic seal) can be a source of liability concerns. This issue is a document security issue that can be handled during implementation because enterprise systems such as FileNet include user validation protocols that manage the level of access users have to specific documents. It was therefore not necessary to address the issue during the research.
- **Project document access and retrieval.** District officials highlighted the need to access all project documents easily, especially PS&E document sets, when viewing projects on the screen. The prototype web application supports this functionality. However, district officials recommended using standard design support forms within the interface as templates to retrieve relevant documents associated with a project. Examples of potential template forms could include the TxDOT Design Summary Report (13), Odessa District’s Design Conference Form (21), or relevant templates and checklists from the *Project Delivery and Project Management for TxDOT Projects* document (92). District officials also recommended adding the project description to the CSJ number in the Project dropdown list box.

- **CAD document standards.** District officials highlighted the need for adequate enforcement of CAD file standards (39). Reasons for poor compliance with standards include lack of awareness about the standards by consultants; poor communications between TxDOT project managers and consultants; inadequate cross references among the various guidelines, manuals, and standards that support the TxDOT PS&E development and submission process (12, 39, 92); and lack of vision to anticipate problems when standards are not enforced. Compliance issues range from form and style (e.g., are all features belonging to the same class or using the same cell type stored in the same level? Are colors and line style consistently applied?) to content (e.g., is the coordinate system used correctly? Are driveway slopes properly included in the drawings?). District officials highlighted that MicroStation version 8 offers greater flexibility compared to previous versions, but functionality such as unlimited number of levels and levels that use names instead of numbers can result in problems if standards are not strictly enforced. TxDOT officials also noted that there should be a standard for the management, storage, and archival of CAD documents, which would include items such as folder and file naming conventions as well as procedures for integrating CAD documents with other datasets. The prototype and user interfaces addressed the issue on how to integrate CAD documents with project and feature datasets.

It may be worth noting that during discussions with TxDOT officials, demonstration of the web application enabled officials to observe differences in location for certain features that represented the same object on the ground (e.g., a sign or a manhole cover) but were in separate CAD documents (produced by different consultants). The differences in location were larger than the survey tolerance, which highlighted the need for compliance with appropriate standards and proper coordination between TxDOT and all the teams that work on a project. A web-based application that overlays and displays CAD deliverables on a map would assist project managers and team members in that effort.

- **Plans Online.** As mentioned previously, Plans Online stores project letting and as-built plans and proposals. The system runs on an Alchemy platform that does not interact with other major enterprise systems at TxDOT. As part of the long-term goal for Plans Online to use a system platform consistent with other applications, TxDOT has examined other systems currently in operation at the department, including FileNet and Main Street Texas. TxDOT officials have also expressed interest in the results of this research, particularly in relation to the use of a GIS-based platform for managing engineering documentation spatially.

To assist in this effort, TxDOT officials highlighted the need for EDDM database elements to be consistent with those of Plans Online. For example, as discussed in Chapter 2, Plans Online project indices follow DCIS File 121 project attributes closely. As part of the overall design to integrate projects, documents, and features, the EDDM database supports DCIS attributes. At the same time, although the EDDM prototype web application has some similarities to the Plans Online interface (e.g., the tools to explore project files), the prototype supports several functions that have the potential to complement the Plans Online design and functionality, including the following:

- document attribution and data compatibility with other TxDOT project-based systems such as DCIS and FileNet;
- management of a wide range of project-based document categories, not just project letting and as-built plans and proposals;
- project and document exploration and retrieval through two general mechanisms:
 - a file exploration interface that filters out empty project folders and opens documents in native applications; or
 - a mapping component that supports interactive project and related feature queries and enables users to view project limits, spatial representations of document boundaries and content, and a wide range of spatial features.

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF FINDINGS

Engineering Design Data Management Practices at TxDOT

The researchers identified relevant engineering design data management practices, plans, and systems at TxDOT. To keep the analysis at a manageable level, the review focused on key PDP concepts and data management issues. To gather information, the researchers reviewed relevant manuals and guidelines and met with TxDOT district officials who are involved in several phases of the PDP, including planning, design, and ROW and utilities. The researchers also met with staff from several divisions, including ISD and GSD, to gather detailed information about TxDOT computer systems and standards that involve management of engineering design data.

Project Development Process Review

Depending on the type of project and the corresponding selection process, the path to design, letting, and construction may vary. The TxDOT *Project Development Process Manual* (10) provides information about some 200 major tasks, subtasks, responsible parties, and critical sequencing. The PDP manual includes a diagram that shows sections and subsections in the manual as well as arrows that illustrate overall chapter and section interdependence at a very high level of aggregation. The diagram also shows project levels of authority. For each task in the PDP, there is documentation, which can be in the form of drawings (e.g., layouts, schematics, and plans), submission/review forms, surveys, raw data, analyses and lists, as well as communication and coordination documents such as meeting minutes, phone logs, transmittals, emails, and faxes. Core supporting documents are the 20-page Design Summary Report (13) and the 4-page Form 1002 (14). Many other documents support the PDP process but are not included in the PS&E package.

Although TxDOT intended the PDP manual to provide a clear and consistent definition of project processes and component tasks, in actual practice the manual has several limitations that tend to hinder its usability. The researchers identified several issues, including the following:

- The PDP diagram is a diagram in which “swim lanes” attempt to represent major workflow activities that do not necessarily correspond to functional areas at the PDP level. Further, the PDP diagram suggests major workflow activity and section dependencies that frequently do not correspond to text or task dependencies in the PDP manual. The PDP diagram does not include decision points and feedback mechanisms, which are critical to characterizing business process activities properly. Finally, the PDP diagram is a “catch all” diagram that attempts to represent all types of projects and situations, which can make the use of this diagram, particularly by inexperienced planners and designers, ineffective.
- The PDP manual is not consistent in the way it treats responsible parties, subtasks, and critical sequencing for individual tasks. Critical sequencing text frequently does not

include complete from-dependence and to-dependence information, which forces the reader to navigate through chapters and sections in the manual to find that information.

- Although the PDP manual tends to use terminology consistently, there are cases where inconsistencies in the use and application of technical terms can produce confusion. For example, the terms “layouts,” “planimetric map,” “geometrics,” “schematics,” and “plans” can have different meanings both within the PDP manual and during the course of technical discussions with district officials.

Although district PDP implementations follow the general guiding principles of the PDP manual, there are considerable differences in interpretation and implementation. As an illustration, this report summarized the main characteristics of the PDP implementations at two sample districts: San Antonio and Odessa. In addition to standard statewide TxDOT form templates, the San Antonio District uses checklists for 30 percent, 60 percent, 90 percent, and 100 percent design. The district also uses a flowchart and companion guidelines that focus on critical milestones that define the relationship between the PDP and the utility adjustment process. These guidelines started in the late 1990s as a memorandum of understanding between TxDOT and utility companies to outline expectations and responsibilities during the utility adjustment process. Over time, the guidelines have evolved into a PDP management tool that includes a milestone flowchart, milestone purpose definitions, and typical activities and general document requirements associated with each milestone. Increasingly, district officials see a need to compress PDP activities, e.g., by moving some of the traditional design-phase activities to the planning phase and by adjusting start-to-finish work elements to start-to-start elements. District officials view their PDP guidelines and the schedule compression that results from reaching the “official” design phase when projects are already around 30 percent design complete as helping them to cope with accelerated project schedule demands. The district has also instituted design review and traffic safety review teams to support the PDP and improve work zone safety.

In the case of the Odessa District, in addition to standard statewide TxDOT form templates, the district developed standard operating procedures for project selection and development and PS&E development and review. The procedure for project selection and development includes the requirement for design summary outline documents, which can be in one of three forms: a preliminary estimate worksheet, a design conference form, or the TxDOT DSR. The Odessa District routinely uses this form instead of the standard 20-page TxDOT DSR as a tool to streamline project documentation. The design conference form includes a PDP flowchart. There are several differences between the Odessa District PDP flowchart and the PDP manual flowchart. As opposed to the “standard” PDP flowchart, which only depicts chapters and sections of the PDP manual in a linear fashion, the Odessa District PDP flowchart contains work elements and decision points. Some Odessa District work elements are similar to the PDP manual flowchart, but not all elements map directly or follow the same sequence. Most projects at the Odessa District are relatively straightforward projects that do not involve components such as environmental clearance, retaining walls, ITS, or bridges. As opposed to larger districts, the Odessa District typically handles project design work internally. District personnel routinely take multiple roles in the development of a project, which is typical for rural districts.

Data Management-Related Practices and Plans

TxDOT uses a variety of information systems to support the project development process. As an illustration, the report described DCIS, ROWIS, and TRM. DCIS runs on an Adabas non-relational database platform. Over the years, TxDOT has developed online and/or batch linkages between DCIS and other TxDOT systems. Examples include BAMS/DSS, BPS, CTS, SMS, CMCS, and ETS. Districts have also developed systems that connect to DCIS. Typically, the connection is a read-only connection, where a batch process downloads data from DCIS on a regular basis, e.g., every night. According to TxDOT officials, TxDOT is planning to convert DCIS to a relational database platform. As part of this process, TxDOT developed a preliminary data model and corresponding data dictionary for File 121. TxDOT is also looking at other potential strategies, e.g., the implementation of an Adabas replicator.

ROWIS enables users to track ROW parcel development and fee appraiser work orders during events such as negotiations, settlements, or eminent domain proceedings. The ROW Division also uses ROWIS to track reimbursable utility agreement payments. ROWIS runs on a Microsoft SQL Server platform. The system interface includes screens that display data on topics such as projects, parcels, tasks, owners, CSJs, minute orders, and public agencies.

TRM documents physical and performance characteristics of state highway network segments using the highway reference marker network as a geo-referencing tool. TRM is centerline based, although it does provide for the identification of features on either side of the centerline. TRM also enables the calculation of cumulative distances by using the relative location of the markers along the highway network. While TRM provides data for a wide range of reporting options, it has shortcomings that limit its usability, particularly during the PDP. Because TRM is centerline based and cumulative distance dependent, the positional accuracy of any feature or measure (such as ROW width, roadbed width, or beginning and ending project limits) cannot be better than the positional accuracy of the underlying centerline map. In addition, positional accuracy cannot be better than the longitudinal positional accuracy of *both* reference markers and the underlying centerline map. Although reference markers are supposed to be permanent features on the ground, the reality is frequently quite different. As a result, it is very difficult to determine the actual location of features using cumulative distances alone.

TxDOT is currently implementing FileNet statewide. FileNet runs on an SQL Server platform, which contains pointers to files that are physically stored on a dedicated server at every business unit where TxDOT has implemented FileNet. Users interact with FileNet through a graphical interface that enables users to navigate through folder structures, with additional functionality such as viewing current file users, assigning file attributes or tags, querying, searching, and file versioning. Libraries represent the structure each business unit chooses to organize documents into document classes, record types, and document types (36, 37). In addition, documents have a pre-defined set of attributes, which could vary by library. There is a library for districts (organized around functional areas), which TxDOT developed using lessons learned from the Houston District's experience with FileNet.

Plans Online is a web-based application that TxDOT uses to manage the storage, archival, and delivery of letting, contract, and final/as-built plans; proposals; project addenda; and bid tabs. TxDOT maintains a permanent archive of as-built plans (in digital format – TxDOT does not

archive the original Mylar plans that divisions provide). In addition, TxDOT maintains a 10-year archive of project letting database records. Plans Online runs on an Alchemy platform that enables users to browse through database contents in a folder hierarchy. The viewer also enables users to run queries by project attributes, document attribute fields, document content, file name, folder attribute fields, and document annotations. To populate these attributes, TxDOT follows a standardized procedure that involves scanning and indexing documents. Currently, TxDOT is evaluating platforms for upgrading Plans Online, including the implementation of a GIS-based interface to facilitate document querying and viewing.

A significant development at TxDOT in recent years to improve spatial and temporal characterization of GIS datasets has been the implementation of GAIP. The GAIP architecture replaces the traditional linear referencing method with another method called “dynamic location” that enables the management of each data element of interest independently through tables that contain both spatial and non-spatial attribute values that characterize each attribute record spatially and temporally. A key element of the GAIP architecture is the TxDOT network ground set, which is composed of a cartographic set of centerlines and roadbeds, which gave origin to the formalization of four GAIP-compliant linear referencing systems: Distance from Origin, Control Section, Reference Marker, and Texas Linear Measurement System.

TxDOT uses GIS technology primarily to support programming, planning, and maintenance activities – although the use of GIS to support design, construction, and operations is growing. There are several GIS-based information systems in production or in development at TxDOT. Some of the relevant systems described in this report include Main Street Texas, Right of Way Map Locator, Survey Primary Control Markers, and the Highway Conditions Reporting System.

Engineering Design Data Management Practices at Other Agencies

Use of document management systems at other state DOTs falls into two categories: document management during the PDP and completed project document archival. Several state DOTs are in the process of, or are considering, linking document management systems to a GIS. Although linking GIS with images and documents is not new, most out-of-the-box GIS applications only provide basic table joining capabilities, making simple “hotlinking” inadequate in an environment where projects may generate thousands of documents. To address this limitation, a number of applications have appeared over the last few years that customize document management systems by including GIS interfaces and query forms that combine data elements from both document management system and GIS environments.

The researchers contacted the following jurisdictions in Texas to develop an understanding of current engineering data management practices and plans around the state: the Cities of Austin, Dallas, Denton, Houston, Richardson, and San Antonio, as well as Bexar and Harris Counties. Interaction with these agencies led to a number of observations, including the following:

- Agencies are beginning to encourage or require the submission of plans in digital format. Typical file submission formats include native CAD file formats and PDF. Internally, the agencies tend to archive digital files in TIF or PDF. Some agencies have developed

standards for symbology and layers, and at least one agency has developed quality control checks via code to ensure features are located on their designated layers.

- The use of EDMS is increasing, with different agencies at different stages in the implementation of those systems. Implementation approaches vary widely, ranging from systems developed internally to COTS software combinations. Integration of GIS into EDMS also varies widely, from no integration to relatively simple interfaces to more sophisticated custom-built interfaces. Issues the various agencies noted in relation to the implementation of EDMS and the integration of GIS technologies into those systems include data quality and completeness, system redesigns and adjustments, acceptance, maintenance costs, implementation strategy, and standardization.

Engineering Design Data Model

The development of the prototype data model followed a number of requirements and guiding principles, including the following:

- **Data integration.** The model included integration points with TxDOT existing systems, such as DCIS, FileNet, and MST. The identification of those integration points was at a high conceptual/logical level because, with the exception of MST, detailed database design documents of other systems were not available to the researchers. Given these limitations, the researchers created “place holders” in the prototype database structure for tables and fields that are related to project data (which are DCIS related) or engineering documents (which are FileNet related). During implementation, it should be possible to replace the “place holders” with pointers to relevant existing systems.
- **Compatibility with existing TxDOT information systems.** The data model developed in this research is compatible with existing TxDOT data architecture requirements.
- **Focus on architecture, not user interfaces.** At TxDOT’s request, the research focused on data modeling and identification of implementation issues, not on GUI development. For data model testing purposes, the researchers developed simple offline (standalone) and online prototype GUIs. The level of functionality of these GUIs, while adequate for assessing the feasibility of the data model and conducting database tests, would probably not reflect the level of functionality expected of a production-level system. Whenever possible, the researchers included data elements in the database design to make sure the database would support appropriate GUI developments.

At the highest level, managing engineering design data involves managing three types of data (Figure 44): data about documents, data about planned or existing features on the ground, and data about projects. The researchers’ approach to developing EDDM was to consider not just the main areas in Figure 44, but also their many-to-many relationships (e.g., a project can have many documents and/or be associated with many features, a document can be associated with many projects and/or features, and a feature can be associated with many documents and/or projects). Figure 45 shows the corresponding high-level logical model.

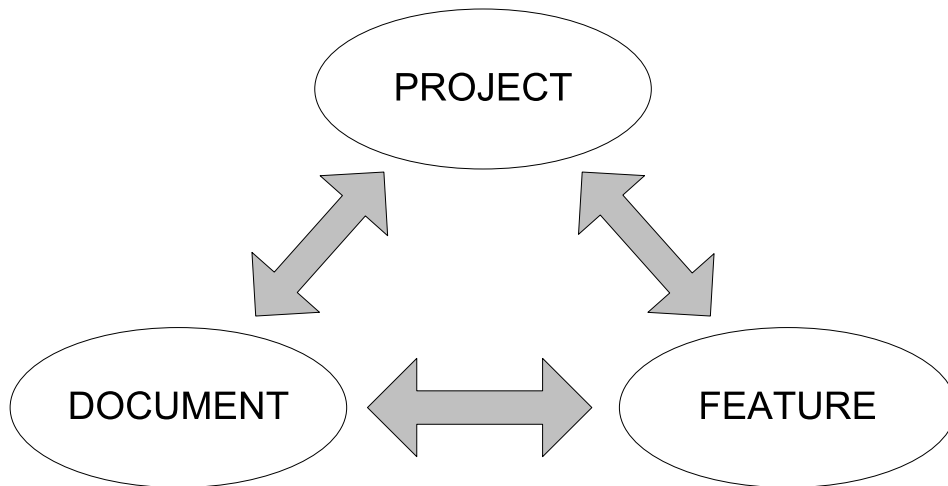


Figure 44. Engineering Design Data Model – Conceptual Design.

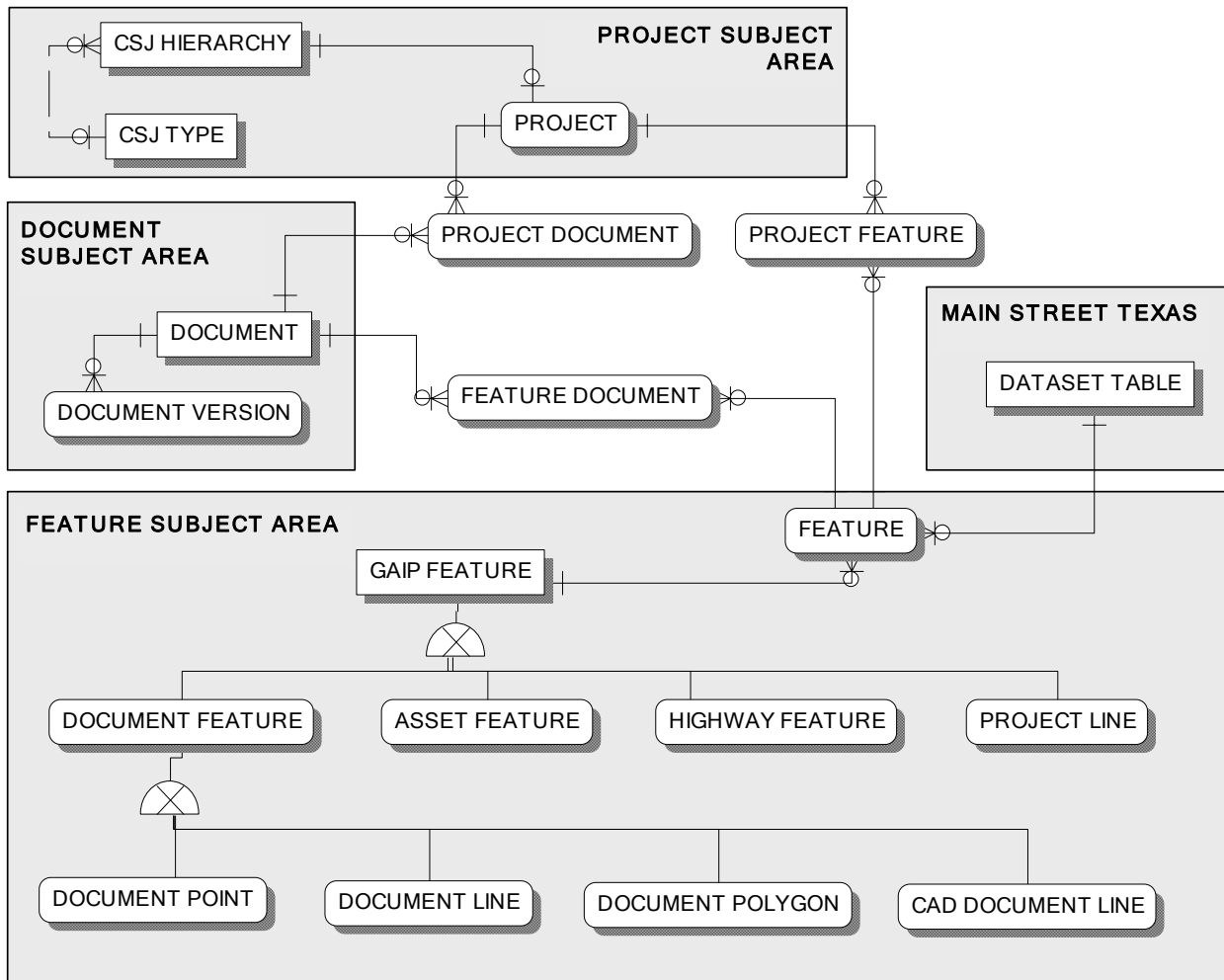


Figure 45. Engineering Design Data Model Overview.

The formal EDDM data model was in ERwin Data Modeler format, which is a standard data modeling tool at TxDOT. For clarity, the model includes three subject areas, one for each core entity in EDDM. The PROJECT Subject Area consists of PROJECT, related lookup tables, and linkages to other entity subject areas (Figure 13, Table 20). PROJECT is a subset of DCIS File 121. To ensure compatibility with DCIS, PROJECT maintains the same structure as DCIS File 121. As a result, PROJECT does not follow TxDOT data architecture standards. Developing a standard-compliant version of PROJECT would have been possible but redundant, as TxDOT has already started the process to develop a standard-compliant version of DCIS.

The DOCUMENT Subject Area consists of DOCUMENT, related lookup tables, and linkages to other subject areas (Figure 14, Table 22). In EDDM, DOCUMENT and several other entities within the DOCUMENT Subject Area are “place holders” for equivalent entities in the FileNet database structure. The researchers did not have access to the FileNet data model, and it was not possible to determine how closely the entities in the DOCUMENT Subject Area match the corresponding entities in FileNet. Therefore, during implementation, it may be necessary to modify some of the entities in this subject area, particularly at the physical level. This limitation is not likely to be critical because, at the logical level, the model in Figure 14 explicitly considers the main data elements necessary to characterize documents and document sets, as well as FileNet document classes, records types, and document types.

The FEATURE Subject Area consists of FEATURE, related lookup tables, and linkages to other subject areas (Figure 16, Table 25). There are two general types of features: GAIP features and non-GAIP features. A GAIP FEATURE is a GAIP-compliant feature. A NON-GAIP FEATURE is a non-GAIP compliant feature. At the lowest level, the primary key for GAIP features and non-GAIP features is a TXDOT UNIQUE ID attribute. TXDOT UNIQUE ID is unique within each feature class, but not necessarily across features classes, i.e., different feature entities could share the same TXDOT UNIQUE ID values. The primary key of the FEATURE entity is composed of TABLE UNIQUE ID (which is a foreign key to DATASET TABLE and provides the feature class name) and TXDOT UNIQUE ID (which is unique within each feature class and defines the feature ID). The combination of TABLE UNIQUE ID and TXDOT UNIQUE ID makes FEATURE a comprehensive index of features in the database, facilitating query transactions that involve other subject areas.

Connecting the PROJECT, DOCUMENT, and FEATURE Subject Areas are the PROJECT DOCUMENT, PROJECT FEATURE, and FEATURE DOCUMENT entities. PROJECT FEATURE identifies features associated with a project. PROJECT DOCUMENT identifies documents associated with a project. FEATURE DOCUMENT identifies features associated with a document.

Prototype Database Implementation

TxDOT provided sample data associated with four highway construction projects: three projects in the San Antonio District and one project in the Odessa District. Of the 8816 documents received, the researchers used 7784 documents (or 88 percent) for the prototype platform. Most of the documents were MicroStation files (2850 or 37 percent) or as-built plans (2392 or 31 percent). Processing the data involved integrating project data in the database; developing a

physical file structure to simulate the FileNet file structure; developing an inventory of PDP document categories and mapping those categories to the FileNet-compatible file structure; integrating feature, spatial, and non-spatial document data in the prototype; and linking project, document, and feature data in the database.

Mapping TxDOT design document categories to the TxDOT FileNet library structure was a major effort. In general, there were four types of matches: direct matches, multiple matches, partial matches, and no matches. The [appendix](#) includes a listing of the corresponding FileNet document types. Direct matches occurred when mapping from TxDOT design document categories to FileNet document types was positive and straightforward. Multiple matches occurred when there were multiple FileNet document types for a single TxDOT design document category. Partial matches occurred when FileNet document types did not exactly fit the definition of TxDOT design document categories, potentially resulting in confusion and/or mapping errors. No matches occurred when it was not possible to match TxDOT design document categories to FileNet document types, in which case the researchers generated additional FileNet document types or renamed/moved document types.

The researchers mapped 7784 files to eight FileNet document classes. This task was challenging because districts used their own project-based folder structures, which do not correspond well with the standard FileNet file structure. Another challenge was that project datasets frequently contained multiple instances of files with the same name in different folders. As a result, the researchers assumed that duplicate files with exact names but different dates were versions of a document. In addition, the researchers were concerned with the possibility of multiple instances of files with the same name in different projects. These situations made it necessary to develop a file logical and physical naming convention, where the file logical name was the same (0030ill.dgn), but the physical names had project and version suffixes to differentiate the various instances of the file (e.g., 0030ill_190_1.dgn, 0030ill_190_2.dgn, and 0030ill_190_3.dgn).

Certain document types had special challenges. For example, in the case of CAD documents, the database included attribute data contained in plans, layouts, elevations, and detailed views, such as sheet number, group sheet number, and sheet index titles. For the prototype database, the researchers extracted these data manually from as-built plans that Plans Online provided. In total, the researchers registered 2394 as-built plans in the database. It may be worth noting that during implementation, extracting the data manually would not be necessary because Plans Online uses OCR software to assist in the process of extracting attribute data from as-built plans.

It is possible to overlay a wide range of documents in a GIS environment. There are two general types of spatial documents: (a) documents that contain all the necessary geo-reference data and (b) documents for which the spatial data component is missing, incomplete, or incorrect, and it becomes necessary to apply a procedure to geo-reference the files. Many spatial documents, e.g., CAD files, are not native GIS applications, and displaying those files in a GIS environment can degrade interface performance quite significantly. Other spatial documents, e.g., large aerial photographs, can also degrade performance because of the time it takes to render the images on the screen. To address these issues, the researchers generated geo-referenced outlines that represent the spatial boundaries of those documents and provided links to access the documents

on an as-needed basis. In general, the procedure to generate the spatial outlines was to geo-reference the documents first and then to extract the corresponding spatial boundaries.

For the prototype database, the researchers geo-referenced 88 CAD documents and produced spatial outlines for each document. These CAD documents either were in State Plane Texas South Central coordinates or had an “unknown” coordinate system. Documents that used State Plane Texas South Central coordinates were in “surface” coordinates. As a result, it was necessary to apply a scale transformation using a combined scale factor to display the CAD files correctly in the GIS. The researchers normalized the scale transformation process by creating a generic world file that applied to individual CAD files. For CAD files with an “unknown” coordinate system, the researchers used an interactive CAD transformation tool that enabled the rotation, scaling, and translation of MicroStation files within the GIS and the corresponding generation of companion world files. To automate the production of CAD document outlines in the GIS, the researchers developed a script in ArcGIS ModelBuilder.

The researchers also geo-referenced 256 raster as-built plan documents and produced spatial outlines for each document. In general, raster documents in the sample dataset did not have a defined coordinate system. To geo-reference these documents, the researchers used the standard geo-referencing tool in the GIS. Geo-referencing involved translating, scaling, rotating, and/or “rubbersheeting” raster documents to their correct location. As in the case of CAD documents, the geo-referencing tool produced world files for geo-referenced raster documents.

Geo-referencing and extracting boundaries of CAD and raster documents had a number of challenges. First, having an accurate reference dataset is critical to ensure acceptable geo-referencing results. Second, CAD files frequently distort segment lengths when it is not critical to show the feature locations to scale, e.g., in the case of barrier layouts or sign locations. In this case, the CAD outline and the “geo-referenced” document would provide a general idea of geographic location, but not accurate coordinates. Third, CAD files frequently show several separate road sections on the same sheet. In this case, the researchers decided to generate multiple document outlines, one for each road segment depicted in the CAD file. Fourth, although the automated scripts to generate boundaries worked reasonably well, there were performance issues while in batch mode or when the CAD file had a large number of details.

Developing a comprehensive inventory of features during the research was not practical. To illustrate the general methodology, the researchers generated records for 15 sample feature classes within the following categories: project lines, document features, asset features, highway features, and geo-political features. Of the 15 feature classes, three classes were highway features or geo-political features the researchers imported from TxDOT-provided datasets.

Prototype Testing

In order to test the EDDM database design, examine potential implementation and integration issues with other systems, and demonstrate the EDDM model to a variety of audiences, the researchers used three different environments: Microsoft Access, ESRI ArcGIS, and Microsoft Internet Explorer. In line with the scope of the research, the testing effort focused on the EDDM

architecture rather than the user interfaces (although, by necessity, the researchers designed and built the testing user interfaces in a way that could support the testing effort efficiently).

Each testing environment fulfilled a role in the testing process. The Access and ArcGIS testing environments focused on basic database design and relationship testing using a variety of “ready-made” tools that expedited the testing process. For portability, the researchers exported the data to an ESRI personal geodatabase (in Access format). This portable configuration enabled the demonstration of EDDM to audiences in situations where online access was not possible.

Access testing involved the development of a number of queries and forms to test items such as database design and compliance with database integrity constraints. This environment enabled the development of queries and forms to retrieve datasets in tabular form such as detailed project data, list of features associated with a project, document and document versions associated with a project, documents and document versions associated with a feature, and features associated with each document version. The testing environment included a hyperlink that enabled opening and viewing documents in their native applications and/or a suitable viewer on local computers.

ArcGIS testing involved the use of “joins” between GIS feature classes and non-spatial tables to retrieve project and document data when querying features using the GIS user interface. The testing environment also included a hyperlink to open and view documents in their native applications and/or a suitable viewer on the client computer. ArcGIS, without the support of extensions or custom code, has limited table-joining capabilities. To bypass this limitation, the researchers linked feature-specific pre-joined tables to feature class tables. While developing a customized application within ArcGIS to support all the necessary queries and forms to extract a wide range of datasets would have been possible, developing those queries and forms in the Access testing environment described above was much faster and easier during the research phase. During implementation, it should be possible to develop a customized application in ArcGIS to support similar querying and reporting capabilities as in the Access environment.

The Internet Explorer testing environment focused on the examination of potential implementation and integration issues with other systems and as a tool to demonstrate how EDDM could potentially function in a web-based environment (which proved useful during discussions with TxDOT officials when issues such as EDDM implementation, portability, and functionality were raised). Testing involved the development of a customized web application that enables the retrieval of project-related documents using tabular and/or map views. To the extent possible, the web application used web forms and source code the researchers had already developed for other TxDOT research projects. In some cases, it was necessary to develop and/or customize forms and functions. However, the level of customization was kept to a minimum.

The researchers met with Odessa District, San Antonio District, and General Services Division officials to gather feedback regarding EDDM, develop additional understanding about engineering documentation management practices and plans at TxDOT, and discuss potential mechanisms for integration of EDDM into existing business processes at TxDOT. Several recommendations from TxDOT officials resulted in changes to the prototype database and user interfaces. In other cases, where changes were not feasible during the research (either because of research scope limitations or because the proposed changes would be more appropriate for an

implementation phase), the researchers compiled the comments into potential implementation recommendations. Discussions during the feedback phase addressed a number of issues, including coordinate systems, FileNet implementation, data access and security, project document access and retrieval, CAD document standards, and compatibility with Plans Online.

RECOMMENDATIONS

This section summarizes recommendations for implementation resulting from the EDDM development and testing phases. The recommendations cover the following areas:

- EDDM implementation,
- project development process,
- CAD documents,
- FileNet implementation, and
- GIS practices.

EDDM Implementation

- **Develop strategy for GIS-based project data management.** District and division feedback indicated that a GIS-based portal for project-based document access and management could help improve or optimize project management processes. Implementation of that portal requires the participation of a wide range of stakeholders at TxDOT. As the research demonstrated, managing project data in a GIS environment involves the integrated management of project data, document data, and feature data, which in terms of system integration, means the development of integration points among systems and programs such as FileNet, DCIS, MST, and Plans Online.
- **Conduct pilot EDDM demonstrations.** The research showed it is possible to integrate project data and documents in a GIS environment. The research phase involved processing thousands of documents from four sample projects. However, because the research did not take place within the context of the typical activities of an active project, it was not possible to test many critical elements that are relevant to the implementation of a GIS-based project data management strategy. Examples include the impact of actual workflows and data flows on the ability of a project manager to use GIS as a project management tool, determination of required levels of GIS data access and technical expertise at the district, system integration issues, coordination with appropriate TxDOT divisions, determination of document types that need to be included in the GIS-based framework, optimization of the EDDM data model, and confirmation of the approaches discussed in the research for the population and maintenance of a GIS-based project linear feature. Examination of these elements is timely, given the current status of the implementation of systems such as FileNet and MST across the state. Pilot EDDM demonstrations would also provide the opportunity to examine issues such as hardware and bandwidth requirements to implement and run EDDM efficiently at the district level. As mentioned previously, the development of the prototype data model followed requirements such as data integration and compatibility with existing TxDOT systems,

with a focus on architecture-related issues, not user interfaces. For a pilot EDDM demonstration, the functional and system requirements would need to be more comprehensive. Table 36 provides a draft list of the corresponding user needs, functional requirements, and system requirements.

Table 36. Draft User Needs and Requirements for EDDM Implementation.

User/Business Needs	Functional Requirements	System Requirements
Document management environment	Upload, manage, display, version, and track PDP documents	Use FileNet functionality and EDTIS standards as a basis
Compatibility with TxDOT business and technology tools	Use software tools that are compatible with TxDOT GIS core architecture	Develop prototype using ESRI and Oracle
	Use TxDOT-specified software for data modeling	Use ERwin for data modeling
	Use existing GIS datasets	Use existing TxDOT GIS datasets as a foundation
Flexibility and scalability	Use a logical model, physical model, and data dictionary compliant with TxDOT standards	Use TxDOT data architecture standards
	Use data models in TxDOT-specified format	Develop Entity-Relationship (ER) Diagram and data dictionary in ERwin
	Support TxDOT GIS data architecture and web portals	Compatible with GAIP and MST
	Support TxDOT project management systems	Compatible with DCIS
	Support TxDOT document management systems	Compatible with FileNet and Plans Online
Data resource optimization	Eliminate duplicate databases	Use relational database architecture and TxDOT-approved system interfaces
	Ensure enterprise-wide data integrity management	Make attribute datatypes and definitions consistent across systems
System access	Provide access to authorized TxDOT users	Use Intranet for TxDOT access
	Provide access to authorized external users	Use Internet for external access
	Optimize access to mainframe data	Develop project data warehouse with read-access to DCIS
	Provide “single-point” login	Create “portal” front end that accesses all systems needed for engineering design data management
	Allow data access based on user privilege	Create a universal ID and password for a “portal” front end to engineering design data systems
Support for various file formats, reference systems, and timestamps	Include geo-referencing fields (route, control section, shape) in database design to associate documents with highway network	Create tables for linear locations and shape files for two-dimensional locations associated with documents
	Support geo-referenced files (e.g., survey control data, geo-referenced CAD files)	Create tables and links that point to geo-referenced documents
	Support non-geo-referenced CAD files	Create tables and links that point to non-geo-referenced documents
	Provide historical data retrieval	Add GAIP-compatible attributes for time stamping documents
GUI interface requirements	Provide a user-friendly mapping tool	Develop user interfaces (e.g., web browser, ArcGIS desktop) using elements that are already familiar to users
	Implement a spatial user interface	Build online and offline GIS-based user interfaces
	Provide query forms and reporting templates that resemble standard TxDOT forms	Build query forms and reporting templates using standard form templates (e.g., DSR, Form 1002)
	Provide ad-hoc query and reporting templates	Develop ad-hoc query and reporting templates based on user needs

Project Development Process

- **Review project development process and update manuals.** The research showed there are several areas where TxDOT could improve or optimize practices that could lead to streamlining project delivery. TxDOT is moving from procedure-based management approaches to results-based management approaches, e.g., with the implementation of the total cost initiative, where districts are becoming responsible for all the cost components of a project. Particularly for engineers and planners with relatively little experience, whose knowledge of the (usually) lengthy process it takes to move a project from inception to construction and operation is scant at best, it is critical to know the PDP well and develop a good understanding of potential strategies to optimize the PDP to address individual project needs. To address these needs, the researchers strongly advise TxDOT to conduct a thorough examination of the PDP and update relevant manuals and supporting documentation (e.g., 10, 11, 12, 13, 14, 92).

This research examined the PDP from the standpoint of the documentation that is associated with typical PDP tasks. It may be worth noting that, through other active research projects, the researchers have been involved in the review of other specific aspects of the PDP. For example, as part of research project 0-5475, the researchers are examining PDP elements that deal with the utility adjustment process. Likewise, through research project 0-5696, the researchers are reviewing spatial data needs related to the long-range transportation planning process, and through research project 0-6065, the researchers are evaluating ways to integrate the utility adjustment process and the environmental process more effectively. However, there is a need for a more holistic view of the entire PDP, one that explicitly considers different types of projects and the necessary integration points with relevant PDP documents and guidelines.

- **Develop tool to extract PDP components and required documentation for specific projects.** Along with the review of the PDP and update of relevant supporting documentation, the researchers strongly recommend that TxDOT develop a tool to assist project managers in identifying and selecting specific PDP components and required documentation for specific projects. For this tool to be useful in practice, it is essential to ensure adequate integration points with *actual* TxDOT systems, documentation, and data, including specific PDP manual tasks (10), the *PS&E Preparation Manual* (12), and standard TxDOT forms (e.g., the TxDOT Design Summary Report [13]). Ideally, a project manager would be able to select PDP tasks from a menu of options (that could include a list of pre-defined tasks based on project type), develop a project timeline, determine input and output documents associated with each task, and assign responsibilities. Developing this tool could be part of the EDDM implementation.
- **Accelerate DCIS modernization.** DCIS runs on an Adabas non-relational database platform. Over the years, TxDOT has developed online and/or batch linkages between DCIS and other TxDOT systems. Typically, batch processes download DCIS data to client computers. However, the current DCIS architecture is quite limiting, and it is urgent for TxDOT to accelerate plans to migrate DCIS to a platform that is more consistent with today's systems, data structures, and communication protocols and that

complies with TxDOT's data architecture. This migration would maximize the usefulness and benefits of the DCIS data, eliminate problems such as delays in data access by end users, and eliminate the need for the continued development of multiple local versions of DCIS components and data – which contribute to data redundancy and data integrity problems.

CAD Documents

- **Update and enforce CAD document standards.** Feedback from districts and review of the sample data indicated there is a need to update TxDOT CAD standards and to improve the enforcement of those standards. District officials highlighted that MicroStation version 8 offers greater flexibility compared to previous versions, but functionality such as unlimited number of levels and levels that use names instead of numbers can result in problems if standards are not strictly enforced. Reasons for poor compliance with standards include lack of awareness by consultants about the standards; poor communications between TxDOT project managers and consultants; inadequate cross references among the various guidelines, manuals, and standards that support the TxDOT PS&E development and submission process (12, 39, 92); and lack of vision to anticipate problems when standards are not enforced.

Enforcement of CAD standards should include the requirement to use an appropriate coordinate system and provide adequate CAD file metadata documentation (e.g., by including the combined surface factor value to use to facilitate CAD data exchange with databases in other platforms, e.g., GIS based).

- **Develop strategy to build GIS-based datasets from CAD documents.** CAD files often contain a wealth of data (e.g., project centerlines, roadbeds, existing and proposed infrastructure) that, properly managed, could be a valuable source to help develop and maintain GIS-based datasets. In most cases, survey procedures back up the positional accuracy of features depicted in CAD files. Frequently, those features also include cells or other similar objects that could have equivalent feature names in a database table, therefore facilitating their extraction and conversion into GIS features. The idea of using CAD files to help populate and maintain GIS databases is not new. This research used the concept extensively, and other similar efforts, including recent efforts at TxDOT, have also demonstrated its potential. However, for the concept to be feasible, a comprehensive strategy is necessary. That strategy would include elements such as consolidating TxDOT's list of survey feature codes and cells to match GIS feature classes, eliminating the use of cells to describe feature variations that in reality feature attributes could manage more effectively, enforcing CAD standards, and archiving as-built CAD files permanently along with the as-built image files that TxDOT currently archives through Plans Online.
- **Develop standards and/or guidelines for CAD document management.** Although there are CAD standards at TxDOT, the standards do not address issues such as management, storage, and archival of CAD documents. TxDOT officials noted that there should be a standard for the management, storage, and archival of CAD documents,

which would include items such as folder and file naming conventions as well as procedures for integrating CAD documents with other datasets. To assist in this process, it would also be advisable to develop scripts to conduct data quality control tests and assign flags to affected folder and/or file records immediately after creating and/or receiving the documents. Implementation of this recommendation would result in better quality control of CAD documents and help to increase their usability and reliability.

FileNet Implementation

- **Optimize FileNet libraries.** Following the EDTIS Project Content Services library standards, FileNet uses document classes, record types, and document types to organize documents in libraries (36). TxDOT is currently implementing FileNet statewide. However, this research identified areas, such as advance project development, project design, right of way, and traffic operations, where the FileNet library structure needs modifications to accommodate document characteristics and data flows during the PDP properly. Other areas may need optimization as well, but were not identified because the sample documents handled during the research phase did not cover those areas.

In response to a research technical memorandum on draft engineering document integration, GSD began developing changes to the FileNet library structure. One important change was the consolidation of the advance project development and project design document classes into one document class. Other changes involved changes in document class names and the expansion of record and document types. At the same time, other TxDOT units, e.g., the Environmental Affairs Division and the Right of Way Division, have made recommendations or are beginning to examine potential changes to the FileNet library structure to address their needs.

Optimizing the FileNet library is urgent considering TxDOT's August 2009 estimated completion date for the FileNet implementation across the state (97). To assist in this process, the researchers strongly recommend that TxDOT use the services of an external team to support GSD and the various TxDOT units where FileNet is being implemented. The role of the team would be to review FileNet document classes, record types, and document types for completeness and accuracy; coordinate with designated points of contact at each unit to make appropriate revisions to the FileNet library; interact with GSD to help TxDOT realize its goal of an integrated document management strategy while, at the same time, supporting individual divisions and districts in developing and maintaining their own FileNet implementations; and provide technical advice to GSD on the robustness of the resulting product.

- **Add spatial data mapping component to FileNet.** The current FileNet implementation at TxDOT does not enable mapping between documents and their corresponding geographic location. However, for an agency such as TxDOT that relies on geographic location for most of its business processes, it is critical to have the ability to map and visualize documents in relation to physical locations on the road network and to derive intelligent information from the documents (not just basic indexing information). It

would therefore be advisable to include a spatial mapping component to the TxDOT FileNet implementation.

GIS Practices

- **Clearly define GAIP features and attributes.** There is inconsistency and lack of clarity in the way TxDOT defines GAIP features and feature attributes. For example, the *TxDOT Graphic Data Standard (49)*, which is the main point of reference for compliance with the GAIP architecture at TxDOT, does not properly identify the role of the TXDOT UNIQUE ID attribute or clarify the primary key for GAIP features. Subsequent interim documents at TxDOT have clarified the role of the unique ID attribute, but there is still confusion in several other areas. For example, according to the data standard document, a change in a GAIP feature would involve “retiring” the existing feature record (essentially by populating the “to date” field) and adding a new record with the new value(s). However, there is no clarity whether the new record needs a new TXDOT UNIQUE ID value (which would have a rippling effect across the enterprise) or under which conditions it might be possible to update an attribute value instead of having to retire the entire record. Likewise, the available documentation is not clear regarding how systems such as MST handle multiple GAIP features, which makes it difficult to understand, among other things, the critical role of MST tables such as DATASET TABLE and DATASET FIELD. To address these issues, the researchers recommend that TxDOT update existing GAIP-related manuals and guidelines and make that documentation available to users on the TxDOT website.
- **Reevaluate the need to append “point,” “line,” or “polygon” to GIS feature names.** The current TxDOT data architecture requires appending the word “point,” “line,” or “polygon” to GIS entity names (43). This practice is inconvenient for several reasons. First, it makes developing formal definitions for GIS features difficult. Following the TxDOT standard, an entity definition is appropriate when the definition describes the person, place, thing, concept, or event that the business must manage, i.e., when the definition works properly at the individual table record level. For example, a proper definition for a Utility Pole feature would be that a utility pole is a support structure for aboveground utility installations, street lighting, and other similar appurtenances. However, providing a similarly effective definition when the name of the feature is Utility Pole Point is challenging. The standard also requires entity attributes to describe one entity characteristic. For the example above, an attribute called Utility Pole Material would enable the proper characterization of the pole material (e.g., wood). However, Utility Pole Point Material would not since “wood” is not a characteristic of a point.

Second, the point, line, or polygon designation is in reality a data type indicator, which the database and GIS environments already manage efficiently through other mechanisms. In some cases, it appears necessary to append the data type indicator to the feature name to differentiate GIS features that describe the same feature at different levels of resolution (e.g., City Point versus City Polygon). However, through properly worded naming conventions, it is usually possible to avoid having to use data type indicators in feature names. For example, in the case of city features, one option would

be to use feature names such as City and City Limit (point and polygon data types, respectively).

- **Disseminate the TxDOT data architecture standard.** With the data architecture standard (43), TxDOT has one of the best tools available for the design and production of robust, scalable, standard-compliant databases. The researchers have had the opportunity to use the TxDOT data architecture standard for a number of research initiatives, and the result, inevitably, has been database designs that are rational and “make sense.” In addition to industry-standard database normalization requirements, the TxDOT data architecture standard offers two significant advantages. First, it provides standardization around the use of a single data modeling environment in order to complete critical tasks (logical model, physical model, and data dictionary), which facilitates data modeling activities, database design documentation, and data exchange. Second, it provides standardization around the use of robust entity, attribute, table, and field naming conventions, which, if used properly, contribute to improve database design quality. Although learning how to use the data architecture standard is not a trivial exercise, there are significant long-term benefits that make the learning process worth the investment. Both internal and external users would benefit from a wider dissemination of the data architecture standard. The researchers recommend that TxDOT publish the standard on its website and develop training materials for internal and external data modelers.
- **Apply the TxDOT data architecture standard to all GIS datasets at TxDOT.** Unfortunately, not all TxDOT-produced GIS databases comply with the TxDOT data architecture standard. Further, there are cases where both standard-compliant and non-standard-compliant versions of the same GIS datasets are in circulation, frequently containing different data. The researchers have experienced this situation while using sample GIS datasets for a number of research initiatives. For example, in one case the researchers received from one TxDOT unit samples of standard-compliant copies of key datasets such as roadway centerline, roadbeds, districts, and counties. Later, for a different research project, the researchers received from a different TxDOT unit non-standard-compliant versions. Unfortunately, table names, field names, and even data types and content were different. For example, in one case the control section table expressed control sections as six-digit numbers (e.g., 035104), the district table included district codes, and the county table included a complete listing of county IDs used by different state agencies in Texas. By comparison, in the other case the control section table expressed control sections differently (e.g., 351-4), the district table included district names but not codes, and the county table included county IDs that did not match any of the IDs included in the older versions the researchers had previously received.

Maintaining multiple, different versions is detrimental and can have serious negative effects in terms of data redundancy and data integrity problems. To address this situation, the researchers strongly recommend that TxDOT adopt a single strategy for the design, population, and maintenance of GIS datasets at the department. The strategy should adopt the TxDOT data architecture standard.

Recommendation Implementation Sequence

Different recommendations have different priority levels, implementation costs, and expected return on investment (ROI) benefits. Table 37 provides a summary of relative priority, investment levels, anticipated ROI, and implementation time frame for each recommendation in the previous section. For convenience, Table 38 also lists all the recommendations, ranked by investment level and anticipated ROI.

Table 37. Research Recommendation Summary.

Recommendation	Priority ¹	Investment ²	Anticipated ROI ³	Time Frame ⁴
EDDM implementation				
Develop strategy for GIS-based project data management	Critical	\$	High	Short term
Conduct pilot EDDM demonstrations	High	\$\$	Very high	Mid-term
Project development process				
Review project development process and update manuals	Medium	\$	Medium	Mid-term
Develop tool to extract PDP components and required documentation for specific projects	Medium	\$\$	High	Mid-term
Accelerate DCIS modernization	Critical	\$\$\$	High	Mid-term
CAD documents				
Update and enforce CAD document standards	Critical	\$	High	Mid-term
Develop strategy to build GIS-based datasets from CAD documents	Medium	\$	Medium	Short term
Develop standards and/or guidelines for CAD document management	Medium	\$	Medium	Mid-term
FileNet implementation				
Optimize FileNet libraries	Critical	\$\$	Very high	Mid-term
Add spatial data mapping component to FileNet	High	\$\$	High	Short term
GIS practices				
Clearly define GAIP features and attributes	High	\$	Medium	Short term
Reevaluate the need to append “point,” “line,” or “polygon” to GIS feature names	High	\$	Medium	Short term
Disseminate the TxDOT data architecture standard	High	\$\$	Medium	Short term
Apply the TxDOT data architecture standard to all GIS datasets at TxDOT	Critical	\$	High	Mid-term

¹ Priority indicates the relative importance of a recommendation.

² Investment indicates the relative amount of resources (time, personnel, money) needed to undertake a recommendation.

³ Anticipated return on investment indicates potential benefits associated with a recommendation relative to the level of investment.

⁴ Time Frame indicates the approximate completion time for a recommendation, where “short term” is 1-2 years, “mid-term” is 3-5 years, and “long term” is 5 years or more.

Table 38. Research Recommendations Ranked by Investment Level and Anticipated ROI.

Recommendation	Priority¹	Investment²	Anticipated ROI³	Time Frame⁴
Develop strategy for GIS-based project data management	Critical	\$	High	Short term
Update and enforce CAD document standards	Critical	\$	High	Mid-term
Apply the TxDOT data architecture standard to all GIS datasets at TxDOT	Critical	\$	High	Mid-term
Clearly define GAIP features and attributes	High	\$	Medium	Short term
Reevaluate the need to append “point,” “line,” or “polygon” to GIS feature names	High	\$	Medium	Short term
Review project development process and update manuals	Medium	\$	Medium	Mid-term
Develop strategy to build GIS-based datasets from CAD documents	Medium	\$	Medium	Short term
Develop standards and/or guidelines for CAD document management	Medium	\$	Medium	Mid-term
Optimize FileNet libraries	Critical	\$\$	Very high	Mid-term
Conduct pilot EDDM demonstrations	High	\$\$	Very high	Mid-term
Add spatial data mapping component to FileNet	High	\$\$	High	Short term
Disseminate the TxDOT data architecture standard	High	\$\$	Medium	Short term
Develop tool to extract PDP components and required documentation for specific projects	Medium	\$\$	High	Mid-term
Accelerate DCIS modernization	Critical	\$\$\$	High	Mid-term

¹ Priority indicates the relative importance of a recommendation.

² Investment indicates the relative amount of resources (time, personnel, money) needed to undertake a recommendation.

³ Anticipated ROI indicates potential benefits associated with a recommendation relative to the level of investment.

⁴ Time Frame indicates the approximate completion time for a recommendation, where “short term” is 1-2 years, “mid-term” is 3-5 years, and “long term” is 5 years or more

REFERENCES

1. Texas Transportation Partnerships ... Connecting You to the World. Texas Transportation Commission, Austin, Texas, August 2001. http://www.dot.state.tx.us/cst/construction_strategies.htm. Accessed August 30, 2007.
2. TxDOT Strategic Plan 2007–2011. Texas Department of Transportation, Austin, Texas, 2007. http://www.dot.state.tx.us/services/government_and_public_affairs/strategic_plan.htm. Accessed August 30, 2007.
3. Transportation Equity Act for the 21st Century. Public Law 105-178, 105th Congress, 1998. <http://www.fhwa.dot.gov/tea21/h2400.htm>. Accessed August 30, 2007.
4. Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users. Public Law 109-59, 109th Congress, 2005. <http://www.fhwa.dot.gov/safetealu/legis.htm>. Accessed August 30, 2007.
5. Summary of Categories. Texas Department of Transportation, Austin, Texas, November 2006. http://www.dot.state.tx.us/publications/transportation_planning.htm. Accessed August 30, 2007.
6. Project Selection Process. Texas Department of Transportation, Austin, Texas, November 2006. http://www.dot.state.tx.us/publications/transportation_planning.htm. Accessed August 30, 2007.
7. *Texas Administrative Code. Title 43, Part 1, Chapter 15, Subchapter J.* [http://info.sos.state.tx.us/pls/pub/readtac\\$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=43&pt=1&ch=15&rl=121](http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=43&pt=1&ch=15&rl=121). Accessed August 28, 2007.
8. Guide to Design Criteria. Texas Department of Transportation, Austin, Texas, September 2002. http://www.dot.state.tx.us/business/manuals_publications.htm. Accessed August 30, 2007.
9. *Roadway Design Manual.* Texas Department of Transportation, Austin, Texas, October 2005.
10. *Project Development Process Manual.* Texas Department of Transportation, Austin, Texas, August 2003.
11. Project Development Process Chart. Texas Department of Transportation, Austin, Texas, April 1999.
12. *PS&E Preparation Manual.* Texas Department of Transportation, Austin, Texas, April 2005.
13. Design Summary Report (DSR). Texas Department of Transportation, Austin, Texas, May 2004. <http://www.dot.state.tx.us/forms/design.htm>. Accessed August 30, 2007.
14. P. S. & E. Submission Data. Form 1002, Texas Department of Transportation, Austin, Texas, December 2004. <http://www.dot.state.tx.us/forms/design.htm>. Accessed August 30, 2007.

15. San Antonio District Standards and Forms. San Antonio District, Texas Department of Transportation, San Antonio, Texas, 2007.
<http://www.dot.state.tx.us/sat/specinfo/index.htm>. Accessed August 30, 2007.
16. San Antonio District PDP Milestones. San Antonio District, Texas Department of Transportation, San Antonio, Texas, October 2007.
<http://www.dot.state.tx.us/sat/specinfo/index.htm>. Accessed August 30, 2007.
17. Committee Charter and Rules Governing Operation, San Antonio District Design Review Team. San Antonio District, Texas Department of Transportation, San Antonio, Texas, October 2004.
18. Committee Charter and Rules Governing Operation, San Antonio District Traffic Safety Review Team. San Antonio District, Texas Department of Transportation, San Antonio, Texas, November 2005.
19. TxDOT – Odessa District Standard Operating Procedure No. TP 07-01. Subject: Project Selection and Development. Odessa District, Texas Department of Transportation, Odessa, Texas, August 2004.
20. TxDOT – Odessa District Standard Operating Procedure No. TP 01-02. Subject: PS&E Development and Review. Odessa District, Texas Department of Transportation, Odessa, Texas, January 2002.
21. Design Conference Form. Texas Odessa District, Department of Transportation, Odessa, Texas, February 2004.
22. *Utility Manual*. Texas Department of Transportation, Austin, Texas, July 2005.
23. *Environmental Manual*. Texas Department of Transportation, Austin, Texas, October 2004.
24. *Texas Administrative Code. Title 13, Part 1, Chapter 6, State Records*.
[http://info.sos.state.tx.us/pls/pub/readtac\\$ext.ViewTAC?tac_view=4&ti=13&pt=1&ch=6](http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=13&pt=1&ch=6). Accessed August 30, 2007.
25. State of Texas Records Retention Schedule for Texas Department of Transportation. Form SLR 105, Texas State Library and Archives Commission, Austin, Texas, July 2005.
26. District Record Copy Responsibility List, TxDOT Records Retention Schedule. Texas State Library and Archives Commission, Austin, Texas, n.d.
27. Plans Online Data Flow. General Services Division, Texas Department of Transportation, Austin, Texas, December 2005.
28. Plans Online. Texas Department of Transportation, Austin, Texas, March 2006.
<http://www.dot.state.tx.us/business/plansonline/plansonline.htm>. Accessed August 30, 2007.
29. *DCIS User Manual*. Texas Department of Transportation, Austin, Texas, June 2006.
30. DCIS Data Dictionary Report. Information Systems Division, Texas Department of Transportation, Austin, Texas, May 11, 2006.

31. *SAT Construction Project Database User Guide*. San Antonio District, Texas Department of Transportation, San Antonio, Texas, 2004.
32. *ROWIS District User Guide*. Texas Department of Transportation, Austin, Texas, May 2006.
33. *Traffic Data and Analysis Manual*. Texas Department of Transportation, Austin, Texas, September 2001.
34. *Texas Reference Marker (TRM) System User's Manual*. Texas Department of Transportation, Austin, Texas, January 2005.
35. FileNet P8 Platform. IBM, 2007. <http://www.filenet.com/index.asp>. Accessed August 30, 2007.
36. Electronic Document Technologies Implementation and Support (EDTIS): Content Services Library Standards, Version 3.4. Information Systems Division, Texas Department of Transportation, Austin, Texas, January 2006.
37. Users Guide for Accessing Austin's District's Electronic Document Management System – TxDocs Online. Information Systems Division, Texas Department of Transportation, Austin, Texas, November 1, 2005.
38. MacMorran, T. 06-2007 Summary of Proposed EDTIS CS Library Standards Revisions. Texas Department of Transportation, Austin, Texas, June 2007.
39. CAD Standards. Texas Department of Transportation, Austin, Texas, 2007. <http://www.dot.state.tx.us/business/standards.htm>. Accessed August 30, 2007.
40. State Highway 130. Lone Star Infrastructure, Pflugerville, Texas, 2007. <http://www.sh130.com/>. Accessed August 30, 2007.
41. Baker, G. ProjectWise and You. Lone Star Infrastructure, February 2005.
42. File Management System (FMS). San Antonio District, Texas Department of Transportation, San Antonio, Texas, March 2006. <http://www.dot.state.tx.us/sat/specinfo/index.htm>. Accessed August 30, 2007.
43. *Data Architecture*. Texas Department of Transportation, Austin, Texas, February 2006.
44. Moore, J. This Year's Models: Business Process. Federal Computer Week, April 19, 2004. <http://www.fcw.com/fcw/articles/2004/0419/feat-bizmodel-04-19-04.asp>. Accessed August 30, 2007.
45. *State of Texas Digital Base Map Plan*. Texas Geographic Information Council, Austin, Texas, November 2004. <http://www.dir.state.tx.us/tgic/pubs/pubs.htm>. Accessed August 30, 2007.
46. *Digital Texas. 2004 Biennial Report on Geographic Information Systems Technology*. Texas Geographic Information Council, Austin, Texas, September 2004. <http://www.dir.state.tx.us/tgic/pubs/pubs.htm>. Accessed August 30, 2007.
47. StratMap. Texas Natural Resource Information System, Texas Water Development Board, Austin, Texas, 2007. <http://www.tnris.state.tx.us/StratMap.aspx>. Accessed August 30, 2007.

48. TxDOT Production GIS Data. Information Systems Division, Texas Department of Transportation, Austin, Texas, March 2006.
49. *TxDOT Graphic Data Standard*. Texas Department of Transportation, Austin, Texas, August 2004.
50. Dynamic Location. Terra Genesis, Chandler, Arizona, 2005.
http://www.terragenesis.com/dynamic_location.html. Accessed August 30, 2007.
51. TxDOT Glossary. Texas Department of Transportation, Austin, Texas, February 2006.
<ftp://ftp.dot.state.tx.us/pub/txdot-info/gsd/manuals/glo.pdf>. Accessed August 30, 2007.
52. *TxDOT Survey Manual*. Texas Department of Transportation, Austin, Texas, February 2006.
53. *Manual of Practice for Land Surveying in the State of Texas*. Texas Society of Professional Surveyors, Austin, Texas, February 2006.
54. GAIP Data Model. Information Systems Division, Texas Department of Transportation, Austin, Texas, March 2006.
55. Wyman, M., and P. Abbott. Main Street Texas: Using Geography to Integrate Data. Terra Genesis, Chandler, Arizona, April 2004.
56. Patterson, J. Geographic Information Systems Architecture and Infrastructure: Doing Business on Main Street. Information Systems Division, Texas Department of Transportation, Austin, Texas, n.d.
57. GENII: Genesis Enterprise Information Integrator. Quick Reference Guide. Terra Genesis, Chandler, Arizona, December 2004.
58. Statewide Right of Way. Texas Department of Transportation, Austin, Texas, 2007.
http://www.dot.state.tx.us/gis/row_state/viewer.htm. Accessed August 30, 2007.
59. Survey Primary Control Markers. Texas Department of Transportation, Austin, Texas, 2007. http://www.dot.state.tx.us/gis/prime_ctrl/viewer.htm. Accessed August 30, 2007.
60. Highway Condition Reporting System. Texas Department of Transportation, Austin, Texas, 2007. http://www.dot.state.tx.us/GIS/HCRS_main/viewer.htm. Accessed August 30, 2007.
61. Texas House Bill 1516, 79th Legislature, Regular Session, 2005.
62. Data Center Services. Department of Information Resources, Austin, Texas, 2007.
<http://www.dir.state.tx.us/datacenter/index.htm>. Accessed August 30, 2007.
63. Texas Data Center Strategy: Status Report on Migration and Consolidation. Department of Information Resources, Austin, Texas, August 2006.
<http://www.dir.state.tx.us/pubs/datacenter/2006status/DataCenterStrategy.pdf>. Accessed August 30, 2007.
64. TREX Transportation Explorer. Georgia Department of Transportation, Atlanta, Georgia, 2007. http://app5-trex-web.dot.state.ga.us/trex_external/viewer.htm. Accessed August 30, 2007.

65. Paving the Way to Enterprise GIS. *ArcNews*, Environmental Systems Research Institute, Redlands, California, Vol. 29, No. 1, Spring 2007, p. 21.
66. 2006 Kentucky Department of Transportation HEEP Report. Highway Engineering Exchange Program, September 2006. <http://www.heepweb.org/ProgramsReports/Reports/HEEPAgencyReports/tabid/96/EntryID/14/Default.aspx>. Accessed August 30, 2007.
67. Project Manager Toolbox. Kentucky Transportation Cabinet, Frankfort, Kentucky, 2007. http://transportation.ky.gov/progmgmt/web_site/pmtoolbox/. Accessed August 30, 2007.
68. Project Plan Locator. RAM Consulting Corporation, Dulles, Virginia, 2003. <http://www.ram-corp.com/projects/Docs/RC-MR-TAB4-111.htm>. Accessed August 30, 2007.
69. Ozbay, K., and N. Noyan. *Evaluation and Development of MIS Interface*. Publication FHWA-NJ-2003-002. New Jersey Department of Transportation, Trenton, New Jersey, February 2003. <http://www.state.nj.us/transportation/refdata/research/reports/FHWA-NJ-2003-002.pdf>. Accessed August 30, 2007.
70. Pacatte, L., B. Hoefer, and R. Harman. More Than an Upgrade: The Austin Water Utility Experience. 2004 ESRI Users Conference, San Diego, California, 2004. <http://gis.esri.com/library/userconf/proc04/docs/pap1975.pdf>. Accessed August 30, 2007.
71. AMANDA Enterprise Software. CSDC Systems, Mississauga, Ontario, Canada, 2007. <http://www.csdcsystems.com/products/amanda.aspx>. Accessed August 30, 2007.
72. POSSE. Case of Study: City of Dallas, Texas. Computronix, Edmonton, Alberta, Canada, 2007. http://www.computronix.com/download/CaseStudy-Dallas_LMS.pdf. Accessed August 30, 2007.
73. Mapping System Flash Demonstration. City of Denton, Texas, 2007. <http://gisweb.cityofdenton.com>. Accessed August 30, 2007.
74. GIS Power Point Presentation. City of Denton, Texas 2007. <http://gisweb.cityofdenton.com>. Accessed August 30, 2007.
75. Denton, TX, Wins National Honors for City-Wide Laserfiche Project. LaserFiche, Long Beach, California, 2006. <http://www.laserfiche.com/newsroom/04-04-22denton.html>. Accessed August 30, 2007.
76. Electronic Project Files Users Guide: Capital Improvement Project Management System. Public Works & Engineering, City of Houston, Texas, 2006.
77. Geographic Information and Management System. Public Works & Engineering, City of Houston, Texas, 2007. <http://www.gims.houstontx.gov/>. Accessed August 30, 2007.
78. Kendra, S. Integrating Document Management with GIS. 2002 Annual Conference, Geospatial Information and Technology Association, Tampa, Florida, March 17–20, 2002. <http://www.gisdevelopment.net/proceedings/gita/2002/municipal/gita2002043pf.htm>. Accessed August 30, 2007.

79. Public Works Department – Capital Programs Division. City of San Antonio, Texas, 2007. <http://www.sanantonio.gov/capprog>. Accessed August 20, 2007.
80. Bexar County – Welcome to the Infrastructure Services Department. San Antonio, Texas, 2007. <http://www.bexar.org/bcinf>. Accessed August 20, 2007.
81. Bally, A. Harris County’s Development of an Enterprise Wide Asset Management System. 2007 ESRI Users Conference, San Diego, California, 2007. http://gis.esri.com/library/userconf/proc07/papers/papers/pap_1080.pdf. Accessed August 30, 2007.
82. Statement No. 34. Basic Financial Statements – and Management’s Discussion and Analysis – for State and Local Governments. Governmental Accounting Standards Board, Norwalk, Connecticut, June 1999.
83. Zipf, P. Technology-Enhanced Project Management. *Journal of Management in Engineering*, Vol. 16, No.1, 2000, pp. 34–39.
84. Back, W., and L. Bell. Quantifying Process Benefits of Electronic Data Management Technologies. *Journal of Construction Engineering and Management*, Vol. 121, No. 4, 1995, pp. 415–421.
85. Rojas, E., and A. Songer. Web-Centric Systems: A New Paradigm for Collaborative Engineering. *Journal of Management in Engineering*, Vol. 15, No. 1, 1999, pp. 39–45.
86. Rezgui, Y., and P. Debras. An Integrated Approach for a Model Based Document Production and Management. *ITcon*, Vol. 1, 1996, pp. 1–24.
87. Caldas, C., L. Soibelman, and J. Han. Automated Classification of Construction Project Documents. *Journal of Computing in Civil Engineering*, Vol. 16, No. 4, October 2002, pp. 234–243.
88. Hajjar, D., and S. AbouRizk. Integrating Document Management with Project and Company Data. *Journal of Computing in Civil Engineering*, Vol. 14, No. 1, January 2000, pp. 70–77.
89. Statewide TxDOT CAD Standard Plan Files. Texas Department of Transportation, Austin, Texas, 2007. <http://www.dot.state.tx.us/business/standardplanfiles.htm>. Accessed August 30, 2007.
90. TxDOT MST Entity Descriptions. Information Systems Division, Texas Department of Transportation, Austin, Texas, September 2006.
91. Adams, T., N. Koncz, and A. Vonderohe. *Guidelines for the Implementation of Multimodal Transportation Location Referencing Systems*. Report 460. National Cooperative Highway Research Program, Washington, D.C., 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_460.pdf. Accessed August 30, 2007.
92. *Project Delivery and Project Management for TxDOT Projects*. Consulting Engineers Council of Texas, Texas Department of Transportation, Austin, Texas, n.d. <http://www.dot.state.tx.us/business/consultantservices.htm>. Accessed August 30, 2007.

93. Quiroga, C., E. Kraus, R. Pina, K. Hamad, and E. Park. *Incident Characteristics and Impact on Freeway Traffic*. Publication FHWA/TX-05/0-4745-1, Texas Department of Transportation, Austin, Texas, October 2004.
94. *CAD Transformation Toolbar*. Environmental Systems Research Institute, July 2001. <http://arcobjectsonline.esri.com/ArcObjectsOnline/default.asp?URL=/arcobjectsonline/samples/arcmap/cad/transformbar/transcadbarprj.htm>. Accessed August 30, 2007.
95. Texas Natural Resources Information System. Texas Water Development Board, Austin, Texas, 2007. <http://www.tnris.state.tx.us/default.aspx>. Accessed August 30, 2007.
96. Quiroga, C., K. Hamad, and E. Kraus. *Inventory of Utilities – Summary Report*. Publication FHWA/TX-07/5-2110-01-4. Texas Department of Transportation, Austin, Texas, January 2008.
97. 2007 Texas Department of Transportation (TxDOT) HEEP Report. Highway Engineering Exchange Program, 2007. <http://www.heepweb.org/ProgramsReports/Reports/HEEPAgencyReports/tabid/96/EntryID/27/Default.aspx>. Accessed August 30, 2007.

APPENDIX. MAPPING PDP DOCUMENT CATEGORIES TO THE FILENET FILE STRUCTURE

GENERAL METHODOLOGY AND RESULTS

Chapter 5 described the process to map PDP document categories to the FileNet file structure. This appendix summarizes the results of the analysis. Table 39 lists FileNet document types associated with four types of matches between PDP document types and FileNet document types:

- **Direct matches (yellow shading in Table 39).** Direct matches occurred when mapping from TxDOT design document categories to FileNet document types was positive and straightforward.
- **Multiple matches (clear shading in Table 39).** Multiple matches occurred when a single TxDOT design document category could potentially map to multiple FileNet document types. Whenever possible, the researchers selected one of the existing FileNet document types and highlighted the corresponding record in Table 39 in yellow.
- **Partial matches (blue shading in Table 39).** Partial matches occurred when the correspondence between TxDOT design document category and FileNet document type was not necessarily straightforward or intuitively clear. Whenever possible, the researchers selected the closest FileNet document type and marked the corresponding record in Table 39 in blue.
- **No matches (green shading in Table 39).** No matches occurred when it was not possible to match TxDOT design document categories to FileNet document types. In many cases, the researchers generated additional FileNet document types. In other cases, it was necessary to rename or move document types.

Table 39 includes 343 different FileNet document types used for the population of the prototype database (including 72 new document types as well as 43 document types the researchers renamed or moved). This sample represents a relatively small portion of the TxDOT FileNet library (which includes 1280 document types). However, readers should note that the focus of the research, and therefore the document and data gathering process, was design documents and associated data. As mentioned previously, the researchers used 7784 documents for the prototype platform. Most of the documents used were MicroStation files or as-built plans.

Table 39. FileNet File Structure Analysis Results.

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
Design Conference Forms			
ODA	Design Conference Form	Design Conference	2.8.2
PDP	Design Summary Report (DSR)	Design Conference	2.8.2
PDP	Preliminary Design Summary Report (DSR)	Design Conference	2.8.2
ODA	Preliminary Estimate Worksheet	Cost Estimate	2.2.1
Cost Estimate Forms and Documents			
PDP	Cost Estimate	Estimate and Quantities	12.8.6
PDP	DCIS Seal, Date, and Release Estimate	Estimate and Quantities	12.8.6
PDP	DCIS/Estimator Cost Estimate	Estimate and Quantities	12.8.6
ODA	Preliminary Cost Estimate	Cost Estimate	2.2.1
Cost Estimate Forms and Documents			
PDP	Program Overrun Memorandums	Letting	12.10.14
PDP	Project Final Cost Estimate	Estimate and Quantities	12.8.6
PDP	Project Programmed Cost Estimate	Cost Estimate	2.2.1
General Notes			
PS&E	Basis of Estimate	Estimate and Quantities	12.8.6
PS&E	General Design Notes	General Notes	12.8.9
PS&E	General Notes	General Notes	12.8.9
PS&E	Specification Supplemental Data	Specification	12.8.14
General Plans Estimate			
PS&E	Average Low Bid Unit Prices Web Pages	Estimate and Quantities	12.8.6
PS&E	Data on Terminal Spool (DOTS) Bids Tabulation File	Estimate and Quantities	12.8.6
PS&E	Minute Order Number 108851 (Proposal Guaranty Amount)	Minute Order	16.15.4
		Minute Order	14.13.3
		Minute Order	1.6.6
PS&E	Plans Estimate	Estimate and Quantities	12.8.6
PS&E	Public Interest Justification Statement	Supporting Documentation	1.22.7
Bidding Proposal			
PS&E	Forms	Child Support Form	12.10.8
		HUB Form	12.10.12
PS&E	General Notes	General Notes	12.8.9
PS&E	Proposal	Letting	12.10.14
PS&E	Special Provisions	Special Provision	12.8.12
PS&E	Special Specifications	Special Specification	12.8.13
Proposal Sheets			
PS&E	Supplemental Proposal Sheets	General Plan	12.8.17
PS&E	Supplemental Sheets Signed, Sealed, and Dated by Engineer	General Plan	12.8.17
Specifications			
PS&E	Form 1814 New Provisions/Special Specifications	Form 1814 Proposed Special Provision or Special Specification	12.8.8
PS&E	List of Governing Specifications and Special Provisions	Specification	12.8.14
PS&E	Special Provisions	Special Provision	12.8.12
PS&E	Special Specifications	Special Specification	12.8.13
PS&E	Triple Zero Special Provisions	Special Provision	12.8.12
Miscellaneous Forms and Documents			
PS&E	Americans with Disabilities Act (ADA) / Texas Accessibility Standard (TAS) Design Variances	Design Variance	12.5.2
PDP	As-Built Construction Plans	Final As-Built Plan	3.1.1
PDP	Contract Time Determination Schedule	Contract	1.28.5
PDP	Construction Time Determination Schedule	Construction	1.28.4
SAT	Critical Path Method (CPM) Review for Contract Time Determination	Evaluation and Monitoring	4.7.5
SAT	Design Contract Schedule	Contract	1.28.5
PS&E	Design Waiver Document	Design Waiver	12.5.3
ODA	Estimate of Project Work Effort for Work Order	Estimate	4.7.4
PS&E	Project Development Schedule	Project	1.28.6
PS&E	Proposed Workplan	Working Paper	12.13.1
PDP	Public Hearing Certification	Certification	1.22.5
PDP	Public Hearing Summary	Summary	1.22.6
		Meeting Minutes and Notes	2.10.3

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
DSR	Public Involvement Plan	Supporting Documentation	1.22.7
PS&E	Request for Design Exception	Design Exception	12.5.1
PS&E	Request for Non-Use of Accelerated Construction Procedures	Form 1002 PS&E Submission Data Sheet	12.8.7
SAT	Review Letters	Review	12.8.19
SAT	Road Closure Contact List	Contact	1.11.3
PS&E	Submission Schedule	Submission	1.28.7
SAT	Submittal Letters	Submittal	12.8.18
PS&E	Value Engineering Study	Design Study	12.8.5
PS&E	Warranties/Guarantees (Comply with 23 CFR 635.413)	Working Paper	12.13.1
PDP	Work Order for Additional Data/Work	Work Authorization	4.7.13
Surveying and Photography			
PDP	Aerial Photography	Aerial Photography	2.13.2
CEC	Baseline Horizontal/Vertical Alignment Coordinates	Staking and Alignment Coordinates	12.3.9
CEC	Baseline Ties to ROW Monuments	Survey Control	2.13.5
CEC	Contour Maps	Elevation Points and Models	2.13.4
CEC	Cross Sections of Drainage Channels	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Digital Terrain Models (DTM)	Elevation Points and Models	2.13.4
CEC	Field Surveying	Field Surveying	2.13.6
PDP	Other Surveys	Field Surveying	2.13.6
CEC	Photogrammetry	Aerial Photography	2.13.2
DSR	Planimetric Maps	Planimetrics	2.13.3
CEC	Planimetrics (Digital Format)	Planimetrics	2.13.3
CEC	Planimetrics (Hardcopy)	Planimetrics	2.13.3
CEC	Poles, Manholes, Valves, Storm, and Sanitary Sewer Flowlines	Field Surveying	2.13.6
CEC	Primary Project Horizontal and Vertical Surveying Control	Survey Control	2.13.5
CEC	Profiles of Drainage Facilities	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Profiles/Cross Sections of Intersecting Streets	Cross Section	12.3.1
ODA	Request for Aerial Photography	Aerial Photography	2.13.2
CEC	ROW Staking	Staking and Alignment Coordinates	12.3.9
PDP	Site Photographs or Video	Site Photographs or Video	2.13.1
		Form 1135, Photographs	14.9.5
		Bridge Inspection Photo	12.2.2
		Scour Reports and Photos	12.2.14
CEC	Soil Core Hole Staking	Staking and Alignment Coordinates	12.3.9
SAT	Subsurface Utility Engineering (SUE) Plans	SUE Deliverable	14.19.2
CEC	SUE Report	SUE Deliverable	14.19.2
CEC	Uncontrolled Aerial Photography (Contact Prints)	Aerial Photography	2.13.2
Agreements and Permits			
PS&E	Advance Funding Agreements	Advance Funding Agreement (AFA)	4.1.1
		Advance Funding Agreement Utility	4.1.2
PS&E	Agreements	Agreement	4.1.3
		Agreement Letter	4.1.6
PS&E	Airway-Highway Clearance Permit	Environmental Permit	5.5.5
PS&E	Environmental Permits	Environmental Clearance or Permit	12.8.4
		Environmental Permit	5.5.5
		Environmental Permit	2.1.4
PS&E	Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) General Environmental Permit	Environmental Permit	5.5.5
PS&E	Escrow Agreements	Escrow Agreement	4.1.14
PS&E	Federal Aviation Administration (FAA) Construction Height Environmental Permit	Environmental Permit	5.5.5
PS&E	FAA Project Planning Near an Airport Environmental Permit	Environmental Permit	5.5.5
PS&E	Federal Emergency Management Agency (FEMA) Conditional Letter of Map Revision (CLOMR) Floodplain Environmental Permit	Environmental Permit	5.5.5
PS&E	FEMA Letter of Map Revision (LOMR) Floodplain Environmental Permit	Environmental Permit	5.5.5
PS&E	FHWA/Department of Defense (DOD) Interstate Vertical Clearance Environmental Permit	Environmental Permit	5.5.5
PS&E	Governmental Agreement	Federal Project Authorization and Agreement	4.1.15
PDP	Joint-Use ROW Agreements	Joint Use Agreement	14.20.11

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	Local Agency Agreement	Agreement City	4.1.4
		Agreement County	4.1.5
		Agreement Local Government	4.1.8
		Agreement MPO	4.1.9
		Supplemental Contractual Agreement City	4.1.30
		Supplemental Contractual Agreement County	4.1.31
PS&E	Memo of Agreement	Memorandum of Agreement (MOA)	4.1.20
		Tentative Memorandum of Agreement	4.1.33
PS&E	Memo of Understanding	Memorandum of Understanding	4.1.21
PDP	Multiple-Use ROW Agreements	Multiple Use Agreement (MUA)	4.1.22
PDP	Municipal Construction Agreement	Agreement Local Government	4.1.8
PDP	Municipal Maintenance Agreement (MMA)	Municipal Maintenance Agreement	4.1.23
PS&E	Other Agreements	Agreement LPA Acquisition	4.1.7
		Custodial Agreement	4.1.12
		Environmental Agreement	5.5.1
		Grant Agreement	4.1.17
		Occupancy Agreement	4.1.24
		Petroleum Substance Agreement (PSA)	4.1.25
		Service Agreement	4.1.28
		Sign Agreement	4.1.29
		Utility Pole Agreement	4.1.35
		PS&E	Other Permits	City Review	10.10.1
Driveway Permit	10.10.2		
Landscape Permit	10.10.3		
Permit Plan Set	10.10.4		
Sign Permit Registration	14.16.8		
Use of ROW Permit	10.10.5		
Utility Permit	10.10.6		
PS&E	Permits	Permit	2.5.2
PS&E	Railroad Agreement	Master Railroad Agreement	4.1.19
		Railroad Agreement	4.1.26
PDP	Safety Lighting Agreements	Safety Lighting Agreement	4.1.27
PS&E	Texas Commission on Environmental Quality (TCEQ) Well Plugging/Capping Environmental Permit	Environmental Permit	5.5.5
PDP	Traffic Signal and Illumination Executed Agreement	Traffic Signal Agreement	4.1.34
PS&E	U.S. Corps of Engineers Section 10 Environmental Permit	Environmental Permit	5.5.5
PS&E	U.S. Corps of Engineers Section 404 Wetlands/Environmental Permit	Environmental Permit	5.5.5
PS&E	U.S. Corps of Engineers U.S. Coast Guard Environmental Permit	Environmental Permit	5.5.5
PS&E	United States Geological Survey (USGS) Changing Gauging Stations Environmental Permit	Environmental Permit	5.5.5
Environmental Forms and Documents			
PDP	Environmental Affairs Remediation Plan Approval	Mitigation Plan	5.5.6
SAT	Environmental Questionnaire	Environmental Documentation	5.5.4
PDP	Environmental Re-Evaluation Letter/Document	Environmental Documentation	5.5.4
PDP	Environmental Site Assessment (ESA) Phase I	Site Assessment	5.5.9
PDP	Environmental Site Assessment Phase II	Site Assessment	5.5.9
		Site Assessment	2.1.8
PDP	Environmental Site Investigation	Site Assessment	5.5.9
PDP	Hazardous Materials Remediation Cost Estimates	Mitigation Cost	16.2.4
PDP	Initial Hazardous Materials Site Assessment	Report	6.8.5
PDP	Natural Resource Agency Commitments	Commitments and Resources	5.5.12
PDP	Potential Design Modifications and Mitigation Alternatives to Reduce Impacts	Mitigation Plan	5.5.6
		Mitigation Plan	2.1.5
Environmental Clearance and Study			
PDP	Air Quality Analysis	Congestion Mitigation and Air Quality (CMAQ)	16.2.2
PDP	Approved Finding of No Significant Impact (FONSI)	Finding of No Significant Impact	5.2.5
PDP	Approved Record of Decision (ROD)	Record of Decision	5.2.6
PS&E	Categorical Exclusion	Categorical Exclusion	5.2.1
PDP	Cultural Resource Study	Commitments and Resources	5.5.12

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	Environmental Assessment	Environmental Assessment	5.2.2
PS&E	Environmental Clearance Document	Environmental Clearance or Permit	12.8.4
		Environmental Clearance	2.1.2
		Environmental Clearance	5.2.3
		Environmental Clearance	5.5.3
		Environmental Clearance	16.8.1
		Environmental Clearance	16.9.1
DSR	Environmental Commitments	Commitments and Resources	5.5.12
PS&E	Environmental Impact Statement	Environmental Impact Statement	5.2.4
PDP	Environmental Mitigation Cost Estimate	Mitigation Plan	2.1.5
PDP	Landscape Recommendations	Landscaping and Irrigation	12.8.15
PDP	Natural Resources Study	Commitments and Resources	5.5.12
PDP	Noise Analysis	Noise Analysis	5.5.13
PDP	Project Alternatives Description	Alternatives Studies	5.5.15
PDP	Project Environmental Document Exhibits	Environmental Documentation	5.5.4
PDP	Public Hearing Certification on Environmental Impacts	Certification	1.22.5
PDP	Public Hearing Summary on Environmental Impacts	Summary	1.22.6
DSR	Purpose and Need Statement	Alternatives Studies	5.5.15
PDP	Section 4(F) Evaluation	Alternatives Studies	5.5.15
PDP	Section 6(F) Evaluation	Alternatives Studies	5.5.15
PDP	Socioeconomic/Environmental Justice Analysis	Alternatives Studies	5.5.15
PDP	Water Quality	Water Quality	5.5.14
Hydraulic Forms and Documents			
PDP	Additional Survey Data for Outfall Design	Field Surveying	2.13.6
PDP	Bridge Classification Structure Requirements	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Control House Design	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Corps of Engineers Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Cross Drainage Facility Design	Culvert Notes, Calculations, and Plans	12.1.13
PDP	Culvert Hydrology Design	Culvert Notes, Calculations, and Plans	12.1.13
PDP	Cumulative Conveyance Curve	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Discharge Hydrographs	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Elevation Vs Discharge Curve	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Existing/Proposed Major Outfall Storm Drains and Detention Ponding	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	FEMA Hydraulic Computer Model	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	FEMA Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	FEMA NFI Program Participants	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Floodplain Cross Section	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Floodplain Encroachments	Floodplain Encroachment	5.5.18
PDP	Hydraulic Calculation Computer Runs	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Hydraulic Calculation Sheet	Hydrology Notes, Calculations, and Plans	12.12.1
CEC	Hydraulic Drainage Study	Hydrology Notes, Calculations, and Plans	12.12.1
PS&E	Hydraulic Report	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Hydrologic Study	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Inflow/Outflow Locations for Drainage Areas	Hydrology Notes, Calculations, and Plans	12.12.1
CEC	Notice of Intent (NOI) for SW3P Activities	SW3P Plan	5.5.8
PDP	Other Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Outfall Design	Culvert Notes, Calculations, and Plans	12.1.13
PDP	Outside Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Parallel Ditch and Culvert Facility Design	Culvert Notes, Calculations, and Plans	12.1.13
PDP	Permanent and Temporary Erosion Control Design	Erosion Control	5.5.11
PDP	Potential Outfall and Stream Crossing Locations	Hydrology Notes, Calculations, and Plans	12.12.1
ODA	Preliminary Hydraulic Report	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Pump Type and Size Selection	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Runoff Calculations	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Runoff Computations	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Runoff Estimate From Watershed	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Site Drainage History	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Standard Calculation Tables	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Storm Drain Hydrology Design	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Stream Crossing Hydraulic Analysis (Existing)	Stream Hydrology Notes, Calculations, and Plans	12.1.14
PDP	Stream Crossing Hydraulic Analysis (Proposed)	Stream Hydrology Notes, Calculations, and Plans	12.1.14

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PDP	Stream Gage Data	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Stream Water Surface Elevation Analysis	Stream Hydrology Notes, Calculations, and Plans	12.1.14
PDP	U.S. Natural Resources Conservation Service (NRCS) Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	U.S. NRCS Reports	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	USGS Hydraulic Studies	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	USGS/FEMA Maps	Map, Diagram or Sketch	5.5.19
PDP	Water Crossing Scour Evaluation	Stream Hydrology Notes, Calculations, and Plans	12.1.14
PDP	Wetland Reports	Wetlands Report	5.5.17
Traffic Item Forms and Documents			
PDP	Accident Data	Accident	16.13.1
PDP	Annual Automatic Traffic Recorder (ATR) Report	Traffic Data	16.12.4
PDP	Annual District Traffic Maps	Traffic Data	16.12.4
PDP	Annual Vehicle Classification Report	Traffic Data	16.12.4
PDP	County Road/Urban Saturation Count Maps	Traffic Data	16.12.4
DSR	Crash Analysis	Crash Data	15.9.10
PS&E	FAA Form 7460-1	Environmental Permit	5.5.5
PDP	Individual Traffic Forecasts and Existing Counts	Local Traffic Forecasts and Existing Counts	15.9.1
PDP	Lighting Justification Report	Electrical and Lighting Design and Plans	15.11.10
PDP	Lighting Warrant and Condition Analysis	Electrical and Lighting Design and Plans	15.11.10
PDP	Luminary Survey and Assessment	Electrical and Lighting Design and Plans	15.11.10
PDP	Roadway Information System Data	Roadway Information File	16.13.5
PDP	Traffic Data	Traffic Data	15.9
		Traffic Data	2.1.9
		Traffic Data	16.10.8
ODA	Traffic Data Request	Traffic Data	15.9
CEC	Traffic Evaluations and Projections	Design Study	12.8.5
PDP	Traffic Level of Service Analyses	Design Study	12.8.5
PS&E	Traffic Signal Executed Authorization Form	Authorization	1.25.1
PS&E	Traffic Signal Warrant Analysis	Design Study	12.8.5
Traffic Control Forms and Documents			
PDP	Construction Access Description	Sequence of Construction	15.11.6
PDP	Construction Sequence Description	Sequence of Construction	15.11.6
PS&E	Construction Speed Zone Request	Agreement Local Government	4.1.8
PS&E	Form 1201-1	Agreement Local Government	4.1.8
PDP	Road Closure Approval	Temporary Closure Agreement	4.1.32
PDP	Road Closure Executed Agreement	Temporary Closure Agreement	4.1.32
PS&E	Road Closure Letters of Concurrence	Temporary Closure Agreement	4.1.32
PDP	Road Closure Memorandum	Temporary Closure Agreement	4.1.32
PDP	Road Closure Request	Temporary Closure Agreement	4.1.32
CEC	Special Provision of Traffic Handling (Narrative)	Sequence of Construction	15.11.6
PDP	Traffic Control Contract Requirements	Contract Provision	15.11.1
Bridge Forms and Documents			
PDP	Bridge Design Exceptions	Design Exception	12.5.1
PDP	Bridge Inspection Reports	Bridge Inspection Follow-Up Action Worksheet	12.2.1
		Form 1085 Bridge Inspection Record	12.2.8
PDP	Bridge Load Rating and Condition Survey	Load Rating	12.2.10
		Structural Condition History Off System	12.2.18
		Structural Condition History On System	12.2.19
SAT	Drill Shaft Data	Foundation Drilled Shaft or Pile	12.1.3
PDP	Existing Structure and Channel Surveys	Field Surveying	2.13.6
		Bridge Inventory Record	12.2.3
		Form 1387 Bridge Appraisal Worksheet	12.2.9
		NBI Printout	12.2.12
PDP	Public Hearing Certification on Bridge Type Restrictions	Certification	1.22.5
PDP	Public Hearing Certification on Wall Types, Heights, Locations, or Aesthetic Treatments	Certification	1.22.5
PDP	Public Hearing Summary on Bridge Type Restrictions	Summary	1.22.6
PDP	Public Hearing Summary on Wall Types, Heights, Locations, or Aesthetic Treatments	Summary	1.22.6
Geotechnical Forms and Documents			
PDP	Bridge Deck/Foundation Geotechnical Survey/Coring	Foundation Drilled Shaft or Pile	12.1.3

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
CEC	Bridge Foundation Study	Foundation Drilled Shaft or Pile	12.1.3
PDP	Embankment and Cut Slopes Geotechnical Survey	Earthwork	12.3.10
CEC	Foundation Reports	Foundation Drilled Shaft or Pile	12.1.3
PDP	Geotechnical Lab/Field Investigations	Geotechnical Notes and Calculations	12.1.4
PDP	Geotechnical Foundation Design Details	Foundation Drilled Shaft or Pile	12.1.3
PDP	Geotechnical Surveys	Geotechnical Notes and Calculations	12.1.4
PDP	High Mast Illumination Foundation Geotechnical Survey	Electrical and Lighting Design and Plans	15.11.10
PDP	Overhead Sign Bridge Foundation Geotechnical Survey	Signs	15.11.7
ODA	Pavement Deflection Testing	Non-Destructive Testing (NDT)	12.11.6
PDP	Pavement Structure Geotechnical Survey/Coring	Test Data	12.11.9
PDP	Preliminary Geotechnical Surveys	Geotechnical Notes and Calculations	12.1.4
PDP	Retaining and Noise Wall Foundation Geotechnical Survey	Retaining Wall Notes, Calculations, and Plans	12.1.12
CEC	Retaining Wall Foundation Study	Retaining Wall Notes, Calculations, and Plans	12.1.12
PDP	Signal Mast Arm Foundation Geotechnical Survey	Signal Design and Plans	15.11.11
PDP	Soil Reports	Geotechnical Notes and Calculations	12.1.4
SAT	Surface Aggregate Selection Form	Materials	12.3.5
PDP	Trench Excavation Protection Geotechnical Survey	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Work Order for Additional Geotechnical Data	Work Authorization	4.7.13
Pavement Forms and Documents			
PDP	Detour Pavement Analysis	Analysis	12.11.1
PS&E	Pavement Design Report	Report	12.11.8
SAT	Pavement Foundation/Design Approval Memo	Approval	12.11.2
PDP	Preliminary Pavement Design Report	Report	12.11.8
PDP	Temporary Pavement Design	Report	12.11.8
Roadway Forms and Documents			
PDP	Assessment of Landscape and Aesthetic Issues	Landscaping and Irrigation	12.8.15
PDP	Bicycle/Pedestrian Accommodation Concept	Bicycle	16.14.2
PDP	Bicycle/Pedestrian Accommodation Concept	Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Design Criteria	Bicycle	16.14.2
PDP	Bicycle/Pedestrian Design Criteria	Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Final Cost Estimates	Bicycle	16.14.2
PDP	Bicycle/Pedestrian Final Cost Estimates	Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Preliminary Cost Estimates	Bicycle	16.14.2
PDP	Bicycle/Pedestrian Preliminary Cost Estimates	Pedestrian	16.14.6
SAT	Driveway Notice and Access Forms	Requests, Notices, and Access Permissions	14.12.10
PDP	Driveway Tie-in Permission Requests	Requests, Notices, and Access Permissions	14.12.10
PDP	Earthwork Volumes (Cut and Fill Quantities)	Earthwork	12.3.10
PDP	Public Hearing Certification on Bicyclist/Pedestrian Accommodation	Certification	1.22.5
PDP	Public Hearing Summary on Bicyclist/Pedestrian Accommodation	Summary	1.22.6
PDP	Railroad Exhibit A	Exhibit A Plan Layout	15.3.5
PDP	Railroad General Notes	Exhibit B Approved PS&E	15.3.6
PDP	Survey Data for Bicycle/Pedestrian Facility Designs	Field Surveying	2.13.6
PDP	Survey Data for Final Design Alignments	Staking and Alignment Coordinates	12.3.9
Right of Way Status			
PS&E	Certification for Clear ROW (Acquisition Complete – Federal Project) Form	Right of Way	14.1.3
PS&E	Certification for Clear ROW (Acquisition Complete – State Project) Form	Right of Way	14.1.3
PS&E	Certification for Clear ROW (Acquisition not Necessary) Form	Right of Way	14.1.3
PS&E	Certification for ROW Encroachments (None or Clear) Form	Encroachment	14.1.1
PS&E	Certification for ROW Encroachments (Not Clear or to Remain in Place) Form	Encroachment	14.1.1
PS&E	Certification for Unclear ROW – Federal Project Form	Right of Way	14.1.3
PDP	Easement Conveyance Documents	Conveyance	14.12.4
		Release of Easement	14.2.4
		Request for Easement	14.2.5
		Temporary Easement	14.2.6
PDP	Existing Constraints and Land Use Structures List	Improvement Removal	14.10.5
PDP	Right of Entry Permission Requests	Requests, Notices, and Access Permissions	14.12.10
PDP	ROW 90 Day Vacate Notice	Requests, Notices, and Access Permissions	14.12.10

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	ROW Acquisition and Encroachment Check	Working Paper	14.21.1
PS&E	ROW Acquisition Certification	Right of Way	14.1.3
PDP	ROW Acquisition Responsibility Methodology	Working Paper	14.21.1
DSR	ROW Adjacent Owner Notification	Requests, Notices, and Access Permissions	14.12.10
PDP	ROW Advance Acquisition Parcel List	Working Paper	14.21.1
PDP	ROW Appraisal Work Orders	Appraisal	14.12.2
PDP	ROW Appraiser Site Analysis	Appraiser Evaluation	14.12.3
PDP	ROW Cost Estimate	Cost Estimate	14.18.2
PDP	ROW Eligible Relocation Assistance Owners and Tenants List	Relocation	14.12.8
PS&E	ROW Encroachment Certification	Encroachment	14.1.1
PDP	ROW Fee Title	Conveyance	14.12.4
PDP	ROW Field and Easement Survey	Field Surveying	2.13.6
CEC	ROW Field Notes	Field Surveying	2.13.6
PDP	ROW Improvement Removal Plan	Improvement Removal	14.10.5
PDP	ROW Improvements List	Improvement Removal	14.10.5
PDP	ROW Improvements Survey	Location Map	14.10.6
PDP	ROW Parcel Acquisition Prioritized Schedule and Parcel Issues	Working Paper	14.21.1
PDP	ROW Project Release	ROW Release	14.13.7
		ROW Release	16.8.5
PDP	ROW Property Appraisal Reports	Appraisal	14.12.2
PDP	ROW Property Descriptions	Property Description and Plat	14.12.6
		Property Description and Plat	14.13.5
PDP	ROW Property Title Reports	Conveyance	14.12.4
PDP	ROW Real Property Improvements List	Improvement Removal	14.10.5
PDP	ROW Request for Hardship Acquisition	Requests, Notices, and Access Permissions	14.12.10
PDP	ROW Salable Improvement Request	Form 1134, Request to Sell ROW Improvement Acquired	14.10.3
SAT	ROW Status Data Sheets	Working Paper	14.21.1
Utility Status			
SAT	Correspondence with Utility	Meeting Minutes and Notes	14.20.13
SAT	Early ROW Release for Utilities	ROW Release	14.13.7
PS&E	Federal Project Authorization and Agreement (FPAA) Form	Letter of Authority	14.20.12
SAT	FHWA Letter of Authorization for Federal Aid to Utilities	Letter of Authority	14.20.12
SAT	Plans Provided by Utility	Plan	14.20.17
PS&E	ROW Utility Conflict Check	Utility Agreement	14.20.22
PDP	Standard Utility Agreement	Utility Agreement	14.20.22
PS&E	State Letter of Authority (LOA)	Letter of Authority	14.20.12
SAT	Utility Accommodation Certification	Utility	14.1.4
PDP	Utility Adjustment Agreement Assembly	Utility Agreement	14.20.22
PDP	Utility Adjustment Construction Records	Utility Agreement	14.20.22
SAT	Utility Adjustment Schedule	Utility Adjustment	1.28.8
PS&E	Utility Clearance Certification	Utility	14.1.4
SAT	Utility Conflict Resolution Certification	Utility	14.1.4
SAT	Utility Coordination Document	Utility Agreement	14.20.22
PDP	Utility Evidence of Reimbursable Interest	Compensable Interest Certificate	14.20.4
SAT	Utility Exception Request	Utility Agreement	14.20.22
PDP	Utility Inventory and Survey	Survey	14.20.21
PDP	Utility Relocation Final Billing Statement	Payment	14.20.16
SAT	Utility Schedule Monitor Person and Adjustment Implementation Notification	Notice of Proposed Installation	14.20.15
PS&E	Utility Status Data Sheets	Working Paper	14.21.1
SAT	Utility Test Hole Requests for Utility Conflicts	Work Authorization	14.19.6
PDP	Utility Notification	Notice	14.20.14
Generate Design Schematic			
CEC	Design Schematic Layout	Schematic	12.3.6
PS&E	Geometric Design Schematic	Schematic	12.3.6
		Schematic	10.13.5
		Schematic	12.1.7
		Schematic	14.12.9
		Schematic	14.13.8
		Schematic	15.3.16

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
		Schematic	16.10.7
		Schematic	14.18.4
		Schematic	14.20.19
ODA	Preliminary Geometric Design Schematic	Schematic	2.11.1
		Schematic	2.10.6
Generate Plan Set			
General Plan Sheets			
PS&E	Estimate and Quantity Sheets	Estimate and Quantities	12.8.6
PS&E	General Notes Sheets	General Notes	12.8.9
PS&E	Index of Sheets	General Plan	12.8.17
PS&E	Project Layout Sheet	General Plan	12.8.17
PS&E	Roadway Typical Section Sheet	Cross Section	12.3.1
PS&E	Summary Sheets	Estimate and Quantities	12.8.6
PS&E	Title Sheet	General Plan	12.8.17
Traffic Control Plan Sheets			
PS&E	Barricade Layout Sheets	Sequence of Construction	15.11.6
PDP	Construction Staging Plans	Sequence of Construction	15.11.6
PS&E	Detour Layout Sheets	Detour	15.11.2
PS&E	Phase Narrative Sheets	Sequence of Construction	15.11.6
PDP	Preliminary Construction Staging Plans	Sequence of Construction	15.11.6
PDP	Road Closure/Detour Map Sheets	Detour	15.11.2
CEC	Temporary Signing, Striping, and Pavement Marking Layout Sheets	Marking	15.11.3
PS&E	Temporary Traffic Signals, Illumination Layout Sheets	Temporary Illumination and Traffic Signals	15.11.9
CEC	Traffic Control Detail Sheets	Sequence of Construction	15.11.6
CEC	Traffic Control Layouts (with SW3P) Sheets	Sequence of Construction	15.11.6
PS&E	Traffic Control Phase Layout/Sequence of Work Sheets	Sequence of Construction	15.11.6
CEC	Traffic Control Sequence of Work	Sequence of Construction	15.11.6
PS&E	Traffic Control Standards Sheets	Standard Sheets	15.11.8
PS&E	Traffic Control Typical Sections for Each Phase Sheets	Sequence of Construction	15.11.6
Roadway Detail Sheets			
PDP	Bicycle/Pedestrian Final Facility Design Plans	Bicycle	16.14.2
		Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Preliminary Facility Design Plans	Bicycle	16.14.2
		Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Preliminary Facility Layouts	Bicycle	16.14.2
		Pedestrian	16.14.6
PDP	Bicycle/Pedestrian Preliminary Facility Typical Sections	Bicycle	16.14.2
		Pedestrian	16.14.6
PDP	Cross Section Sheets	Cross Section	12.3.1
PS&E	Driveway Details Sheets	Design Detail	12.3.12
CEC	Existing Layout Sheets	Planimetrics	2.13.3
CEC	Frontage Road, Ramp, and Turnaround Profile Sheets	Alignment Plan and Profile	12.3.11
PS&E	Horizontal Alignment Data Sheets	Alignment Plan and Profile	12.3.11
PDP	Interchange Layout Sheets	Alignment Plan and Profile	12.3.11
PS&E	Intersection Details Sheets	Design Detail	12.3.12
CEC	Mainlane Profiles and Superelevation Sheets	Alignment Plan and Profile	12.3.11
CEC	Miscellaneous and Wheelchair Ramp Details Sheets	Design Detail	12.3.12
PS&E	Miscellaneous Roadway Details Sheets	Design Detail	12.3.12
CEC	Pavement Contours Sheets	Elevation Points and Models	2.13.4
CEC	Proposed Layout Sheets	Alignment Plan and Profile	12.3.11
PS&E	Roadway Plan and Profile Sheets	Alignment Plan and Profile	12.3.11
PS&E	Roadway Standards Sheets	Design Standard	12.3.13
Retaining Wall Detail Sheets			
CEC	Retaining Wall Elevation Layout Sheet	Retaining Wall Notes, Calculations, and Plans	12.1.12
CEC	Retaining Wall Cross Section Sheet	Retaining Wall Notes, Calculations, and Plans	12.1.12
CEC	Retaining Wall Plan Layout Sheet	Retaining Wall Notes, Calculations, and Plans	12.1.12
CEC	Retaining/Noise Wall Details Sheets	Retaining Wall Notes, Calculations, and Plans	12.1.12
PS&E	Retaining/Noise Wall Layout Sheets	Retaining Wall Notes, Calculations, and Plans	12.1.12
PS&E	Retaining/Noise Wall Standards Sheets	Retaining Wall Notes, Calculations, and Plans	12.1.12
Drainage Detail Sheets			
CEC	Channel Improvement Cross Section Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
CEC	Channel Improvement Details Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Channel Improvement Layout Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Channel Improvement Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Cross Drainage Structure Cross Section Sheets	Culvert Notes, Calculations, and Plans	12.1.13
CEC	Cross Drainage Structure Details Sheets	Culvert Notes, Calculations, and Plans	12.1.13
CEC	Cross Drainage Structure Layout Sheets	Culvert Notes, Calculations, and Plans	12.1.13
PS&E	Culvert Cross Sections, Layout and Detail Sheets	Culvert Notes, Calculations, and Plans	12.1.13
SAT	Ditch Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PS&E	Drainage Area Maps	Hydrology Notes, Calculations, and Plans	12.12.1
PS&E	Drainage Plan and Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PS&E	Drainage Standards Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PS&E	Hydraulic Calculation Sheets/Discharge Curves	Hydrology Notes, Calculations, and Plans	12.12.1
PS&E	Miscellaneous Drainage Details Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Miscellaneous Storm Drainage Details Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Overall Drainage Area Boundaries	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Preliminary Drainage Plans	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Pump Station Control House Detail Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Pump Station Control Panel Detail Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Pump Station Outfall Plan and Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Storm Sewer Detention/Retention Facility Cross Section Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Storm Sewer Detention/Retention Facility Detail Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Storm Sewer Hydraulics Detail Sheets	Hydrology Notes, Calculations, and Plans	12.12.1
PDP	Storm Sewer Inlet, Outfall, and Ditch Plan and Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Storm Sewer Large Ditches and Canals Plan and Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Storm Sewer Master Plan	Drainage Facility Notes, Calculations, and Plans	12.12.2
PDP	Storm Sewer Plan and Profile Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Storm Sewer Section Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
CEC	Storm Sewer/Drainage Layout Sheets	Drainage Facility Notes, Calculations, and Plans	12.12.2
ROW and Utility Sheets			
PS&E	Existing Utilities Plan and Profile Layout Sheets (Optional)	ROW Utility	12.8.11
PS&E	Geometric with ROW and Easements Schematic	Map	14.12.5
PDP	Parcel Plats	Property Description and Plat	14.12.6
		Property Description and Plat	14.13.5
PS&E	Proposed Utilities Plan and Profile Layout Sheets (Optional)	ROW Utility	12.8.11
PDP	ROW Access Lines and Control Map	Map	14.12.5
		ROW Map	2.11.3
		Map	14.18.3
		ROW Map	14.13.2
PDP	ROW Boundaries and Earthwork Limits Map	Map	14.12.5
PDP	ROW Parcels and Easements Map	Map	14.12.5
PDP	Tax Assessor Maps	Property Description and Plat	14.12.6
PDP	Temporary Construction Easement Map	Temporary Easement	14.2.6
PDP	Topographic and Utility Survey	Field Surveying	2.13.6
PDP	Un-cleared ROW Parcel Map	Map	14.12.5
PDP	Utility Adjustment Plans	Schematic	14.20.19
PDP	Utility Layout Sheets	ROW Utility	12.8.11
CEC	Utility Relocation Exhibits Sheets	Relocation	14.20.18
CEC	Utility Relocation Layout Sheets	Relocation	14.20.18
PS&E	Utility Standards (for Each Utility Type) Sheets (Optional)	ROW Utility	12.8.11
Bridge Sheets			
CEC	Braided Ramp Bridge Layout Sheets	Bridge Plan	12.2.4
CEC	Bridge Bearing Seat/Top of Cap Elevation Sheet	Bridge Detail	12.1.15
CEC	Bridge Culvert Sheets	Culvert Notes, Calculations, and Plans	12.1.13
PS&E	Bridge Detailed Quantity Summary Sheets	Estimate and Quantities	12.8.6
CEC	Bridge Details Sheets	Bridge Detail	12.1.15
CEC	Bridge Elevation Layout Sheets	Cross Section	12.2.6
PS&E	Bridge Hydraulic Data Sheets	Stream Hydrology Notes, Calculations, and Plans	12.1.14
PS&E	Bridge Layout Sheets	Bridge Plan	12.2.4
		Plan	12.2.13
		Schematic	12.1.7

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	Bridge Plan and Profile Sheets	Bridge Plan	12.2.4
		Plan	12.2.13
		Schematic	12.1.7
CEC	Bridge Plan Layout Sheets	Bridge Plan	12.2.4
		Plan	12.2.13
		Schematic	12.1.7
PS&E	Bridge Standards Sheets	Standard Drawing	12.1.9
CEC	Bridge Structural Detail Sheets	Bridge Detail	12.1.15
CEC	Bridge Typical Section Sheets	Cross Section	12.2.6
PDP	Existing Structure Layout Sheets	Location Map	12.2.11
CEC	New Ramp Structures	Bridge Detail	12.1.15
CEC	Replacement Structures	Bridge Detail	12.1.15
PS&E	Structural Standards Sheets	Standard Drawing	12.1.9
Traffic Item Sheets			
PS&E	Electrical and Illumination Layout Sheets	Electrical and Lighting Design and Plans	15.11.10
PS&E	Electrical and Illumination Standards Sheets	Electrical and Lighting Design and Plans	15.11.10
CEC	Illumination Detail Sheets	Electrical and Lighting Design and Plans	15.11.10
PDP	ITS Detail Sheets	Traffic Management System Plans	15.11.12
PDP	ITS Plan Sheets	Traffic Management System Plans	15.11.12
PS&E	Overhead Sign Bridge Details Sheets	Signs	15.11.7
CEC	Overhead Sign Bridge Layout Sheets	Signs	15.11.7
CEC	Pavement Marking and Delineation Layout Sheets	Marking	15.11.3
PS&E	Pavement Markings and Markers Layout Sheets	Marking	15.11.3
PS&E	Pavement Markings and Markers Standards Sheets	Marking	15.11.3
CEC	Permanent Illumination Layout Sheets	Electrical and Lighting Design and Plans	15.11.10
CEC	Roadway Illumination Plan Layout Sheets	Electrical and Lighting Design and Plans	15.11.10
PS&E	Sign Details Sheets	Signs	15.11.7
PS&E	Signing and Delineation Layout Sheets	Signs	15.11.7
PS&E	Signing and Delineation Standards Sheets	Signs	15.11.7
CEC	Signing and Markings Layout (Schematic)	Signs	15.11.7
DSR	Signing Schematic Sheets	Signs	15.11.7
CEC	Signing, Striping, and Pavement Markings Detail Sheets	Schematic	15.11.5
CEC	Signing, Striping, and Pavement Markings Layout Sheets	Schematic	15.11.5
PS&E	Summary of Large Signs Sheets	Signs	15.11.7
PS&E	Summary of Small Signs Sheets	Signs	15.11.7
CEC	Temporary Illumination Layout Sheets	Temporary Illumination and Traffic Signals	15.11.9
CEC	Temporary Traffic Signal Sheets	Temporary Illumination and Traffic Signals	15.11.9
CEC	Traffic Management System Details Sheets	Traffic Management System Plans	15.11.12
PS&E	Traffic Management System Layout Sheets	Traffic Management System Plans	15.11.12
PS&E	Traffic Management System Standards Sheets	Traffic Management System Plans	15.11.12
CEC	Traffic Signal Basis of Estimate	Signal Design and Plans	15.11.11
CEC	Traffic Signal Construction Detail Sheets	Signal Design and Plans	15.11.11
CEC	Traffic Signal Detail Sheets	Signal Design and Plans	15.11.11
CEC	Traffic Signal Estimate and Quantity Sheet	Signal Design and Plans	15.11.11
CEC	Traffic Signal General Notes	Signal Design and Plans	15.11.11
PS&E	Traffic Signal Layout Sheets	Signal Design and Plans	15.11.11
CEC	Traffic Signal Phasing Sequence Diagram	Signal Design and Plans	15.11.11
CEC	Traffic Signal Plan Sheets	Signal Design and Plans	15.11.11
PS&E	Traffic Signal Standards Sheets	Signal Design and Plans	15.11.11
CEC	Traffic Signal Wiring Diagram and Conduit Sheet	Signal Design and Plans	15.11.11
PS&E	USGS Map and Airport Distances/Elevations	Map, Diagram, or Sketch	5.5.19
Environmental Issue Sheets			
SAT	Construction Site Notice	Coordination and Review	5.5.2
PDP	Environmental Mitigation Plan Sheets	Mitigation Plan	5.5.6
PDP	Environmental Mitigation Plan Sheets for Historic Structures	Mitigation Plan	5.5.6
PS&E	Environmental Permits, Issues, and Commitments Sheet	Environmental Permit	5.5.5
		Environmental Permit	2.1.4
PS&E	Environmental Standards Sheets	Plan Sheet	5.5.16
PDP	Hazardous Materials Remediation Plan	Mitigation Plan	5.5.6
PS&E	Storm Water Pollution Prevention Plan	SW3P Plan	5.5.8
		SW3P Plan	2.1.7
SAT	Temporary Erosion Sediment and Water Pollution Sheets	Erosion Control	5.5.11

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	Wetland Mitigation Plan Sheets	Mitigation Plan	5.5.6
Miscellaneous Item Sheets			
PS&E	Landscaping/Irrigation Details Sheets	Landscaping and Irrigation	12.8.15
PS&E	Landscaping/Irrigation Layout Sheets	Landscaping and Irrigation	12.8.15
PDP	Miscellaneous Structures Details Sheets	Bridge Detail	12.1.15
PDP	Miscellaneous Structures Plan Sheets	Bridge Detail	12.1.15
PS&E	Removal Item Types Sheets	Removal	12.8.16
PS&E	Removal Sheets (Optional)	Removal	12.8.16
Railroad Sheets			
CEC	Miscellaneous Railroad Sketches	Drawing	15.3.4
PS&E	Railroad Bridge Layout Sheet	Plan	15.3.14
CEC	Railroad Exhibit A Sheets	Exhibit A Plan Layout	15.3.5
CEC	Railroad Grade Crossing Warning Systems (Signals)	Exhibit A Plan Layout	15.3.5
PS&E	Railroad Grade Crossing Layout Sheets	Plan	15.3.14
PS&E	Railroad Plan and Profile Sheets	Plan	15.3.14
PS&E	Railroad Track Details Sheets	Details	15.3.20
CEC	Railroad Underpasses	Exhibit A Plan Layout	15.3.5
PS&E	Track Typical Section Sheets	Details	15.3.20
Addendums			
PS&E	Addendum Information Sheet	Addendum	12.8.1
PS&E	Addendum Notice	Addendum	12.8.1
PS&E	Addendum Package	Addendum	12.8.1
PS&E Submissions and Processing			
PS&E	Accelerated Construction Procedures Form (Form 1002, Page 4)	Form 1002 PS&E Submission Data Sheet	12.8.7
PS&E	Acknowledgement Sheet	Review	12.8.19
SAT	Change Order	Change Order	4.7.1
SAT	Change Order Summary Sheet	Change Order	4.7.1
SAT	Final Plans Submission Form	Submittal	12.8.18
PS&E	Final PS&E Review and Revision Notification Form	Review	12.8.19
PS&E	Form 1002	Form 1002 PS&E Submission Data Sheet	12.8.7
PS&E	Proposed Basic Design Data Information (Form 1002, Page 3)	Form 1002 PS&E Submission Data Sheet	12.8.7
SAT	PS&E Review Comments	Review	12.8.19
PS&E Checklists			
CEC	30% Design Checklist	Design Checklist	12.8.21
CEC	60% Design Checklist	Design Checklist	12.8.21
CEC	90% Design Checklist	Design Checklist	12.8.21
CEC	Bridge Layout Checklist	Product Checklist	12.8.24
CEC	District PS&E Submission Checklist	PS&E Submission Checklist	12.8.22
PS&E	District Review PS&E Checklist	PS&E Review Checklist	12.8.23
PS&E	Division Review PS&E Checklist	PS&E Review Checklist	12.8.23
SAT	San Antonio PS&E Submission Checklist	PS&E Submission Checklist	12.8.22
CEC	Schematic Checklist	Product Checklist	12.8.24
SAT	TxDOT Consultant Contract Management Office (CCMO) 30% Design Checklist	Design Checklist	12.8.21
SAT	TxDOT CCMO 60% Design Checklist	Design Checklist	12.8.21
SAT	TxDOT CCMO 90% Design Checklist	Design Checklist	12.8.21
Pre-Letting and Post-Letting Forms and Documents			
PS&E	Commission Minute Order No. 106788 (Pre-Letting Overrun Approval)	Letting	12.10.14
PS&E	Construction Division Letter of Award of Contracts	Contract Award	12.10.10
PS&E	Contract Services Financial Clearance Form	Financial Clearance	16.8.2
SAT	Contract Submittal Log	Evaluation and Monitoring	4.7.5
PS&E	District Payment Request to Contractor for Additional Costs	Financial Review	4.7.6
PS&E	Important Notice to Contractors Regarding Outstanding Right of Way Acquisition	Requests, Notices, and Access Permissions	14.12.10
PS&E	Important Notice to Contractors Regarding Outstanding Utilities	Requests, Notices, and Access Permissions	14.12.10
PS&E	Important Notice to Contractors Regarding ROW Encroachments	Requests, Notices, and Access Permissions	14.12.10
PS&E	Important Notice to Contractors Regarding Unvacated ROW Parcels	Requests, Notices, and Access Permissions	14.12.10

Table 39. FileNet File Structure Analysis Results (Continued).

Document Type by Information Source		FileNet Document Type	
Source ¹	Document Category	Document Type	FileNet Code
PS&E	Letting Overrun Justification Memorandum – District Review Project	Letting	12.10.14
PS&E	Letting Overrun Justification Memorandum – Division Review Project	Letting	12.10.14
PS&E	Letting Overrun Justification Memorandum and Recommendations	Letting	12.10.14
PS&E	Notice of Financial Clearance for Bid Opening and Award Form	Financial Clearance	16.8.2
PS&E	Notice to Contractors	Correspondence	4.7.3
SAT	Preconstruction Meeting	Meeting Notice	12.8.20
PS&E	Pre-Letting Update and Report	Letting	12.10.14
PS&E	Work Order	Work Authorization	4.7.13
SAT	Work Start Letter	Work Authorization	4.6.16

¹ Source: CEC: Consulting Engineers Council of Texas
 DSR: TxDOT Design Summary Report Document Type
 ODA: TxDOT Odessa District Document Type

PDP: TxDOT PDP Manual Document Type
 PS&E: TxDOT PS&E Manual Document Type
 SAT: TxDOT San Antonio District Document Type

SPECIFIC SITUATIONS

In mapping design document categories to the most appropriate FileNet library structure, there were specific situations where there was not a clear choice of FileNet document type for a design document category. The following sections identify specific conflicts while mapping design document categories to the FileNet Library structure along with the solutions identified during the research phase. Readers should note that those solutions are preliminary. During the implementation phase, a careful review of all document classes, document types, and record types should be undertaken to determine the most appropriate design document category mapping structure.

Administrative Document Class

Public Hearing Certification, Summaries, and Involvement Documents

The FileNet library structure did not have the following document types:

- public interest justification statement;
- public involvement plan;
- general public hearing certification;
- general public hearing summaries;
- public hearing certifications for bicyclist, environmental, pedestrian, bridge type restrictions, wall types, heights, locations, or aesthetic treatments; and
- public hearing summaries for bicyclist, environmental, pedestrian, bridge type restrictions, wall types, heights, locations, or aesthetic treatments.

The researchers added the following document types to the Public Hearings (1.22) record type:

- Certification (1.22.5),
- Summary (1.22.6), and
- Supporting Documentation (1.22.7).

Traffic Signal Authorization Documents

The FileNet library structure did not include a document type for traffic signal executed authorization forms. The researchers mapped this document category to the Authorization (1.25.1) document type (Releases and Authorizations record type).

Schedule Documents

The FileNet library structure did not have the following document types:

- construction schedule,
- contract schedule,
- project schedule,
- submission schedule, and
- utility adjustment schedule.

The researchers added the following document types to the Schedules (1.28) record type:

- Construction (1.28.4),
- Contract (1.28.5),
- Project (1.28.6),
- Submission (1.28.7), and
- Utility Adjustment (1.28.8).

In addition, several files appeared to be associated with the Primavera software suite. From the documentation provided, it was not clear whether TxDOT would register all, some, one, or none of the Primavera files into FileNet. For simplicity, the researchers registered all sample Primavera project schedule files for the prototype.

Advance Project Development Document Class

Cost Estimate Documents

The FileNet library structure did not have document types for Primavera project cost estimate files. The researchers mapped these files to the Cost Estimate (2.2.1) document type (Estimates record type). For a specific project, Primavera generates a set of cost estimate files. From the documentation provided, it was not clear whether TxDOT would register all, some, one, or none of the Primavera files into FileNet. For simplicity, the researchers registered all sample Primavera project cost estimate files for the prototype.

Surveying, Photogrammetry, and Photography

The FileNet library structure had a SurveyBook (12.3.7) document type (Design Engineering Reference record type, Project Design document class) but not FileNet document types for the following document categories:

- aerial photogrammetry,
- planimetrics,
- elevations and elevation models,
- survey control points, and
- facility location points and survey data for facility designs.

In addition, the FileNet library structure had a Bridge Inspection Photo (12.2.2) document type (Bridge Folders and Inspections record type, Project Design document class), and a Form 1135, Photographs (14.9.5) document type (Property Management record type, Right of Way document class) but not FileNet document types for site visit photographs. The researchers added a Project Data Collection (2.13) record type with the following document types:

- Site Photographs or Video (2.13.1),
- Aerial Photography (2.13.2),
- Planimetrics (2.13.3),
- Elevation Points and Models (2.13.4),
- Survey Control (2.13.5), and
- Field Surveying (2.13.6).

ROW Determination

The FileNet library structure had a ROW Determination (2.11) record type with document types for Acreage Estimate (2.11.1), Cost Estimate (2.11.2), Map (2.11.3), and Schematic (2.11.4) in the Advance Project Development document class. Although ROW determination is part of the preliminary engineering phase, ROW determination is also a critical ROW component. For this reason, the researchers removed the ROW Determination (2.11) record type from the Advance Project Development document class and created a ROW Determination (14.18) record type in the Right of Way document class.

Contracts Leases and Agreements Document Class

Construction Speed Zone Requests and Municipal Construction Agreements

The FileNet library structure did not have document types for construction speed zone requests, Form 1201-1, or municipal construction agreements. The researchers mapped these document categories to the Agreement Local Government (4.1.8) document type (Agreements record type), under the assumption that these documents were agreements with local governments.

Escrow Agreements

The FileNet library structure did not have a document type for escrow agreements. The researchers added a new document type Escrow Agreement (4.1.14) (Agreements record type).

Subsurface Utility Engineering and Utility Agreement Documents

The FileNet library structure had Subsurface Utility Engineering (4.12) and Utility Agreements (4.13) record types in the Contracts Leases and Agreements document class. Those record types, and the associated documents, are part of the project development process. In particular, utility agreements are a ROW function at TxDOT. The researchers moved the Subsurface Utility Engineering (4.12), and the Utility Agreement (4.13) record types and their associated document types to the Right of Way document class.

Environmental Affairs Document Class

Environmental Permits

The FileNet library structure had one document type for environmental permits, i.e., Environmental Permit (5.5.5) (Project Environmental record type), which appeared to be adequate for handling a wide range of environmental permits, including those listed below. For this reason, the researchers did not create additional document types.

- EPA NPDES General Environmental Permit,
- FAA Construction Height Environmental Permit,
- FAA Project Planning near an Airport Environmental Permit,
- FEMA CLOMR Floodplain Environmental Permit,
- FEMA LOMR Floodplain Environmental Permit,
- FHWA/DOD Interstate Vertical Clearance Environmental Permit,
- TNRCC Well Plugging/Capping Environmental Permit,
- U.S. Corps of Engineers Section 10 Environmental Permit,
- U.S. Corps of Engineers Section 404 Wetlands/Environmental Permit,
- U.S. Corps of Engineers U.S. Coast Guard Environmental Permit,
- USGS Changing Gauging Stations Environmental Permit, and
- Airway-Highway Clearance Permit.

Environmental Documents

The FileNet library structure did not have document types for the following:

- erosion control design or plans;
- standard or detail environmental plan sheets;
- environmental or natural resource agency commitments, in addition to natural or cultural resources studies;
- noise analysis;

- water quality analysis; and
- project alternative description, purpose-and-need statements, environmental justice analyses, and Section 4(f) and 6(f) (10) evaluations.

The researchers added the following document types to the Project Environmental record type:

- Erosion Control (5.5.11),
- Commitments and Resources (5.5.12),
- Noise Analysis (5.5.13),
- Water Quality (5.5.14),
- Alternative Study (5.5.15), and
- Plan Sheet (5.5.16).

Floodplain and Wetland Documents

The FileNet library structure did not have document types for floodplain encroachment and wetland reports. The researchers added new document types Wetlands Report (5.5.17) and Floodplain Encroachment (5.5.18) (Project Environmental record type).

USGS Map

The FileNet library structure did not have a document type for USGS maps that include a depiction of airport distances and elevations. This document is necessary for FAA airport environmental permits. The researchers added a new document type Map, Diagram, or Sketch (5.5.19) (Project Environmental record type) for these types of document categories. The researchers mapped other types of maps (e.g., USGS maps without airport information, general project-related maps, diagrams, and sketches) to the Drawing (12.3.3) document type (Design Engineering Reference record type, Project Design document class).

Maintenance Operations Document Class

Traffic Control Plans

The FileNet library structure had a Traffic Control Plans record type (10.13) within the Maintenance Operations document class. However, there are many different types of traffic control plans at TxDOT, including traffic control plans for highway construction, highway maintenance, and utility installations on the ROW. For simplicity, the researchers renamed the Traffic Control Plans record type to Maintenance Traffic Control Plans (10.13) and created the Traffic Control Device Inventory (15.10) and the Construction Traffic Control Plans (15.11) record types in the Traffic Operations document class. During implementation, it may be necessary to evaluate the feasibility of moving all traffic control plans to the Traffic Operations document class.

Project Design Document Class

Culvert, Drainage, and Hydrology Documents

The FileNet library structure had the following document types for drainage analysis, design, and plans under the Bridge Engineering Reference record type:

- Drainage Notes and Calculations (12.1.2) and
- Hydraulic Notes and Calculations (12.1.5).

The researchers added the following document types to the Bridge Engineering Reference record type:

- Culvert Notes, Calculations, and Plans (12.1.13), which includes outfalls; and
- Stream Hydrology Notes, Calculations, and Plans (12.1.14).

The FileNet library structure did not have document types for hydrology or drainage facilities such as culverts, pumps, channels, ditches, outfalls, storm drains, and stream crossings that are not components of a bridge structure. Furthermore, the FileNet library structure did not distinguish between documents that describe rainfall and/or drainage calculations and documents that describe the facilities that channel that rainfall. As a result, the researchers added the Drainage Engineering Reference (12.12) record type with the following document types:

- Hydrology Notes, Calculations, and Plans (12.12.1), which includes hydrologic studies, computer models, and other similar topics; and
- Drainage Facility Notes, Calculations, and Plans (12.12.2), which includes storm drainage, detention ponds, pumps, control houses, channels, and ditches.

Retaining Wall Documents

The FileNet library structure did not have document types for retaining wall layouts, sections, details, standards, or calculations. The researchers added the Retaining Wall Notes, Calculations, and Plans (12.1.12) document type to the Bridge Engineering Reference record type.

Detailed Bridge Documents

The FileNet library structure did not have document types for the following:

- bridge bearing seat/top of cap elevation sheet,
- bridge details sheets,
- bridge structural detail sheets,
- miscellaneous structures details sheets,

- new ramp structures, and
- replacement structures.

The researchers added the Bridge Detail (12.1.15) document type to the Bridge Engineering Reference record type.

Staking and Alignment Coordinate Documents

The FileNet library structure did not have document types for the following:

- baseline horizontal/vertical alignment coordinates,
- row staking, and
- soil core hole staking.

The researchers added the Staking and Alignment Coordinates (12.3.9) document type to the Design Engineering Reference record type.

Earthwork Documents

The FileNet library structure did not have a document type for earthwork volumes (cut and fill quantities). The researchers added the Earthwork (12.3.10) document type to the Design Engineering Reference record type.

Roadway Design Documents

The FileNet library structure did not have roadway document types for the following:

- driveway details sheets;
- existing layout sheets;
- frontage road, ramp, and turnaround profile sheets;
- horizontal alignment data sheets;
- interchange layout sheets;
- intersection details sheets;
- main lane profiles and superelevation sheets;
- miscellaneous and wheelchair ramp details sheets;
- miscellaneous roadway details sheets;
- proposed layout sheets;
- roadway plan and profile sheets; and
- roadway standards sheets.

The researchers added the following document types to the Design Engineering Reference (12.3) record type:

- Alignment Plan and Profile (12.3.11),
- Design Detail (12.3.12), and
- Design Standard (12.3.13).

Estimate and Quantities Documents

The FileNet library structure did not have document types for the following:

- general estimate and quantity sheets;
- estimate and quantity sheets for bridges, drainage, or roadways;
- summary sheets;
- average low bid unit prices web pages; and
- bid tabulation files (bid tabs).

The researchers used the Estimate (12.8.6) document type (Plans Specifications and Estimates record type) and renamed the document type to Estimate and Quantities as a mapping for any document providing a materials summary or quantity list.

Landscaping and Irrigation Documents

The FileNet library structure did not have document types for landscaping and irrigation plan sheets, notes, or computations. The researchers added the Landscaping and Irrigation (12.8.15) document type to the Plans Specifications and Estimates record type.

Miscellaneous Project Plan Documents

The FileNet library structure did not have document types for the following:

- removal item types sheets;
- removal sheets;
- supplemental proposal sheets;
- supplemental sheets signed, sealed, and dated by engineer;
- title sheet;
- index of sheets; and
- project layout sheet.

The researchers added the following document types to the Plans Specifications and Estimates (12.8) record type:

- Removal (12.8.16) and
- General Plan (12.8.17).

PS&E Plan

The Plan (12.8.10) document type (Plans Specifications and Estimates record type) appears to be a repository for the final PS&E plan set. Accordingly, the researchers mapped all PS&E plans (i.e., those plans that make up the PS&E assembly) in CAD format to the Plan document type. Likewise, the researchers mapped letting plans (normally files in TIFF or PDF format) to the Letting Plan (12.6.1) document type (Letting Plans record type).

For completeness, while mapping project design documents to the FileNet library structure, the researchers mapped CAD-generated plan documents to FileNet document classes according to the associated document type. For example, the researchers mapped traffic control plans to the Maintenance Operations document class, environmental plans to the Environmental Affairs document class, and traffic signal plans to the Traffic Operations document class.

Project Submittal, Review Letters, and Project Meeting Notice

The FileNet library structure did not have document types for the following:

- project or P&SE submittals,
- project review letters and forms, and
- project meeting notices.

The researchers added the following document types to the Plans Specifications and Estimates (12.8) record type:

- Submittal (12.8.18),
- Review (12.8.19), and
- Meeting Notice (12.8.20).

Checklist Documents

The Proposal Development record type includes a Checklist (12.10.7) document type. However, the FileNet library structure did not have document types for the following document categories:

- preliminary design and design deliverable checklists,
- design milestone checklists (e.g., 30 percent design), and
- PS&E submission and review checklists.

These checklists are actually not part of the proposal development process. As a result, the researchers added the following document types to the Plans Specifications and Estimates (12.8) record type:

- Design Checklist (12.8.21),
- PS&E Submission Checklist (12.8.22),

- Review PS&E Checklist (12.8.23), and
- Product Checklist (12.8.24).

Miscellaneous Letting Documents

The FileNet library structure had a Proposal Development (12.10) record type in the Project Design document class. This record type contains the following document types:

- Acceptance (12.10.1),
- Advertisement (12.10.2),
- Bid Analysis (12.10.3),
- Bid Proposal Successful (12.10.4),
- Bid Proposal Unsuccessful (12.10.5),
- Bond and Insurance (12.10.6),
- Checklist (12.10.7),
- Child Support Form (12.10.8),
- Contract (12.10.9),
- Contract Award (12.10.10),
- Correspondence (12.10.11),
- HUB Form (12.10.12),
- Letter of Authority (12.10.13),
- Letting (12.10.14),
- Negotiation (12.10.15),
- Pre-bid Conference (12.10.16),
- Prequalification (12.10.17),
- Proposal Accepted (12.10.18),
- Proposal Rejected (12.10.19), and
- Selection (12.10.20).

These document types indicate that the Proposal Development record type includes more than just creation of the project proposal document – it also includes project development functions (e.g., Selection, Negotiation, etc.). As a result, the researchers mapped the Letting Overrun Justification Memorandum, Commission Minute Order No. 106788 (Pre-letting Overrun Approval), and Pre-letting Update and Report document categories to the Letting (12.10.14) document type in the Proposal Development record type.

Right of Way Document Class

ROW Determination

As mentioned previously, the FileNet library structure had a ROW Determination (2.11) record type in the Advance Project Development document class. The researchers removed the ROW Determination record types from the Advance Project Development document class and created

the ROW Determination (14.18) record type to the Right of Way document class with the following document types:

- Acreage Estimate (14.18.1),
- Cost Estimate (14.18.2),
- Map (14.18.3), and
- Schematic (14.18.4).

Subsurface Utility Engineering Documents

As mentioned previously, the FileNet library structure had a Subsurface Utility Engineering (4.12) record type in the Contracts Leases and Agreements document class. The researchers removed the Subsurface Utility Engineering record type from the Contracts, Leases, and Agreements document class and added a Subsurface Utility Engineering (14.19) record type to the Right of Way document class with the following document types:

- Correspondence (14.9.1),
- Deliverable (14.9.2),
- Media Information Form (14.9.3),
- Meeting Minutes and Notes (14.9.4),
- Statement (14.9.5), and
- Work Authorization (14.9.6).

Utility Agreement Documents

As mentioned previously, the FileNet library structure had a Utility Agreements (4.13) record type with 23 associated document types in the Contracts Leases and Agreements document class. The researchers deleted the Utility Agreement record type from the Contracts Leases and Agreements document class and created the Utility Relocation (14.20) record type in the Right of Way document class. The researchers also moved the original 23 document types to the Utility Relocation (14.20) record type. The affected document types were as follows:

- Adjustment (14.20.1),
- Affidavit (14.20.2),
- Billing (14.20.3),
- Compensable Interest Certificate (14.20.4),
- Consultant Contract Review (14.20.5),
- Cost Estimate (14.20.6),
- Date of Eligibility Request (14.20.7),
- Determination of Eligibility (14.20.8),
- Funding (14.20.9),
- Indemnity Agreement (14.20.10),
- Joint Use Agreement (14.20.11),
- Letter of Authority (14.20.12),

- Meeting Minutes and Notes (14.20.13),
- Notice (14.20.14),
- Notice of Proposed Installation (14.20.15),
- Payment (14.20.16),
- Plan (14.20.17),
- Relocation (14.20.18),
- Schematic (14.20.19),
- Specification (14.20.20),
- Survey (14.20.21),
- Utility Agreement (14.20.22), and
- Utility Easement (14.20.23).

Note: Not all the relocated document types are utility agreement document categories. For example, the Notice of Proposed Installation is in reality a utility permit application, which is normally not part of the PDP. During implementation, TxDOT should move this document type to a more appropriate location.

Several utility agreement-related document categories did not have a direct mapping to the FileNet library structure. [Table 40](#) lists these document categories and the corresponding FileNet document types the researchers used for the mapping.

Table 40. Utility Agreement Document Mapping to FileNet Library Structure.

Utility Document	FileNet Document Type
Correspondence With Utility	Meeting Minutes And Notes (14.20.13)
Utility Coordination Document	Working Paper (14.21.1)
Utility Status Data Sheets	Working Paper (14.21.1)
ROW Utility Conflict Check	Utility Agreement (14.20.22)
Utility Exception Request	Utility Agreement (14.20.22)
Plans Provided By Utility	Plan (14.20.17)
Utility Adjustment Plan	Adjustment (14.20.1)

Utility Certification Documents

The researchers mapped the following certification documents to the Utility (14.1.4) document type (Certifications record type):

- utility adjustment schedule,
- utility conflict resolution certification,
- utility accommodation certification, and
- utility clearance certification.

Requests, Notices, and Access Permission Documents

The FileNet library structure did not have document types for the following:

- driveway tie-in permission requests,
- driveway notice and access forms,
- row request for hardship acquisition,
- right of entry permission requests,
- ROW 90-day vacate notice, and
- ROW adjacent owner notification.

The researchers added the Requests, Notices, and Access Permissions (14.12.10) document type to the ROW Project Files record type.

Supporting ROW Documents

The FileNet library structure did not have document types for the following:

- ROW acquisition and encroachment check,
- ROW request for hardship acquisition,
- ROW parcel acquisition prioritized schedule and parcel issues,
- ROW acquisition responsibility methodology,
- ROW status data sheets, and
- ROW advance acquisition parcel list.

The researchers mapped these document categories to the Working Paper (14.21.1) document type (Working Papers record type) because these document categories act as unofficial working papers.

Traffic Operations Document Class

Railroad Sketches

The FileNet library structure did not have a document type for miscellaneous railroad sketches. The researchers mapped this document category to the Drawing document type (15.3.4) (RR Replanking and Warning Devices record type), assuming a drawing is analogous to a sketch.

Railroad General Notes

The FileNet library structure did not have a document type for railroad general notes. The researchers mapped this document category to the Exhibit B Approved PS&E (15.3.6) document type (RR Replanking and Warning Devices record type) because PS&E submissions include this document category.

Railroad Plan Sheets

The FileNet library structure did not have a document type for railroad plan detail sheets. The researchers added a Details (15.3.20) document type to the Traffic Operations document class under the RR Replanking and Warning Devices record type.

Traffic Data

The FileNet library structure had Traffic Data document types at the following locations:

- Environmental Documentation (2.1.9) record type, Advance Project Development document class;
- Project Environmental (5.5.10) record type, Environmental Affairs document class; and
- Proposed Project Studies (16.10.8) record type, Transportation Planning document class.

However, the FileNet library structure did not have an area for traffic data in the Traffic Operations document class. The researchers added a Traffic Data (15.9) record type in the Traffic Operations document class with the following document types:

- Local Traffic Forecasts and Existing Counts (15.9.1);
- Intersection/Interchange Geometrics and Control Data (15.9.2);
- Intersection Vehicle Count/Turning Volume Data (15.9.3);
- Traffic Signal Operations, Control, and Maintenance Data (15.9.4);
- Traffic Detector Data (15.9.5);
- Traffic Management/Control Data (15.9.6);
- Traffic Simulation Model Data (15.9.7);
- Origin-Destination Data (15.9.8);
- Modal Operations Data (15.9.9); and
- Crash Data (15.9.10).

It may be worth noting that the FileNet library structure did not have document types for the following transportation planning-related traffic data document categories:

- annual ATR report,
- annual district traffic maps,
- annual vehicle classification report, and
- county road/urban saturation count maps.

The researchers mapped these document categories to the Traffic Data (16.12.4) document type in the Transportation Planning document class.

Traffic Control Device Inventories

The FileNet library structure did not have document types for traffic control device inventories. The researchers added a Traffic Control Device Inventory (15.10) record type (in the Traffic Operations document class) with the following document types:

- Markings (15.10.1),
- Signs (15.10.2),
- Signals (15.10.3), and
- ITS (15.10.4).

Construction Traffic Control Plans

As mentioned previously, the FileNet library structure had a Traffic Control Plans record type (10.13) within the Maintenance Operations document class. However, there are many different types of traffic control plans at TxDOT, including traffic control plans for highway construction, highway maintenance, and utility installations on the ROW. The researchers created the Construction Traffic Control Plans (15.11) record type with the following document types:

- Contract Provision (15.11.1),
- Detour (15.11.2),
- Marking (15.11.3),
- Plan Review (15.11.4),
- Schematic (15.11.5),
- Sequence of Construction (15.11.6),
- Signs (15.11.7), and
- Standard Sheets (15.11.8).

Temporary Illumination and Signal Documents

The FileNet library structure did not have the following document types:

- temporary illumination layout sheets and
- temporary traffic signal sheets.

The researchers added the Temporary Illumination and Traffic Signals (15.11.9) document type to the Construction Traffic Control Plans record type.

Lighting, Electrical, Signal Design, and Traffic Management Documents

The FileNet library structure did not have document types for the following:

- lighting justification report;
- lighting warrant and condition analysis;
- luminary survey and assessment;
- electrical and illumination layout sheets;
- electrical and illumination standards sheets;
- illumination detail sheets;
- ITS detail sheets;
- ITS plan sheets;
- permanent illumination layout sheets;
- roadway illumination plan layout sheets;
- signing, striping, and pavement markings detail sheets;
- signing, striping, and pavement markings layout sheets;
- traffic management system details sheets;
- TMS layout sheets;
- TMS standards sheets;
- traffic signal basis of estimate;
- traffic signal construction detail sheets;
- traffic signal detail sheets;
- traffic signal estimate and quantity sheet;
- traffic signal general notes;
- traffic signal layout sheets;
- traffic signal phasing sequence diagram;
- traffic signal plan sheets;
- traffic signal standards sheets; and
- traffic signal wiring diagram and conduit sheet.

The researchers added the following documents types to the Construction Traffic Control Plans (15.11) record type (in the Traffic Operations document class):

- Electrical and Lighting Design and Plans (15.11.10),
- Signal Design and Plans (15.11.11), and
- Traffic Management System Plans (15.11.12).

Construction Access Description

The FileNet library structure did not have a document type for construction access descriptions. The researchers mapped this document category to the Sequence of Construction (15.11.6) document type in the Construction Traffic Control Plans record type because this document involves construction traffic access.