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16. Abstract
A critical process for the timely development and delivery of highway construction projects is the early identification and depiction of utility interests that may interfere with proposed highway facilities. The effective management of such utility interests or conflicts involves utility relocation (or design changes), inspection, and documentation. The large number of stakeholders and the magnitude of the process results in an enormous amount of data. Despite substantial data exchange between stakeholders, there are currently no standards for the exchange of utility data/information in the project development process. The research will address this issue by analyzing specific information flows and data needs to determine data models and by developing a prototype utility conflict data management system. More specifically, the research will perform a comprehensive analysis of utility conflict data/information flows between utility accommodation stakeholders in the TxDOT project development process, develop data models to accommodate work and data flows between such stakeholders, develop a prototype system for the management of utility conflict data, and develop a tool for the visualization and analysis of utility conflicts within the prototype. The report includes a review of utility relocation and coordination practices, describes the development of data models, and illustrates the development of the prototype conflict management system.

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DEVELOPMENT OF A UTILITY
CONFLICT MANAGEMENT SYSTEM

by

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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.

ACKNOWLEDGMENTS

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADO	ActiveX Data Object
AFA	Advance Funding Agreement
APA	Alternate Procedure Approval
ArcGIS	ESRI's Arc Geographic Information System Software
ArcIMS	ESRI's Arc Internet Map Server
ArcSDE	ESRI's Arc Spatial Data Engine
BAMS/DSS	Bid Analysis Management System/Decision Support System
BPM	Business Process Model
BPS	Bid Proposal System
BPMN	Business Process Modeling Notation
CAD	Computer Aided Design
CD-ROM	Compact Disk Read Only Memory
CDA	Comprehensive Development Agreement
CFR	Code of Federal Regulations
CMCS	Construction and Maintenance Contract System
CS	Control Section
CSJ	Control Section Job
CCSJ	Controlling CSJ Number
CSS2	Cascading Style Sheet Level 2 Specification
CTS	Contract Tracking System

DBB	Design-Bid-Build
DBMS	Database Management System
DCIS	Design and Construction Information System
DCO	Design Construction Office
DFD	Data Flow Diagram
DFO	Distance From Origin
DOE	Date of Eligibility
DOT	Department of Transportation
DPS	Department of Public Safety
DSR	Design Summary Report
DTM	Digital Terrain Model
EDMS	Electronic Document Management System
EDTIS	Electronic Document Technologies Implementation and Support
ERwin	Computer Associates® AllFusion ERwin® Data Modeler (now available as CA® ERwin® Data Modeler)
ESRI	Environmental Systems Research Institute
EWA	Emergency Work Authorization
FAQ	Frequently Asked Questions
FCA	Facility Concession Agreement
FDOT	Florida Department of Transportation
FileNet	FileNet® Electronic Document Management System
FIPS	Federal Information Processing Standards
FHWA	Federal Highway Administration

FMS	File Management System
FPAA	Federal Project Authorization and Agreement
FUP	Federal Utility Procedure of the UCMP
GAIP	GIS Architecture and Infrastructure Project
GB	Gigabyte
GENII	Genesis™ Enterprise Information Integrator
GHz	Gigahertz
GIS	Geographic Information System
GPS	Global Positioning System
GS	TxDOT Network Ground Set
HPMS	Highway Performance Management System
HPTMS	Highway Project Task Management System
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
ICAM	Integrated Computer-Aided Manufacturing
ID	Identifier
IDEF	ICAM Definition Language
IDEF0	Integration Definition for Function Modeling
IDEF3	Integration Definition for Process Description Capture Method
IHEEP	International Highway Engineering Exchange Program
IICE	Integration for Concurrent Engineering
IIS	Internet Information Server
Interstate System	National System of Interstate and Defense Highways

LOA	Letter Of Authorization
LOS	Level Of Service
LPA	Local Public Agency
LRS	Linear Referencing System
LUP	Local Utility Procedure
MST	Main Street Texas
NOPI	Notice of Proposed Installation
OCR	Optical Character Recognition
OLAP	Online Analytical Processing
OLTP	Online Transaction Processing
OMG	Object Management Group
PDF	Portable Document Format
PDP	Project Development Process
PMIS	Pavement Management Information System
PS&E	Plans, Specifications, and Estimates
RAM	Random Access Memory
RDBMS	Relational Database Management System
RHiNo	Roadway/Highway Network Inventory
ROW	TxDOT Right of Way Division
ROWIS	Right of Way Information System
SAS	Statistical Analysis Software
SATA	Serial Advanced Technology Attachment
SB	Senate Bill

SMS	Subcontractor Monitoring System
SP	Service Pack
SQL	Structured Query Language
StratMap	Texas Strategic Mapping Program
SUE	Subsurface Utility Engineering
SUP	State Utility Procedure of the UCMP
TACS	Tables and Characteristics System
TB	Terabyte
TGIC	Texas Geographic Information Council
TIF	Tagged Image File
TIP	Transportation Improvement Plan
TNRIS	Texas Natural Resources Information System
TPP	Transportation Planning and Programming Division
TRM	Texas Reference Marker
TRMEOY	Texas Reference Marker End of Year
TSD	Technology Services Division at TxDOT
TSID	TxDOT System Interface Diagram
TSPS	Texas Society of Professional Surveyors
TTA	Texas Turnpike Authority
TxDOT	Texas Department of Transportation
TPP	Transportation Planning and Programming Division at TxDOT
UAA	Utility Agreement Assembly
UACT	Utility Accommodation and Conflict Tracker

UAD	Utility Agreement Database (used by TxDOT ROW)
UAR	Utility Accommodation Rules (formerly Utility Accommodation Policy)
UFD	Utility Facility Database
UIR	Utility Installation Review
UCMP	Utility Cooperative Management Process
UJUA	Utility Joint Use Acknowledgement
UTP	Unified Transportation Program
W3C	World Wide Web Consortium
XHTML	Extensible HyperText Markup Language
XML	Extensible Markup Language

CHAPTER 1. INTRODUCTION

Early identification and depiction of utility interests that may interfere with proposed highway facilities is a critical process for the timely development and delivery of highway construction projects (*1*). Utility conflicts occur as a result of a proposed highway design when a utility facility is in conflict with the proposed highway facility, other utility installations, or non-compliance with the Utility Accommodation Rules (UAR) (*2*). It is then necessary to address or clear such conflicts by using strategies such as (a) introducing a design change to the horizontal or vertical alignment of the proposed highway facility; (b) removing, relocating, or otherwise adjusting the utilities in conflict; (c) implementing an appropriate engineering countermeasure other than a roadway design change or utility adjustment; and (d) accepting an exception to policy. During the process of detecting, confirming, and resolving conflicts, a suspected conflict may also be removed if a subsequent evaluation determines that the utility facility is not in conflict. Highway construction or improvement projects are not prerequisites for utility conflicts to occur since utility conflicts can also occur when utilities propose new installations during the utility permitting process. This research, however, only pertains to utility conflicts that occur during typical highway construction projects.

Utility relocation (sometimes called utility replacement or adjustment [*3*]), requires careful planning and coordination because delays in utility relocation have a tendency to proliferate into project letting and even construction, which may result in delays, increased costs, and/or claims from contractors (*4*, *5*, *6*). Delays that are the result of unresolved utility conflicts also raise concerns for the safety of all parties involved, including the traveling public. Further, delays add to the frustration of the traveling public and may negatively influence public perception about the project. A 2002 survey of state departments of transportation, highway contractors, design consultants, and others identified utility relocations as the most frequent reason for delays in highway construction (*4*). If utility conflicts are discovered early in the design process, small changes to the design may avoid the utility relocation (*7*). Effective management of utility conflicts, which includes identification, relocation (or design changes), inspection, and documentation, is an important factor to keep projects on schedule.

Effective communication, cooperation, and coordination among stakeholders are critical to ensure successful project development (*1*, *8*, *9*). In the case of utilities, the Texas Department of Transportation (TxDOT) facilitates cooperation and communication through the Cooperative Utility Management Process, which is an extensive series of procedures that is part of the TxDOT Project Development Process and described in detail in the TxDOT Utility Manual (*10*). The large number of stakeholders in the process results in an enormous amount of data in the form of communications, agreements, contracts, permits, maps, schematics, images, and design files. Unfortunately, there are currently no standards for the exchange of information. The lack of standards results in a number of district specific approaches and procedures that TxDOT districts employ to make the process work. Although functional, these different approaches and procedures as a whole are often ineffective, incompatible with other processes, and lack desirable features such as real-time dissemination of project data to process participants.

RESEARCH OBJECTIVES

The objective of the research project is to address the issue of utility data exchange in the project development process by developing a prototype utility conflict data management system. More specifically, this research analyzed the specific information flows and data needs to determine a business process model that was transformed into data models for the development of the prototype. The research accomplished this objective by performing an analysis of utility conflict data/information flows between utility accommodation stakeholders in the TxDOT project development process, developing data models to accommodate work and data flows between such stakeholders, and developing a prototype system for the management of utility conflict data.

This report documents the findings of the research project and is organized in chapters as follows:

- Chapter 1 is this introductory chapter.

- Chapter 2 documents the review of utility information flows in the project development process.

- Chapter 3 documents the development of a TxDOT utility relocation business process model and related sub models.

- Chapter 4 documents the perspective of utilities and utility consultants on the utility relocation process.

- Chapter 5 describes the development of data models for the utility data management system prototype.

- Chapter 6 provides a description of the utility data management system prototype.

- Chapter 7 provides conclusions and recommendations.

CHAPTER 2. UTILITY DATA MANAGEMENT PRACTICES AT TXDOT

INTRODUCTION

During the course of a project, TxDOT and utilities exchange large amounts of information. Although currently there are no standards for this exchange of information, there are several TxDOT guidelines that provide recommendations for the exchange of information. The most notable sources of direction for utility coordination are the Project Development Process (PDP) Manual and the Utility Manual. The TxDOT Design Division publishes the PDP Manual, which describes in detail the steps required to develop transportation projects from inception to construction letting (*11*). The Right of Way (ROW) Division publishes the Utility Manual, which is a guideline for all issues pertaining to utilities in construction projects, including legal references, responsibilities, adjustment procedures, agreements, and billings and payments (*10*). The Utility Manual organizes the coordination of utility accommodation activities in a process called the "TxDOT Utility Cooperative Management Process" (UCMP). This process defines authorities and responsibilities for related procedures and aims to improve utility relocation accounting procedures. During the process, several TxDOT district offices and divisions engage with utilities and property owners with different levels of responsibility. In general, TxDOT personnel included in the process are project manager, project design engineer, project construction engineer, district utility liaison, district right of way representative, ROW Division representative, construction contractor, external auditor, Budget and Finance Division representative, and state comptroller. On the utility side, personnel typically include the utility design representative, utility consultant, utility construction representative, and utility inspector. Third parties are Federal Highway Administration (FHWA) representatives, Subsurface Utility Engineering (SUE) provider, local public agencies (LPAs), consultants, and real estate owners.

The legal foundation for the UCMP and source of regulation for the accommodation of utilities within the right of way of state highways in Texas are the UAR (*2*). The UAR follow a federal mandate that requires states to submit a statement to the FHWA on the authority of utilities to use and occupy the state highway right of way, the power of the state department of transportation (DOT) to regulate such use, and the policies the state DOT uses for accommodating utilities within the right of way of federal-aid highways under its jurisdiction (*12*). The rules prescribe minimums relative to the accommodation, location, installation, adjustment, and maintenance of utility facilities within the TxDOT-managed right of way, unless other industry or governmental codes, orders, or laws require utilities to provide a higher degree of protection than provided in the UAR.

METHODOLOGY

The researchers conducted a thorough review of utility adjustments, both reimbursable and non-reimbursable, in the project development process in terms of procedures, data/information flows, and stakeholders. To complete this task, the researchers identified sources that typically provide, receive, or make use of utility information, and their roles, authorities, and requirements in that process.

To gain a good understanding of utility relocation process activities, the researchers used TxDOT's PDP Manual; Utility Manual; and Plans, Specifications, and Estimates (PS&E) Preparation Manual as starting points to analyze utility relocation business processes at TxDOT (*10*, *11*, *13*). The researchers recognized that the outcome of the analysis would represent a theoretical process model that would not necessarily accurately represent the existing process that TxDOT districts use on a daily basis. The researchers then presented this model to officials at the division and district levels and discussed sequence, relationships, and prerequisites of the model's activities and then used the feedback to make modifications to the model. The meetings with TxDOT district officials made evident that each district follows a different procedure to include utility coordination into their project development process. Through discussions with the research advisory panel, the research team concluded to focus on two districts, specifically Houston and San Antonio, and develop a separate utility coordination business process model for each district.

To gain further insight into local processes and customized procedures, the researchers collected utility coordination data at the local level. This data included sample utility conflict lists, project communications, design schematics, agreements, utility adjustment plans, and PS&E documentation. The researchers also gathered sample data from several TxDOT databases, such as the Right of Way Information System (ROWIS), the Houston utility agreement database, the ROW Division's utility agreement database, the Highway Project Task Management System (HPTMS), and the Design and Construction Information System (DCIS). The sample data enabled the researchers to gain an understanding of the type of utility conflict information exchanged and the timing and specific stakeholders affected by such transactions. The researchers then contacted several utilities and utility consultants to obtain information on the perspective of utility coordination from the utility side. The team then used the sample data in combination with the business process models to develop utility coordination data flow diagrams that focus on the flow of information between activities of the business process model to exhibit data exchanges between utility and stakeholders for the resolution of utility conflicts within the project development process.

Concurrently, the researchers reviewed information systems and initiatives that are currently developed or implemented at TxDOT districts. The researchers visited the Austin, Houston, Dallas, and San Antonio Districts to learn about strategies to manage project development and utility conflict data. This task was important to ensure the compatibility of the prototype with existing TxDOT information systems, and to ensure that the prototype makes good use of available data.

REVIEW OF EXISTING TECHNICAL DOCUMENTATION

Several TxDOT manuals contain information about the TxDOT utility relocation process, including the PDP Manual, the PS&E Preparation Manual, and the Utility Manual. The research team reviewed these sources to develop a theoretical utility relocation business process model. The following summarizes the efforts and challenges to produce the model.

TxDOT PDP Manual

The PDP Manual is written primarily for TxDOT personnel as a guideline for project development and outlines activities and responsibilities for several TxDOT groups that may be involved in a project. The manual provides some information about interdependencies between groups and activities, and to some degree the recommended sequence of activities. The manual organizes the PDP into six chapters describing major steps that a project, depending on its complexity, may be subjected to: Planning and Programming, Preliminary Design, Environmental, Right of Way and Utilities, Project Specifications and Estimate Development, and Letting. Each chapter is then further broken down into sections, subsections, and tasks, providing increasing detail about activities. Each section provides an overview of its tasks and some information about the order in which the tasks should be completed. Tasks have a four-digit code of which the first digit indicates the chapter, and the second through fourth digit indicates a task. In addition to the task code, the manual provides a title, description, pertinent project types, responsible party, subtasks, helpful suggestions, critical sequencing, and reference material. The manual also includes a chart that provides an overview of the PDP (Figure 1).

TxDOT PS&E Preparation Manual and Utility Manual

The PDP Manual references several manuals that TxDOT divisions publish to complement the PDP Manual's information provided in each chapter. These manuals include the ROW Division's Utility Manual, which gives an overview of activities related to utility coordination, and the Design Division's PS&E Preparation Manual, which provides detailed information on TxDOT policy with respect to tasks and coordination required to ensure the successful completion of plans, specifications, and estimate. As a result, the Utility Manual and PS&E Preparation Manual overlap with some areas of the PDP Manual and essentially describe these portions of the PDP Manual with a greater amount of detail, slightly different perspective, and somewhat different focus.

PROJECT DEVELOPMENT PROCESS
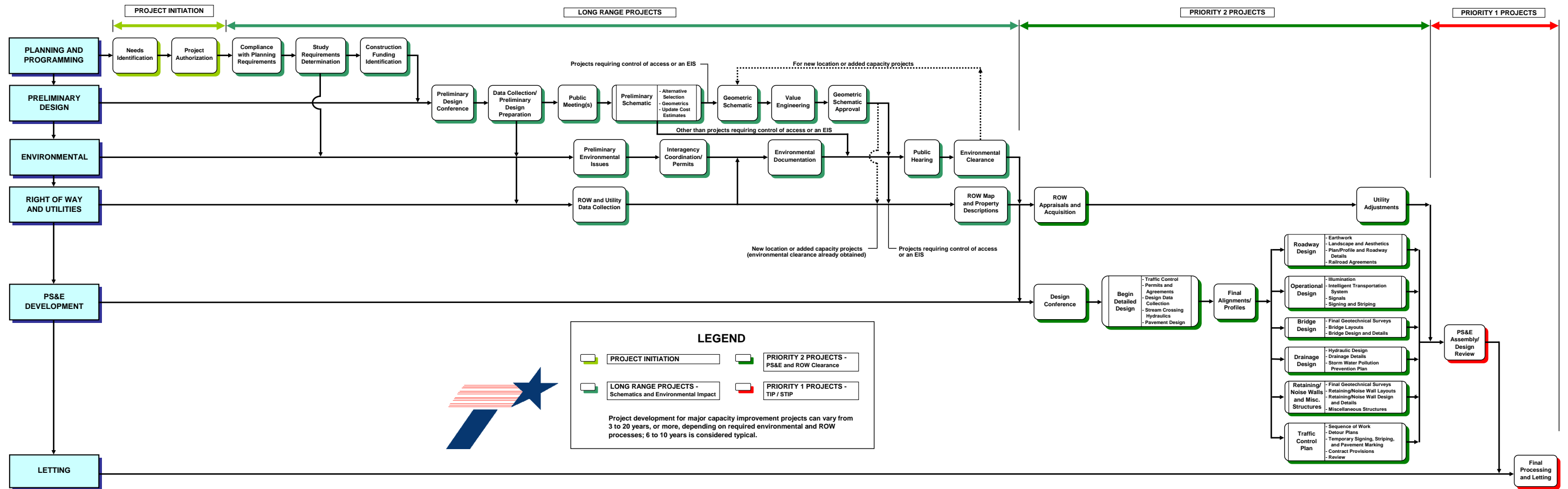
Figure 1. PDP Manual Diagram (Adapted from *14*).

Challenges with Existing Technical Documentation

The review of TxDOT manuals revealed that, for the most part, it is difficult to relate tasks and activities across manuals. Given the overlap of PDP, PS&E, and the Utility Manual, the researchers did not anticipate this result. The review found that a part of the issue is the lack of a common system to arrange the task and activities that the manuals describe. For example, the PDP Manual describes an activity "Design Conference" in Chapter 5, "PS&E Development," Section 1, "Design Conference," and in more detail under "Conduct Design Conference." In the PS&E Preparation Manual the Design Conference can be found in Chapter 1, "Pre-Assembly Activities," Section 1, "Environmental, Design, Right-of-Way and Utility: Requirements and Value Engineering Studies." The Utility Manual describes the Design Conference in Chapter 2, "TxDOT-Utility Cooperative Management Process and Subprocess," Section 1, "TxDOT Utility Cooperative Management Process – The Process," and more specifically in "Design and Utility Construction Phase: Design Conference – Process Activity V." This issue is compounded by the lack of a common labeling system among manuals. In the case of "Design Conference," the PDP Manual enumerates the activity as "task 5020," the Utility Manual uses the label "Process Activity V," and the PS&E manual uses no numbering system at all.

In addition, the research team found that occasionally there are significant differences between descriptions of an activity in different manuals. A comparison of descriptions and recommended attendees using the above example, "Design Conference," illustrates this issue (Table 1).

Table 1. Comparison of Description and Recommended Attendees for Activity "Design Conference."

	PDP Manual	**PS&E Preparation Manual**	**Utility Manual**
Description	Review basic design parameters, concepts, criteria established during Preliminary Design Conference.	Informal meeting to discuss, establish, determine, and finalize agreements, design criteria, geometric design elements, schematic completion, surveying, right of way, and utility adjustments.	Forum to discuss potential utility impacts and promote cooperative solutions before development of more detailed preliminary design.
Attendees	Consult with director of transportation planning and development and area engineer to determine appropriate attendees.	Area engineer office staff; maintenance supervisor; staff directly involved with project, PS&E development, or primary review responsibilities.	Utility design representative, TxDOT design consultant, TxDOT design team, TxDOT utility liaison

It is evident that the description of "Design Conference" in the PDP and PS&E Preparation Manual focuses on the discussion of design issues, whereas the Utility Manual clearly centers on the discussion of utility impacts on design. The list of recommended conference attendees that the respective manuals provide further underlines this difference in perspective: Whereas PDP and PS&E Preparation Manual view the design conference essentially as a TxDOT internal meeting, the Utility Manual emphasizes the involvement of entities outside of TxDOT such as utility design representatives.

The shortage of information on the sequence and dependencies of tasks is a further limitation of the PDP Manual for its use to develop a business process model. This is in part due to the manual's effort to cover many project types, complexities, and potential tasks. However, the existing information about the sequence of tasks is incomplete at best. In its current version, only some sections of the PDP Manual provide an overview of the section's tasks along with just a general statement about the sequence of tasks covered, such as "these tasks may be performed concurrently" or "tasks are listed in approximate chronological order." In addition, no section overview contains information about sequencing of sections within a chapter, or the sequencing of chapters and sections in relation to other chapters and sections of the manual. For example, Section 4 of Chapter 4, "Utility Adjustments," contains five tasks that are "listed in approximate chronological order":

- 4610 Coordinate utility adjustment plans
- 4620 Prepare and execute utility adjustment agreements
- 4630 Utility owners adjust facilities
- 4640 Prepare utility clearance certifications
- 4650 Reimburse utility owners for eligible adjustment costs

The manual suggests an approximate chronological order, whereas in reality some tasks may occur concurrently, may be skipped, or may be performed in a different sequence. There is also no information about what pre-requisites are necessary for a task to start. Likewise, the manual does not provide any information about how these tasks relate to tasks from other sections. For example, there is no information on how task 4610, "Coordinate utility adjustment plans," relates to task 4400, "Obtain contractual agreements with local public agencies," in Section 3 of the same chapter. Similarly, the manual does not provide information about how sections from different chapters relate to each other, for example how Section 4 of Chapter 5, "Roadway Design," relates to Section 7, "Drainage Design," of the same chapter. There is also no information about how "Drainage Design" relates to "Utility Adjustments," which is Section 4 of Chapter 4. Further, there is no information available about how chapters relate to each other, for example how Chapter 4, "Right of Way Utilities," relates to Chapter 5, "PS&E Development." The underlying assumption that chapters and sections are listed in chronological order is not always accurate, as is evident in the example of "Right of Way Utilities" and "PS&E Development," which entail for the most part concurrent activities.

The PDP Manual provides additional "Critical Sequencing" information for about two-thirds of all tasks. However, this information is mostly impractical because it is typically unrelated to other tasks and does not reference task codes. Further, in some cases the information appears to be incongruous, consisting of a warning rather than information on a critical sequence of events, for example:

- "Delays may occur without proper coordination with the MPO and other stakeholders."

- "Request traffic data early."

- "If the project remains idle for three years, a re-evaluation may be required."

In some cases, this information was also repetitiously added under the category "Helpful Suggestions." In other cases, information provided in the "Critical Sequencing" category appeared to be a subtask, rather than information on task sequencing:

- "During the environmental document development stage, the purpose and need statement should be reviewed and updated as needed."

- "Preliminary design can be as simple as a line diagram showing proposed number of lanes, lane drops, and proposed overhead and large ground mounted, guide signs and their proposed locations."

- "Collect funding in accordance with provisions of the agreement."

In some cases, the sequencing information provided in this category was simply not very helpful to determine a recommended sequence of events, for example:

- "Revisions to the schematic are determined as the schematic is refined, hydraulic studies are performed, and a detailed Level of Service analysis is done."

- "Begin this task soon after determining its need to avoid project delay."

In summary, current sequencing information in the PDP Manual is sparse and limited to the sequence of tasks within a section.

DATA MANAGEMENT-RELATED PRACTICES AND PLANS

Document Archival Processes

The Texas State Records Retention Schedule included in the Texas Administrative Code documents minimum document retention schedules and requirements for state agencies (*15*). In addition, each state agency must submit a complete records retention schedule to the State and Local Records Management Division of the Texas State Library and Archives Commission. This records retention schedule 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 (*16*). Typically, districts retain construction and right of way project records for four years after closing a project (normally after the engineer in charge has accepted delivery of the finished construction project). Utility agreements, including utility agreements executed in districts using the local option, must be retained as long as administratively valuable for engineering and legal reference, with a minimum retention requirement of four years after project closing (*16*). After the retention period, most original records may be destroyed except for the following types of right of way documents (*17*):

- right of way conveyances,
- final right of way maps,

- title insurance policies, and
- other instruments pertaining to the state's title to land or interests therein.

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 (*15*). 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.

INFORMATION SYSTEMS RELATED TO UTILITY ACTIVITIES IN THE PDP

TxDOT uses several information systems to support the project development process, including DCIS and ROWIS. TxDOT districts have also developed information systems to help them with routine activities, including the Highway Project Task Management System and the San Antonio District Design and Construction Office (DCO) database. There are also several document management strategies that districts and divisions have implemented or are in the process of implementing. Of particular interest to this project are Bentley ProjectWise, DCIS, FileNet, and the San Antonio District's File Management System (FMS). A short description of systems relevant to utility activities in the PDP follows.

Bentley ProjectWise

ProjectWise is an electronic document management system that allows users to manage various project aspects. It is a client-server software application that runs on the Microsoft® Windows® platform with a similar look and feel of Microsoft Windows Explorer® (Figure 2). ProjectWise is geared to the engineering field and was designed to work with Bentley MicroStation V8. Files reside on a main server and are copied to a local drive for editing, which locks them for editing on the main server. After editing, the edited file is placed back on the server, and the local file is deleted to eliminate duplicate files. Like FileNet, ProjectWise manages files and provides querying and reporting capabilities. Unlike FileNet, ProjectWise includes tools and templates to automate the production of MicroStation drawings. It also retains the structure of MicroStation reference files.
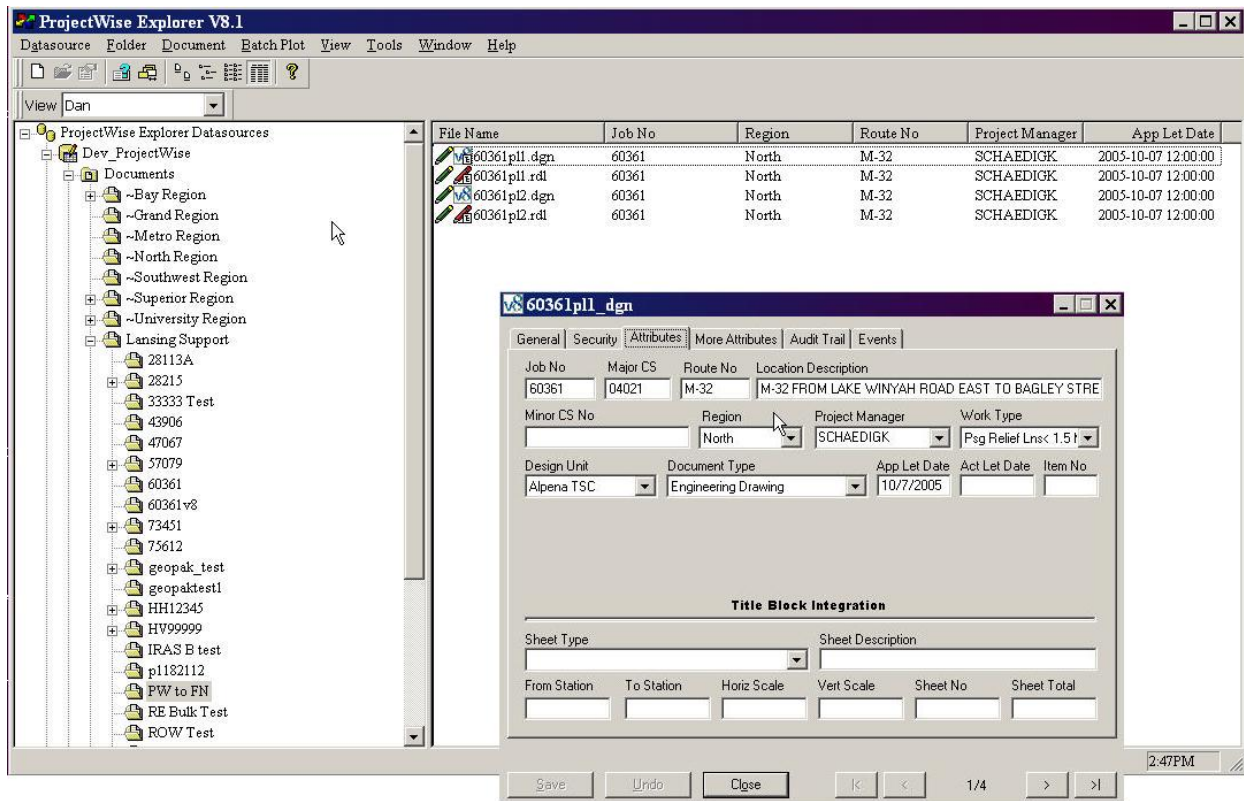
Figure 2. ProjectWise Sample Screenshots (*18*).

TxDOT is currently exploring the use of ProjectWise for management of engineering documents such as MicroStation computer aided design (CAD) drawing files through pilot implementation. TxDOT used ProjectWise successfully during the SH 130 design-build project in Central Texas, which managed over 32,000 files using about 22 gigabyte (GB) of hard drive space (*18*). TxDOT is evaluating the use of ProjectWise for engineering drawing file management. Efforts related to data architectures, models, specifications, file structures, and naming convention are in the early stages of development or have not yet started.

Design and Construction Information System

TxDOT uses the Design and Construction Information System to prepare projects for project specification and estimation development, contract letting, and to track projects throughout the project development process (*19*). The system contains project information such as work descriptions, funding requirements, and dates for proposed activities. DCIS relies on a Tables and Characteristics System (TACS) that contains lookup codes and project-specific files. DCIS uses the control section job (CSJ) number to identify projects uniquely. Each project has information in four key files as follows:

- File 121 - DCIS project information,
- File 122 - DCIS work program,

- File 123 - DCIS project estimate, and
- File 124 - DCIS contract letting.

Table 2 shows a sample of fields for each file. To access the system's data, DCIS provides a large number of project, contract, and utility screens that enable authorized users to complete data inputs and updates, run queries, and create 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. Figure 3 shows a copy of the DCIS project identification screen.

```
ADD MODE          PROJECT IDENTIFICATION (P1)   ENGLISH PROJECT   DCIS.02A
CTL-SEC-JOB 0000-00-001   HWY NO _____   DIST 10   CNTY GREGG        93_
BEG MILE POINT  _0.000  END MILE POINT  _0.000    PROJECT LENGTH MI  __0.000
BEG REF MARKER NUM  ___0  SUFFIX    _      DISPLACEMENT     __0.000
END REF MARKER NUM  ___0  SUFFIX    _      DISPLACEMENT     __0.000
LIMITS FROM    _____
       TO      _____       PROJ CLASS ___
TYPE OF WORK   _____   SPEC BOOK YEAR  93
LAYMANS DESC   _____
               _____
OVERSIGHT  S      PE MANAGER NUMBER   0__            LET SCH FY  ____  __
RESP. SECTION    ___      FUNCTIONAL CLASS  _    FED LETTER OF AUTH   __  _0 _0
                 **CONST**    ***ROW***   STATE LETTER OF AUTH        _0 _0
LATEST EST OF COST  0_____    0_____         UTP AUTHORITY    _
DATE OF LATEST EST  0  0  0     0  0  0    PRES DIST EST LET DATE   _0 _0
AUTHORIZED AMOUNT   0            TRUNK SYS    _    APPROVED LET DATE   _0 _0
CONTRACT CSJ        _____    NHS         _      ACTUAL LET DATE   _0 _0
OTHER PART          0         HURR EVAC RTE  _ PROJ NUM  _____
PROJECT ANCESTORS      _____ _____ _____ _____ _____
PROJECT DESCENDENTS _____ _____ _____ _____ ROW CSJ _____
REMARKS    _____
Enter-PF1---PF2---PF3---PF4---PF5---PF6---PF7---PF8---PF9---PF10--PF11--PF12--
     ID    FIN   EVAL   EST   SUM   PDP   STIP  COST              METR  MENU
```

Figure 3. DCIS Project Identification Screen (*19*).

DCIS has linkages with several TxDOT information systems, including 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), and the Construction and Maintenance Contract System (CMCS).

Table 2. 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

FileNet

FileNet is an enterprise content management system that enables users to share and manage access to files, generate database records to keep track of all documents processed, and produce queries and reports based on a number of attributes (*20*). FileNet resides on top of a database management system (DBMS) such as Oracle®, IBM® DB2®, or Microsoft Structured Query Language (SQL®) Server.

The Houston District started using FileNet in 1996 to track construction project as-built drawings, PS&E documents, and correspondence. TxDOT is currently implementing FileNet statewide using a separate implementation for each business unit within the organization. TxDOT's goal is to move from ad hoc procedures for managing electronic documents to a standard recordkeeping system for document management (*21*). The TxDOT implementation 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. Currently, TxDOT uses two FileNet configurations: a "thick-client" configuration, which requires a client application on user computers, and a "thin-client" configuration called TxDocsOnline, which is web based and uses a browser to interact with the database and the FileNet file server. The "thick-client" provides 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 (Figure 4). The TxDOT FileNet implementation does not support viewing Geographic Information System (GIS) or CAD documents, although this functionality is possible through third-party programs (*22*).

TxDOT's experience with the initial implementation of FileNet has led to the development of a TxDOT specific archiving standard described in the Content Services Library Standards document (*22*). This standard aims to facilitate the use and implementation of FileNet and describes the standards for FileNet libraries consisting of document classes, security parameters, folder settings, standard properties, and document properties. In addition, the standard provides appendices with property definitions, recommended property values, recommended record types, and document types for standard document classes.

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.
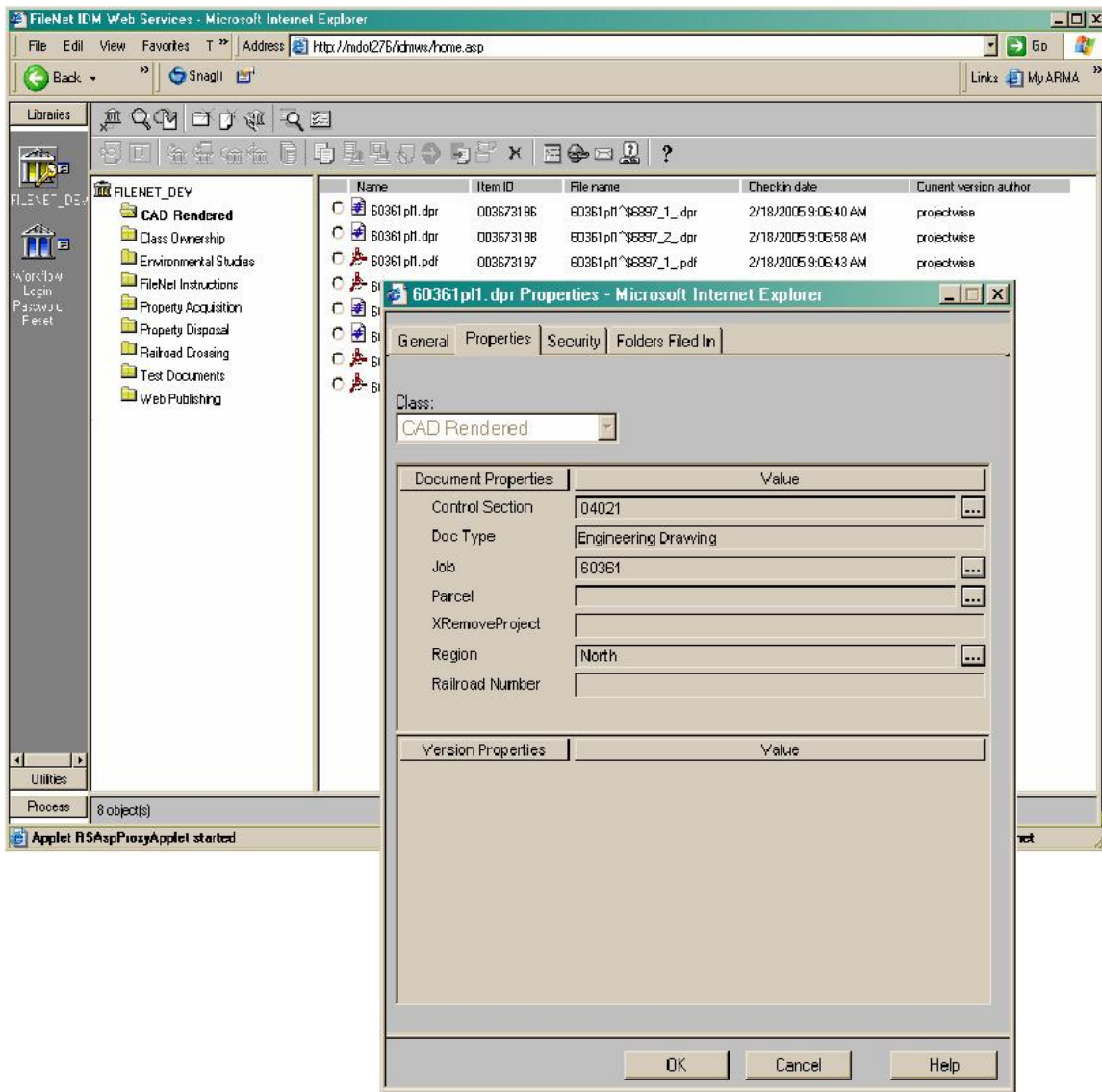
Figure 4. FileNet Sample Screenshots (*23*).

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 (*22*, *24*). Document classes represent the highest folder aggregation level, with one document class per library (Table 3). Document classes have record types, and record types have document types.

Table 4 shows a sample of record types for document type 15, "Right of Way," that pertains to utility conflict management. Each document class, record type, and document type has a numerical code (e.g., 13 for document class "Right of Way," 2 for record type "Easements," and 3 for document type "Drainage Easements"). The combination of the three numerical codes is a unique file code (e.g., 13.2.3) 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, which is not necessarily true for record types or document types. For example, the same record type may have different numerical codes in different document classes. This situation makes it more difficult to use generic lookup tables that index record types and document types to specify the file code.

Table 3. Document Classes in the TxDOT FileNet Implementation (Adapted from *22*).

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

Table 4. Sample of Record Types and Document Types of the "Right of Way" Document Class (Adapted from *22*).

Document Class	Record Type	Document Type	File Code
Right of Way	Certifications	Utility	13.1.4
Right of Way	Easements	Drainage Easement	13.2.3
Right of Way	Easements	Release of Easement	13.2.4
Right of Way	Easements	Request for Easement	13.2.5
Right of Way	Easements	Temporary Easement	13.2.6
Right of Way	ROW Map	Map	13.12.1
Right of Way	ROW Releases	Funding	13.13.1
Right of Way	ROW Releases	Map	13.13.2
Right of Way	ROW Releases	Minute Order	13.13.3
Right of Way	ROW Releases	Payment	13.13.4
Right of Way	ROW Releases	Property Description and Plat	13.13.5
Right of Way	ROW Releases	Resolution	13.13.6
Right of Way	ROW Releases	ROW Release	13.13.7
Right of Way	ROW Releases	Schematic	13.13.8
Right of Way	Utility Accommodation	Adjustment	13.18.1
Right of Way	Utility Accommodation	Affidavit	13.18.2
Right of Way	Utility Accommodation	Compensable Interest Certificate	13.18.3
Right of Way	Utility Accommodation	Consultant Contract Review	13.18.4
Right of Way	Utility Accommodation	Correspondence	13.18.5
Right of Way	Utility Accommodation	Cost Estimate	13.18.6
Right of Way	Utility Accommodation	Date of Eligibility Request	13.18.7
Right of Way	Utility Accommodation	Determination of Eligibility	13.18.8
Right of Way	Utility Accommodation	Funding	13.18.9
Right of Way	Utility Accommodation	Layout Schematic or Drawing	13.18.10
Right of Way	Utility Accommodation	Letter of Authority	13.18.11
Right of Way	Utility Accommodation	Meeting Minutes and Notes	13.18.12
Right of Way	Utility Accommodation	Notice or Notification	13.18.13
Right of Way	Utility Accommodation	Plan	13.18.14
Right of Way	Utility Accommodation	Relocation	13.18.15
Right of Way	Utility Accommodation	Specification	13.18.16
Right of Way	Utility Accommodation	SUE Deliverable	13.18.17
Right of Way	Utility Accommodation	SUE Media Information Form	13.18.18
Right of Way	Utility Accommodation	Survey	13.18.19
Right of Way	Utility Accommodation	Utility Conflict Check	13.18.20
Right of Way	Utility Accommodation	Utility Coordination	13.18.21
Right of Way	Utility Accommodation	Utility Easement	13.18.22
Right of Way	Utility Accommodation	Utility Exception Request	13.18.23
Right of Way	Utility Accommodation	Utility Standard Sheet	13.18.24

Highway Project Task Management System

DCIS contains a wealth of information but resides on a mainframe in a format that limits the access of potential users. The Corpus Christi District has developed a Microsoft Access-based application, called HPTMS, to interact with DCIS. The system is able to download data from DCIS and transfer it to a relational database management system (RDBMS) using Statistical Analysis Software (SAS) scripts. However, the connection operates only in one direction; there is no upload link that would enable HPTMS to upload or update DCIS data. The system allows the user to generate various reports, such as project development schedule, list of projects to be

let, list of projects actually let, 3-year project letting list, list of projects with consultant work, and many others. Figure 5 shows a screenshot of the system.

Figure 5. Corpus Christi District Highway Project Task Management System Screenshots.

San Antonio Construction Project Database

The San Antonio District makes use of the data provided by the HPTMS system in its DCO database, also called the San Antonio Construction Project Database (Figure 6 and Figure 7). The DCO database is used to track change orders, subcontractors, final estimate processing times, claims/disputes, contract acceleration strategies, and others (*25*). Most of the data is entered manually into the system except for pre-construction data, which is downloaded from HPTMS. The San Antonio District shares the data throughout the district and all area offices using a read-

only version of the database. The San Antonio District plans to expand the DCO database to transfer construction data from SiteManager in the future.
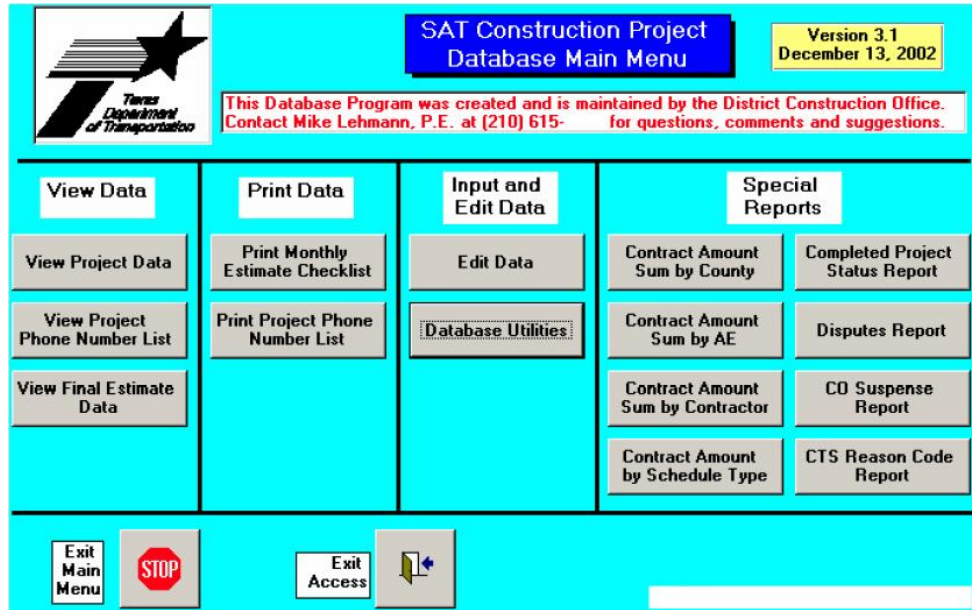
Figure 6. San Antonio District DCO Database Screenshot (*25*).
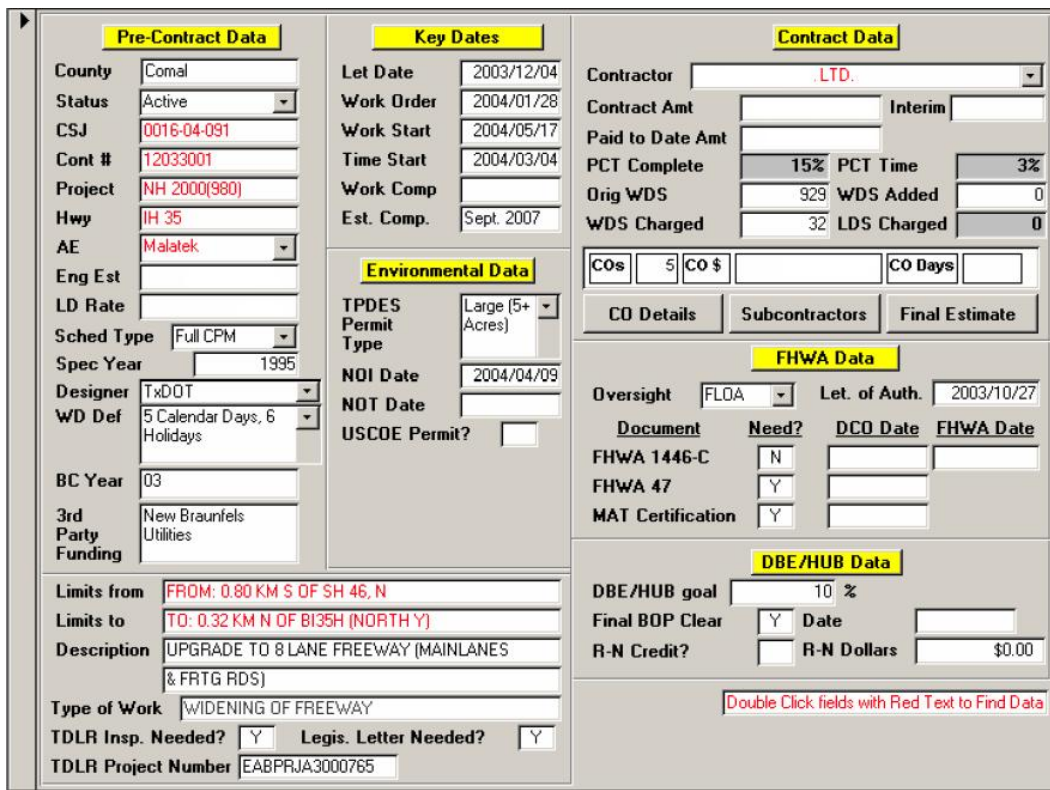
Figure 7. San Antonio District DCO Database "Project Data Entry" Screenshot (*25*).

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 (*26*). 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 8). 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 5 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 5. Plans Online Project and Document Attributes (*26*).

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	
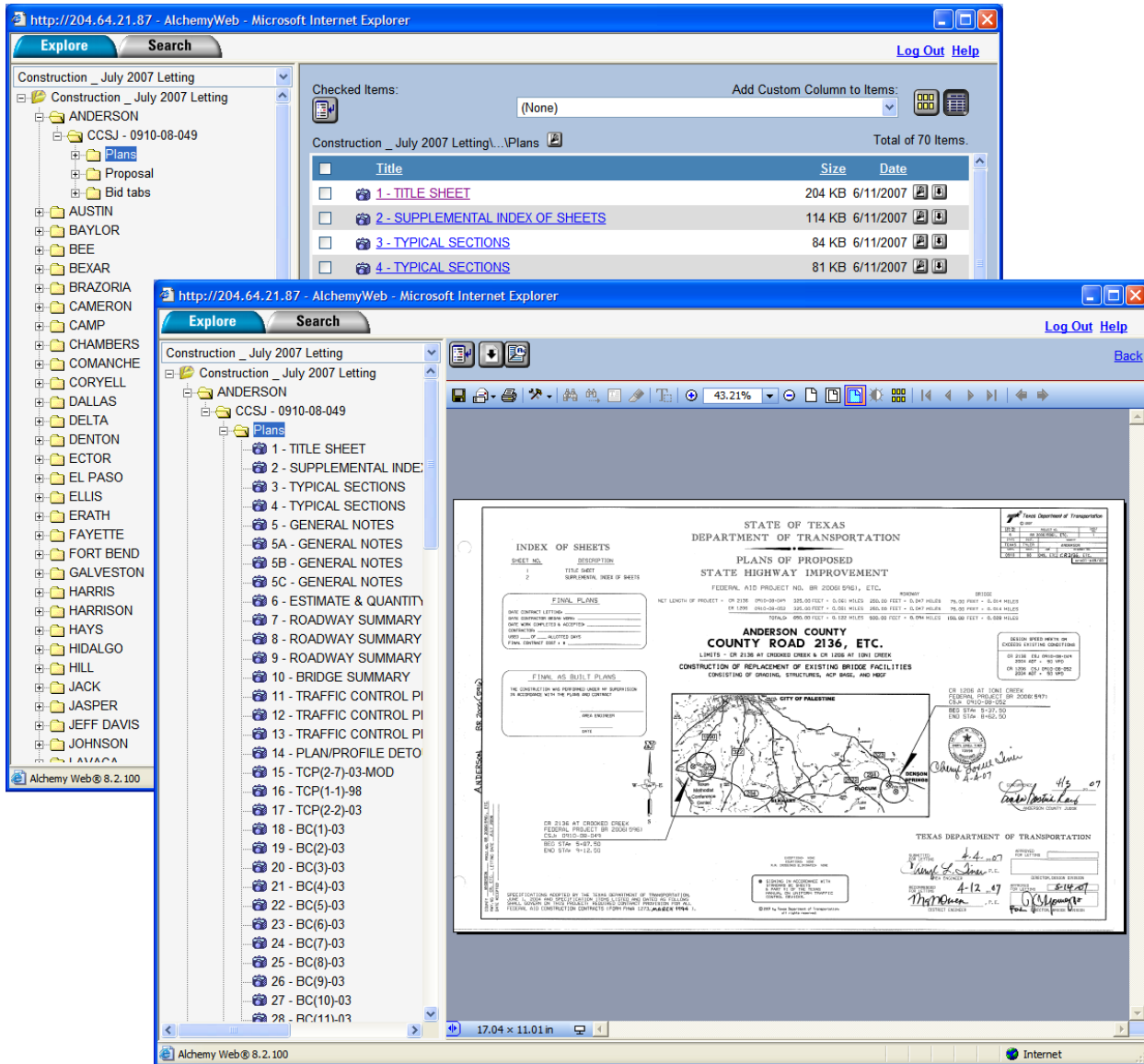
Figure 8. Plans Online Interface (*26*).

Right of Way Information System (ROWIS)

The ROW Division implemented ROWIS in 1997 to track and report financial data of property acquisitions throughout the right of way acquisition process (*27*). The system enables users to capture, track, and report on property acquisition processes such as right of way parcel development during negotiations, settlements, or eminent domain proceedings. Although ROWIS was not designed to accommodate the utility coordination process, the Right of Way Division currently uses ROWIS to track reimbursable utility agreement payments by creating parcel records in ROWIS to represent utility agreements. Figure 9 is a screenshot of the ROWIS application.
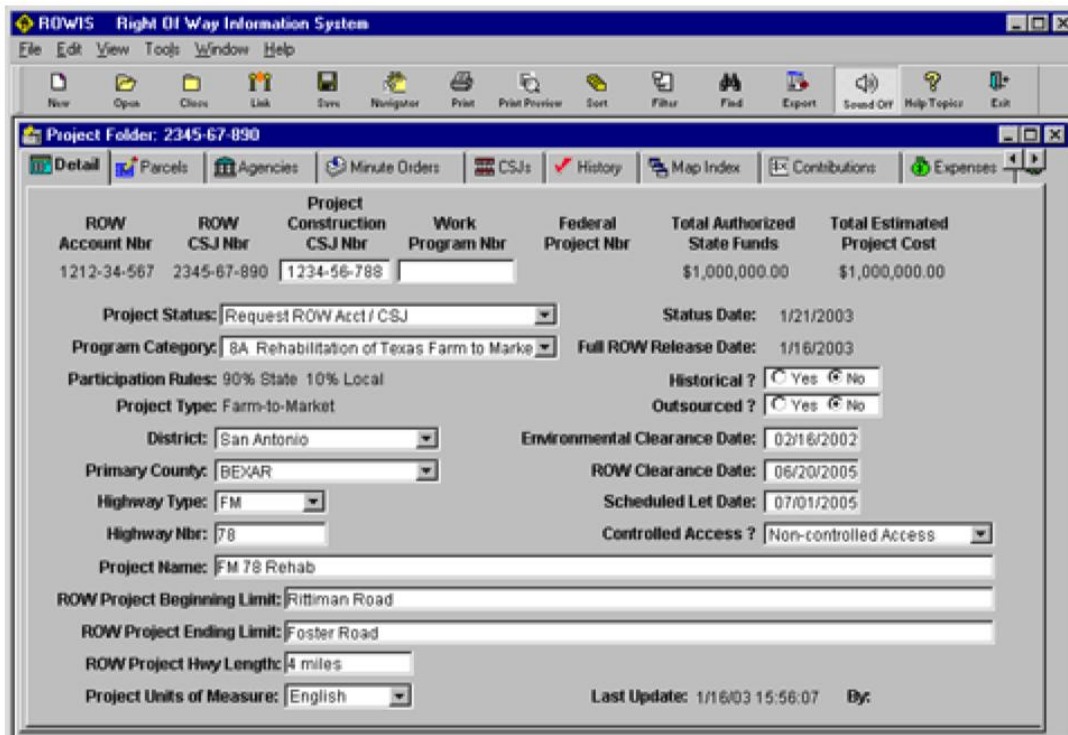
Figure 9. ROWIS Screenshot.

ROWIS runs on a Microsoft SQL Server database platform. Table 6 provides a listing of ROWIS database tables. Figure 10 shows a high-level representation of the ROWIS logical data model that only includes the most relevant entities. The system interface includes screens to display or query data on topics such as projects, parcels, tasks, owners, CSJ numbers, minute orders, and public agencies. A description of the core entities in ROWIS (Parcels, Projects, and Control Section Jobs) follows:

- **Parcels**. The Parcels entity contains attributes that describe property parcels, such as description, appraised value, acquisition status, and several dates including possession date, parcel release date, and total paid date. The primary key in Parcels is Parcel ID (which is also a foreign key in entities Projects, Agencies, Control Section Jobs, and Associates).

- **Projects**. The Projects entity includes attributes that characterize a project including project type code, beginning and ending limits, project CSJ, right of way CSJ, and several date attributes such as estimated letting date or right of way clearance date. The primary key in Projects is Project ID (which is not the same as project CSJ or right of way CSJ). Project ID is a foreign key in entities Parcels, Control Section Jobs, and Agencies. In Projects, the right of way CSJ and right of way account number attributes are inversion entry keys (i.e., they are frequently accessed non-unique attributes).

- **Control Section Jobs**. The Control Section Jobs entity includes attributes that provide additional information about projects, including project CSJ, CSJ type, project limits, and federal funding eligibility. The primary key in Control Section Jobs is CSJ ID, which is

not the same as the project CSJ. CSJ ID provides a linkage between Control Section Jobs and Parcels through the many-to-many entity Control Section Jobs Parcels.

Table 6. List of Database Tables in ROWIS.

AGENCIES	INVOICES	PBCATVLD
APPRAISALS	INVOICES TASKS	PROJECTS
APPRAISED ITEMS	LEGAL NAMES	PRSNL PROP MOVES
ASSOCIATES	LOGIC DRILLDOWN	QUALIFICATIONS
ASSOCIATES DISTRICTS	LOGIC HELP	RENTAL SUPPLEMENTS
ASSOCIATES TASKS	LOGIC LINK	REPORTS SCHEDULED
ASSOCTASK DISPLACEE	LOGIC SEARCH	RESIDENTIAL MOVES
AUDIT LOG	LOGIC WINDOW	ROWIS STATS
CACHE CONTROL	LOGIC WINDOW CONTROL	SECURITY APPS
COMMENTS	MAP SHEET INDEX	SECURITY GROUPINGS
COMPONENTS	MESSAGES	SECURITY INFO
CONTROL SECTION JOBS	MINUTE ORDERS	SECURITY TEMPLATE
CONTROL SECTION JOBS PARCELS	MINUTE ORDERS PARCELS	SECURITY USERS
DISPLACEE	MINUTE ORDERS PROJECTS	SEGMENTS
DISPLACEE DOCUMENTS	NEW ROWIS LOGINS	SEQUENCE NBRS
DOCUMENTS	NON RESIDENTIAL MOVES	STATUS VALUES
ENCUMBRANCES	PARCELS	TASKS
ESTIMATED EXPENSES	PARTICIPATING AGENCIES	TEMP ASSOCIATES TASKS REF
EVENT HISTORY	PARTICIPATING AGENCIES DEPOSIT	TEMP OWNER REFERENCE
EXP CATG CD	PARTICIPATING AGENCIES PARCELS	TEMP PARCEL REFERENCE
EXP TYPE CD	PAYMENT ERRORS	TEMP PROJ PARCEL REFERENCE
FORMS	PAYMENTS	TXDOT DISTRICTS
HOUSING SUPPLEMENTS	PBCATCOL	TYPE CODES
IMPROVEMENTS	PBCATEDT	WORKORDERS
INTEREST OWNERS	PBCATFMT	WORKORDERS TASKS
INTEREST OWNERS ITEMS	PBCATTBL	
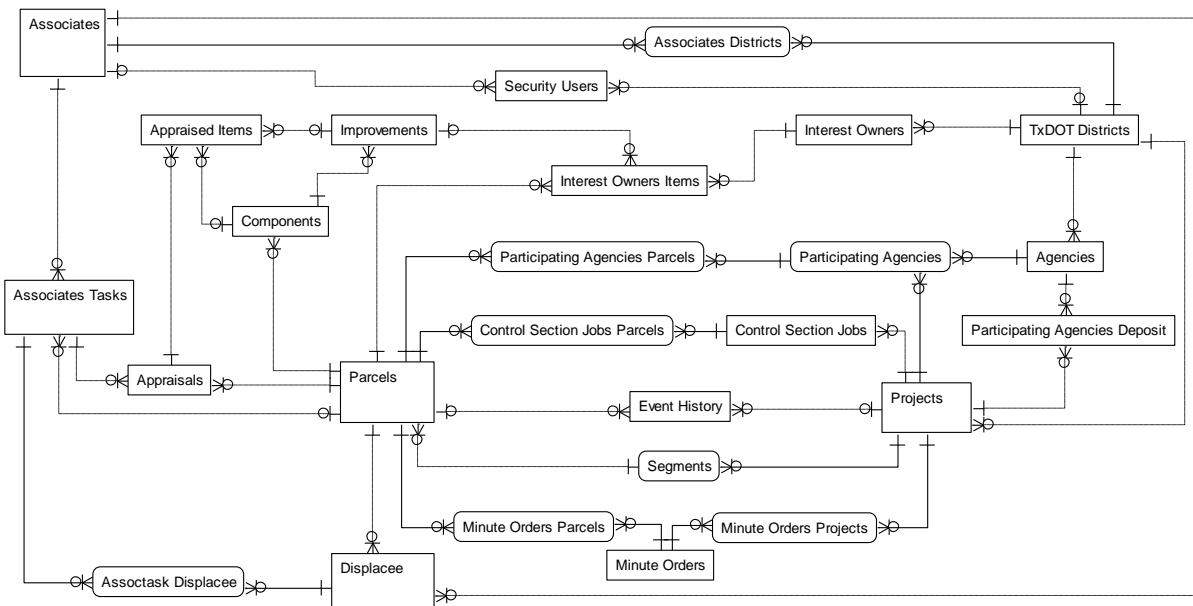
Figure 10. ROWIS High-Level Logical Data Model.

ROWIS uses data produced and managed in DCIS, such as CSJ numbers, federal project number, project limits, and authorized funds. ROWIS is not integrated with DCIS, which means that DCIS data must be manually entered into ROWIS. Data synchronization issues arise when there are data updates in DCIS, since a ROWIS project manager must make the same change in ROWIS manually.

The main function of ROWIS is to support TxDOT's right of way acquisition process. It provides very little support for the management and inventory of right of way assets after the conclusion of the acquisition process. In addition, ROWIS does not have functionality to display (or to provide a link to) right of way parcels or utility adjustments on a map. In fact, the Parcels entity in ROWIS does not contain any spatial data except for a general description of the physical location of the parcel. ROWIS is not compatible with the GIS Architecture and Infrastructure Project (GAIP) and cannot make data available to TxDOT users through Main Street Texas (MST).

For the development of the prototype utility conflict management system, the researchers envision a connection of the data architecture with ROWIS to enable data sharing and reduce data redundancy. The link between the two architectures is an entity called ROWIS CONNECTION, which minimizes the need for changes to the ROWIS architecture. The Project Subject Area in Chapter 5 provides a more detailed discussion of this construct.

Right of Way Division Utility Agreement Database

The Utility Agreement Database (UAD) is a Microsoft Access database the TxDOT ROW Division uses to track payments and billings associated with utility agreements of reimbursable utility adjustments. The TxDOT ROW Division developed the UAD as a temporary solution to provide capabilities to track billing information for reimbursable utility agreements that are currently not implemented in ROWIS. Although the UAD is an extension of functionality that ROWIS does not currently provide, there are no physical connections between the two systems. As such, any project, parcel, or owner-related information must be manually duplicated in the UAD.

The ROW Division provided a copy of the database to the research team. The researchers analyzed the database and created a logical data model of the database in Computer Associates® AllFusion ERwin® Data Modeler (now available as CA® ERwin® Data Modeler) (Figure 11). The researchers then modified the data model to ensure compliance with TxDOT data architecture standards. In the last step, the researchers integrated the standard compliant model into the logical data model of the prototype system for the management of utility conflict data called Utility Accommodation and Conflict Tracker (UACT).

The UACT data model provides the complete functionality of the UAD that is currently in use at the ROW Division. As a result, a future implementation of UACT would render the UAD obsolete. However, this does not address the issue that currently, some of the billing data related to utility agreements must be entered both into ROWIS and into the UAD. Depending on the level of integration that will be feasible between UACT and ROWIS, billing and payment data should only be entered in one of the two systems and then referenced and displayed in the other as needed.

UTILITY
–
REVIEWER
UNUMBER
UTILITY NAME
TYPE OF COUNTY
COUNTY
ROW ACCOUNT 1
ROW ACCOUNT 2
ROW CSJ1
ROW CSJ2
CONSTRUCTION CSJ
BILLED AMOUNT
ROW 120 ESTIMATE
INITIAL ESTIMATE
INITIAL ESTIMATE DATE
AGREEMENT ESTIMATE
EXCEPTION AMOUNT
TOTAL PAID
BETTERMENT PERCENT
SALVAGE GIVEN
ELIGIBILITY RATIO
ROW CHARGES
DATE OF ELIGIBILITY
ROW RECEIVE DATE
ROW RECEIVE YEAR
REVIEW BEGIN DATE
ROW APPROVAL DATE
BILL RECEIVE DATE
AUDIT TRANSFER DATE
AUDIT DATE
PRIOR RIGHT
REIMBURSABLE ADJUSTMENT FLAG
UJUA NEED FLAG
QUITCLAIM NEED FLAG
UAR EXCEPTION DATE
UAR EXCEPTION FLAG
FORM 48 NEED FLAG
CTUC FLAG
CONSULTANT CHARGES FLAG
COMMENT
FINAL PAYMENT DATE
ADJUSTMENT TYPE
ADJUSTMENT CODE
COMPANY CODE
COMPANY MAIL CODE
CONSULTANT CHARGES
ROW CHARGES AMOUNT
ESTIMATED SALVAGE AMOUNT
UJUA APPROVAL DATE
PAYMENT AMOUNT 1
PAYMENT AMOUNT 2
PAYMENT AMOUNT 3
PAYMENT AMOUNT 4
PAYMENT AMOUNT 5
PAYMENT AMOUNT 6
PAYMENT DATE 1
PAYMENT DATE 2
PAYMENT DATE 3
PAYMENT DATE 4
PAYMENT DATE 5
PAYMENT DATE 6
PAYMENT AMOUNT FISCAL YEAR 1
PAYMENT AMOUNT FISCAL YEAR 2
PAYMENT AMOUNT FISCAL YEAR 3
PAYMENT AMOUNT FISCAL YEAR 4
PAYMENT AMOUNT FISCAL YEAR 5
PAYMENT AMOUNT FISCAL YEAR 6
DISTRICT APPROVAL NUMBER
UPPER LIMIT AMOUNT
UPPER LIMIT DATE
EXCEPTION RECEIVE DATE
EXCEPTION RESOLUTION DATE
RETURN DISTRICT DATE
HIGHWAY NUMBER
DATE OF ELIGIBILITY ESTIMATE DATE
DATE OF ELIGIBILITY COST ESTIMATE AMOUNT
ESTIMATE AGREEMENT DATE
ADJUSTMENT START DATE
ESTIMATED ELIGIBILITY RATIO AT DATE OF ELIGIBILITY NUMBER
CONSTRUCTION PROJECT LETTING DATE
ACTUAL AGREEMENT SUBMITTAL DATE
ACTUAL ADJUSTMENT COMPLETION DATE
ALTERNATE PROCEDURE DATE
DATE OF ELIGIBILITY FISCAL YEAR 1 NUMBER
DATE OF ELIGIBILITY FISCAL YEAR 1 ESTIMATE AMOUNT
DATE OF ELIGIBILITY FISCAL YEAR 2 NUMBER
DATE OF ELIGIBILITY FISCAL YEAR 2 ESTIMATE AMOUNT
DATE OF ELIGIBILITY FISCAL YEAR 3 NUMBER
DATE OF ELIGIBILITY FISCAL YEAR 3 ESTIMATE AMOUNT
DATE OF ELIGIBILITY FISCAL YEAR 4 NUMBER
DATE OF ELIGIBILITY FISCAL YEAR 4 ESTIMATE AMOUNT
DATE OF ELIGIBILITY ALL FISCAL YEAR TOTAL AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 1 AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 1 ESTIMATE AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 2 AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 2 ESTIMATE AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 3 AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 3 ESTIMATE AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 4 AMOUNT
TOTAL AGREEMENT ESTIMATE FISCAL YEAR 4 ESTIMATE AMOUNT
TOTAL AGREEMENT ESTIMATE ALL FISCAL YEAR TOTAL AMOUNT
FISCAL YEAR 1 BILLED AMOUNT
FISCAL YEAR 1 BILLED AMOUNT 2
FISCAL YEAR 2 BILLED AMOUNT
FISCAL YEAR 2 BILLED AMOUNT 2
FISCAL YEAR 3 BILLED AMOUNT
FISCAL YEAR 3 BILLED AMOUNT 2
FISCAL YEAR 4 BILLED AMOUNT
FISCAL YEAR 4 BILLED AMOUNT 2
ALL FISCAL YEAR TOTAL BILLED AMOUNT
SUBSEQUENT ENCUMBRANCE NUMBER
FEDERAL ROW PROJECT NUMBER
SALVAGE AMOUNT
LATEST ESTIMATE AMOUNT
LATEST ESTIMATE DATE
ACCRUED DEPRECIATION AMOUNT
ADJUSTMENT DURATION DAYS NUMBER
REIMBURSABLE ADJUSTMENT DATE
UJUA NEED DATE
QUITCLAIM NEED DATE
UTILITY CLOSED DATE
DISTRICT NAME (FK)

ROW FUNDING TYPE
ROW FUNDING TYPE NAME

ROW CONTRACT TYPE
ROW CONTRACT TYPE ID
ROW CONTRACT TYPE NAME

UTILITY REVIEWER
UTILITY REVIEWER ID

NON REIMBURSABLE UJUA
UTILITY UJNR RECORD NUMBER
UTILITY UJNR UNUMBER
UTILITY UJNR REVIEWER
UTILITY UJNR NAME
UTILITY UJNR ROW NUMBER
UTILITY UJNR CSJ NUMBER
UTILITY UJNR DISTRICT
UTILITY UJNR HIGHWAY
UTILITY UJNR LIMITS FROM
UTILITY UJNR LIMITS TO
UTILITY UJNR DATE IN
UTILITY UJNR DATE OUT
UTILITY UJNR APPROVAL DATE
UTILITY UJNR TYPE ADJUSTMENT
UTILITY UJNR RETURN DISTRICT

ROW PROJECT
ROW ACCOUNT NUMBER
HIGHWAY NUMBER
ROW CSJ NUMBER
ROW RELEASE DATE
ROW FUNDING
ROW AP DATE
FIMS IDENTIFIER
ROW COMMENTS
ROW CONTRACT DATE
ROW CONTRACT TYPE

UTILITY COMPANY
UTILITY COMPANY NAME

EXCEPTIONS
EXCEPTION NUMBER
EXCEPTION UTILITY NAME
EXCEPTION COUNTY NUMBER
EXCEPTION ROW CSJ NUMBER
EXCEPTION CONSTRUCTION CSJ NUMBER
EXCEPTION ROW ACCOUNT NUMBER
EXCEPTION HIGHWAY NUMBER
EXCEPTION LIMITS FROM
EXCEPTION LIMITS TO
EXCEPTION TYPE
EXCEPTION APPROVED
EXCEPTION REVIEWER
EXCEPTION COMMENTS

UTILITY BILLING LOG
UTILITY BILLING RECORD
U NUMBER
UTILITY BILLING DATE IN
UTILITY BILLING DATE OUT
UTILITY BILLING NO
UTILITY BILLING AMOUNT
UTILITY BILLING COMMENTS
UTILITY BILLING REVIEWER
DISTRICT
UTILITY NAME
PROJECT NUMBER
PROJECT CSJ
ADMINISTRATIVE CITATION

EXCEPTION TYPE
EXCEPTION TYPE NAME

COUNTY
COUNTY NAME
COUNTY NUMBER
DISTRICT NUMBER
COUNTY TYPE

ADJUSTMENT TYPE
UTILITY ADJUSTMENT TYPE NAME
UTILITY ADJUSTMENT CODE
UTILITY ADJUSTMENT TYPE REVIEW NEED

COUNTY TYPE
COUNTY TYPE ID

CLOSEOUT
UTILITY CLOSEOUT ROW ACCOUNT NUMBER
UTILITY CLOSEOUT COUNTY
UTILITY CLOSEOUT CSJ
UTILITY CLOSEOUT UNUMBER LIST
UTILITY CLOSEOUT DATE PROCESSED
UTILITY CLOSEOUT REVIEWER

UTILITY PARK
UTILITY PARK RECORD
UNUMBER
UTILITY PARK DATE IN
UTILITY PARK DATE OUT
UTILITY PARK CODE
UTILITY PARK COMMENTS
UTILITY PARK REVIEWER
UTILITY PARK DISTRICT
UTILITY PARK UTILITY NAME

UTILITY PARK CODE
UTILITY PARK CODE

FIMS IDENTIFIER
FIMS ID

DISTRICT
DISTRICT NAME
DISTRICT NUMBER
DISTRICT ABBREVIATION

Figure 11. ROW Division Utility Agreement Database Data Model.

San Antonio District File Management System

The San Antonio District FMS is a systematic arrangement of folders, files, and procedures to create uniformity in project development and documentation (*28*). FMS includes a project folder structure, primary and secondary project files, MicroStation libraries, and embedded quantity spreadsheets, which link quantity estimate spreadsheets to CAD files with quantity summaries. FMS relies on a file 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. The manager is the only person who accesses and makes changes to the primary files.

FMS stores all electronic files associated with a project in a root folder with the project's CSJ number. Each CSJ folder contains 25 subfolders that sort project files into functional areas, such as pavement design, roadway, standards, survey, traffic control plan, etc. For each project, there are 11 primary files, which are files that are attached as references to the secondary files (Table 7). To minimize erroneous modifications, only the file manager can access the primary files.

Table 7. FMS Primary File Types (*28*).

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

Texas Reference Marker System

The Texas Reference Marker (TRM) System is a mainframe-based system that documents physical and performance characteristics of the state-maintained highway network using the statewide reference marker network (Figure 12) as a geo-referencing tool (*29*). 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). The Transportation Planning and Programming Division at TxDOT (TPP) produces a variety of data files based on TRM, e.g., the Roadway/Highway Network Inventory (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.
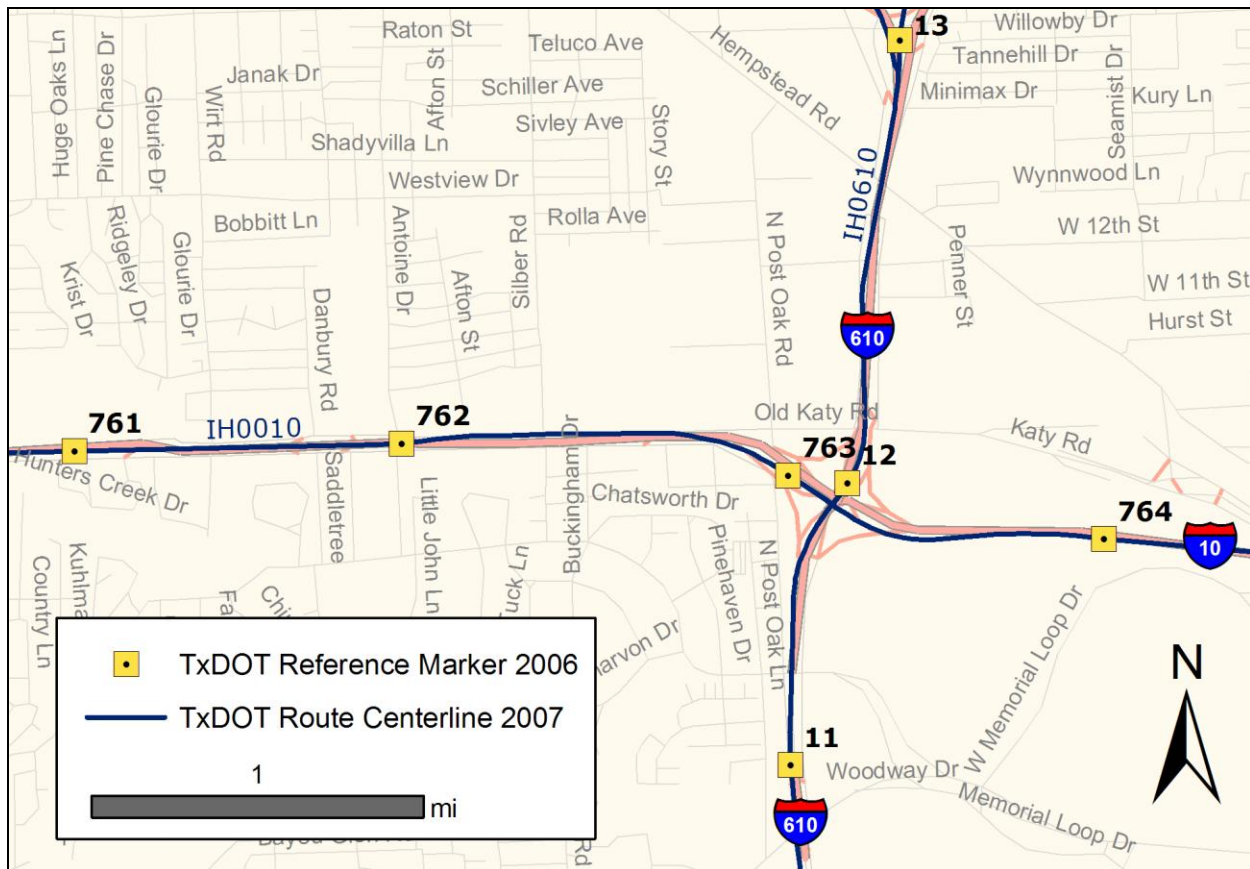
Figure 12. Reference Markers on the State Highway Network at the Intersection of Interstates 10 and 610 in Houston.

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 beginning and ending of a utility line or project limits) cannot be better than the positional accuracy of the underlying centerline map. 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. As a result, it is very difficult to determine the actual location of features using cumulative distances alone.

As an illustration, Figure 13 shows the location of reference marker 492 at FM 1516 and FM 1976 in Converse east of San Antonio. Although the reference marker is physically attached to a sign on the roadside (shown in blue), the reference markers in the GIS files (shown in green and yellow) are located on the map representation of the 2002 centerline of FM 1516 (red line). The reasoning behind this system is that in TRM all measures are given as displacements from the nearest reference marker *along* the highway centerline. As a result, in TRM, the representations of all 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.
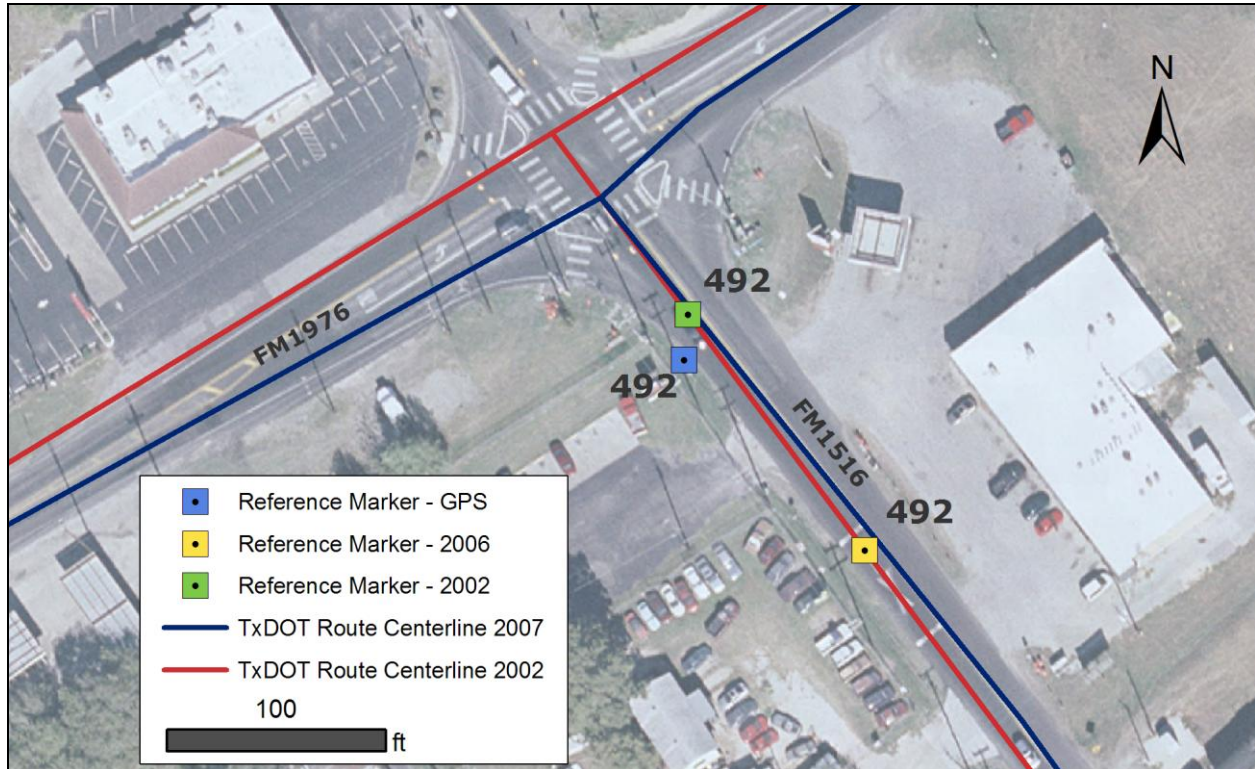
Figure 13. Reference Marker 492 on FM 1516.

If the cumulative distance associated with a reference marker along the centerline of a route is correct, the only error in the location of the reference marker is the offset (or lateral displacement) between reference marker and roadway centerline. As a result, errors associated with a measure involving the reference marker would also be limited to the offset. Unfortunately, the total location error is potentially much larger because of measurement errors associated with longitudinal distances. Figure 13 contains two representations of the TxDOT centerline network (2002 and 2007) and two corresponding representations of reference marker 492. As a reference, Figure 13 also shows the actual location of reference marker 492 on the ground (collected with a meter-level accuracy Global Positioning System [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 2007 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. Notice further that in the 2007 version the

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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 2007 location. It is also not possible to explain why the 2007 version of the reference marker was not defined relative to the 2007 version of the centerline map. In any case, this example gives an indication of the level of accuracy that a user of the TRM System could expect.

GEOGRAPHIC INFORMATION SYSTEM PRACTICES AND PLANS

There are several GIS initiatives in Texas that TxDOT is involved with or supports. These initiatives, under the guidance of the Texas Geographic Information Council (TGIC), include the Texas Base Map Initiative, the Enterprise GIS Initiative, and the Critical Infrastructure Mapping and Emergency Preparedness Initiative. Under the Texas Base Map Initiative, TxDOT created the transportation layer for the Texas Strategic Mapping Program (StratMap), which is available through the Texas Natural Resources Information System (TNRIS). Other contributors to the transportation dataset include municipal, county, and regional agencies. Table 8 provides a summary of production GIS datasets at TxDOT, with an indication of the source (TxDOT or other agency).

Table 8. Production GIS Datasets at TxDOT (*30*).

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

The traditional approach to develop GIS databases along highway networks involves the use of distances along those networks and abstract—usually centerline—representations of the network to map the features, referred to as linear referencing system (LRS). A limitation of this approach is that the positional accuracy of the resulting features is limited by the accuracy of both the underlying highway map and the cumulative distances measured along those routes. To address these limitations, transportation agencies are increasingly relying on absolute location approaches that provide independence from the highway network. Linear referencing is still

useful to enable post-mapping of absolute locations into linear measures that are consistent with referencing systems, such as control section (CS), distance from origin (DFO), and TRM (*31*).

TxDOT GIS Architecture and Infrastructure Project

Transportation agencies are also experimenting with strategies to better handle temporal events in their inventory databases, as well as web-based online transaction and analytical processing (OLTP/OLAP), and GPS. TxDOT has embarked on an initiative to establish a "second generation" enterprise framework for GIS at TxDOT called GAIP (*32*). GAIP includes the establishment of a roadbed LRS, a roadbed specific base map, required computer platforms, and hardware and software components, as well as standards for application development tool sets and databases. The main goals of GAIP are to enable the integration of absolute location measures and relative location measures, facilitate route re-alignment and re-measurement, and facilitate temporal and spatial querying. This approach facilitates versioning control, backup, and recovery and makes monitoring feature life cycles in the database much more tractable. In the GAIP architecture, a feature can be any managed object within the ROW. Examples include roadbeds, pavement markings, pavement condition, highway signs, drainage features, ROW, and geopolitical boundaries.

The GAIP architecture replaces the traditional method of linear referencing or dynamic segmentation with a method called dynamic location. With dynamic segmentation, feature attribute tables defined by from/to values are necessarily associated with a route cartography. An attribute query results in a potential relational join between attribute tables and a segmentation of the route cartography. By comparison, with dynamic location, attribute tables contain all the attribute values (both spatial and non-spatial) that make up that feature at any specific point in space and time (Figure 14). With dynamic location, it is no longer necessary to store route information in the attribute table. Instead, a spatial query enables the translation from absolute locations to linear referencing data element (i.e., cartographic roadway and roadbed centerlines).

Route	From	To	Length	Treatment	Date
66	0	20	20	Sub-Grade	01/01/1990
66	0	10	10	Aggregate Base	02/03/1990
66	10	20	10	Aggregate Base	02/22/1990
66	0	8	8	Initial Pavement	03/01/1990
66	8	20	12	Initial Pavement	04/01/1990
66	0	20	20	RPM	05/01/1990
66	2	7	5	Single Chip	10/19/1995
66	16	20	4	Double Chip	03/15/1998
66	4	12	8	RPM	04/15/1998
66	8	13	5	Crack Sealing	01/20/2000
66	2	15	13	Single Chip	10/10/2001
66	2	20	18	RPM	11/11/2001

"Traditional" Relational Approach

Blob	Treatment	Date
	Sub-Grade	01/01/1990
	Aggregate Base	02/03/1990
	Aggregate Base	02/22/1990
	Initial Pavement	03/01/1990
	Initial Pavement	04/01/1990
	RPM	05/01/1990
	Single Chip	10/19/1995
	Double Chip	03/15/1998
	RPM	04/15/1998
	Crack Sealing	01/20/2000
	Single Chip	10/10/2001
	RPM	11/11/2001

"GAIP" Spatial Object Approach

Figure 14. Traditional and GAIP Approaches to Linear Referencing (*33*).

Using GAIP, a change to a feature (either spatially or non-spatially) is managed by "retiring" the old feature and, as needed, generating 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 indicating the completion of the life cycle for that feature. Note that the new feature receives a new object ID. As a result, it is not possible to associate the old and the new feature using the object ID. The only way to associate the two features is through a spatial query, since the new feature will still occupy the same location of the old feature. Figure 15 provides an example of how GAIP handles new features and changes to existing features.

Figure 15 illustrates the use of GAIP using the example of a GAIP compliant traffic control device inventory. In three images, Figure 15 shows an intersection in the years 2004, 2006, and 2008 and the change in use of traffic control devices. Underneath each image, the figure shows a simplified database table with records corresponding to the image above. In 2004, two stop signs with wooden poles (number one and two) were installed at the intersection, and

correspondingly, two records were created in the database with IDs 100 and 200 and the same start date (the stop sign installation date). The end date field was not populated. In 2006, the intersection was converted to a four-way stop, and two additional stop signs with wooden poles were added to the intersection. The database table below the 2006 image shows two new records with IDs 300 and 400 and a start date of 01/09/2006, and the end date remained again not populated. In 2008, stop signs number one and two installed in 2004 received new metal poles. Using the GAIP structure, two new records were created in the database with IDs 500 and 600, a new start date, and no end date. At the same time, the end date for records 100 and 200 was populated, which effectively retired the features. Note that starting in 01/09/2008, signs one and two are represented in the database by two records each (100 and 500, 200 and 600, respectively). As a result, the only relationship between the two records is the location of the feature. For example, if a user would search the database for the start date of feature 500 using the feature ID only, the database would return 01/09/2008, which would not provide the initial installation date of sign number one. As a result, all queries using the GAIP structure must be spatial and provide a time of reference.
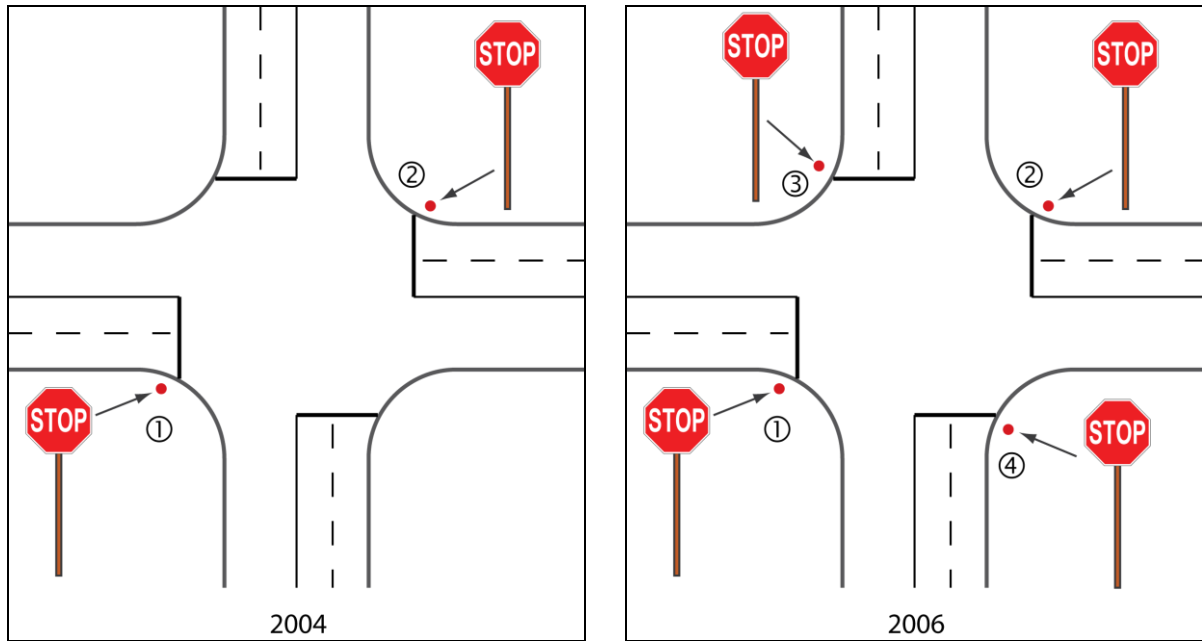
2004

ID	Start Date	End Date	Material	Comment
100	01/09/2004		Wood	New Sign
200	01/09/2004		Wood	New Sign

2006

ID	Start Date	End Date	Material	Comment
100	01/09/2004		Wood	New Sign
200	01/09/2004		Wood	New Sign
300	01/09/2006		Wood	New Sign
400	01/09/2006		Wood	New Sign
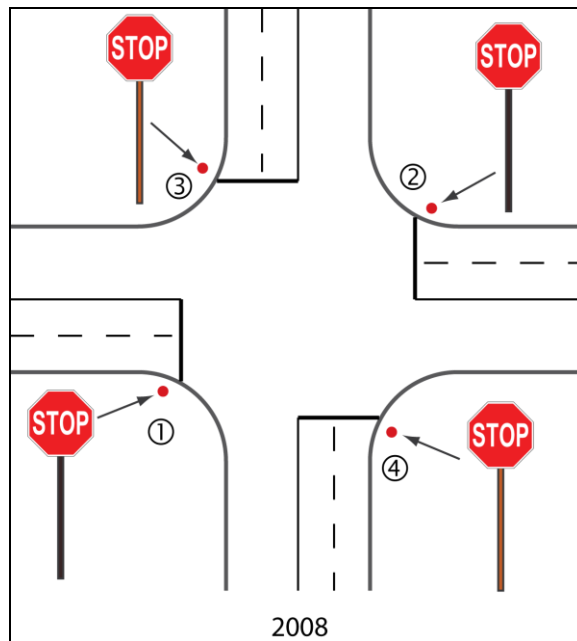
2008

ID	Start Date	End Date	Material	Comment
100	01/09/2004	01/09/2008	Wood	Retired
200	01/09/2004	01/09/2008	Wood	Retired
300	01/09/2006		Wood	New Sign
400	01/09/2006		Wood	New Sign
500	01/09/2008		Metal	New Pole
600	01/09/2008		Metal	New Pole

Figure 15. Data Modeling in GAIP.

A key component of the TxDOT GAIP architecture is a cartographic set of roadbeds and roadway centerlines that make up the TxDOT network ground set (GS) along with the logical and physical data models for the GS (*31*). TxDOT classifies GS components according to jurisdiction, engineering function, and cartographic support. By definition, the GS consists of links and nodes, where the nodes are the link end points and, as such, represent roadbed discontinuities such as merges, splits, and intersections. 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 (*31*). 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 (*34*), the standard does not conform to established survey standards. As a reference, the *TxDOT Survey Manual* (*35*) and the Texas Society of Professional Surveyors' (TSPS) *Manual of Practice for Land Surveying in the State of Texas* (*36*) include requirements for different types of surveys.

TxDOT classifies GS components according to jurisdiction, engineering function, and cartographic support, resulting in the several GS subtypes that TxDOT uses to formalize four GAIP-compliant linear referencing systems: Distance from Origin, Control Section, Reference Marker, and Texas Linear Measurement System. Table 9 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 9. Ground Set and Linear Referencing System Entities, Attributes, and Subtypes (Adapted from *31*, *37*).

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 ongoing efforts at TxDOT to make GIS data available to internal and external users using web-based mapping technology. Some of the systems currently in production or under development that are relevant to this research include the following:

- MST;
- Right of Way Map Locator; and
- Survey Primary Control Markers.

Main Street Texas

MST is a web-based information system TxDOT is using to implement GAIP (*38*). MST uses custom software and a suite of database gateways to provide access to data in multiple database platforms and locations (*39, 40*). MST runs on the Genesis Enterprise Information Integrator (GENII™) (*41*), which is a web-based portal that enables spatial intersect and relational queries for the production of tabular and mapping reports. MST supports OLTP/OLAP to ensure data currency and allow users to perform runtime ad hoc queries (*39*). TxDOT is incorporating a number of data layers within MST, including bridges, roadbeds, routes, geopolitical layers (e.g., cities, district boundaries, zip codes), railroad lines, Unified Transportation Program (UTP) projects, reference markers, county roads, right of way maps, and primary survey controls (*42*). MST runs on an Oracle database platform, using Environmental Systems Research Institute (ESRI®) Arc Spatial Database Engine® (ArcSDE®) for spatial data elements. Figure 16 provides screenshots of the MST index, search, and mapping components.
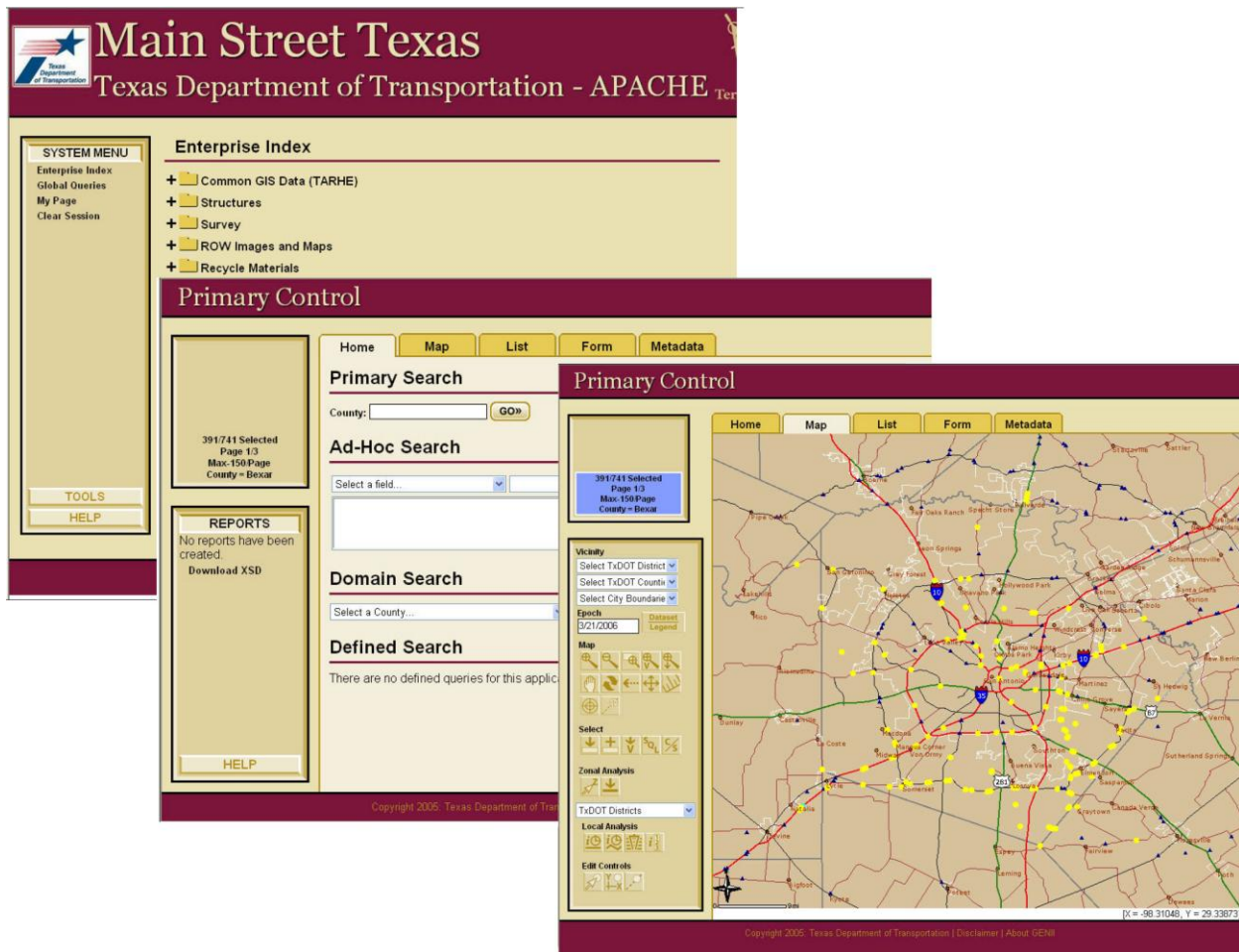
Figure 16. Main Street Texas Sample Screenshots (*43*).

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 right of way maps to interested users (*44*). Traditionally, districts provide paper copies of right of way maps in response to internal or external inquiries. However, finding the correct right of way map(s) and making the corresponding paper copies can be time consuming. The web-based right of way 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 right of way map image files the user can view, download, or print (Figure 17). Currently, the right of way map locator application includes right of way map image files from three TxDOT districts: San Antonio, Fort Worth, and Pharr. TxDOT is extending the system statewide.

The right of way map locator application is GAIP compliant and is included in the MST portal. In the system, each right of way map is a separate object with spatial and non-spatial attributes. For the spatial component, TxDOT modeled the geographic extent of each right of way 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 or the data manager would have to manually plot the extent of the map limits), TxDOT decided to assume the geographic extent of each right of way 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 right of way map files associated with that control section, even if there is only one right of way 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 right of way 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.
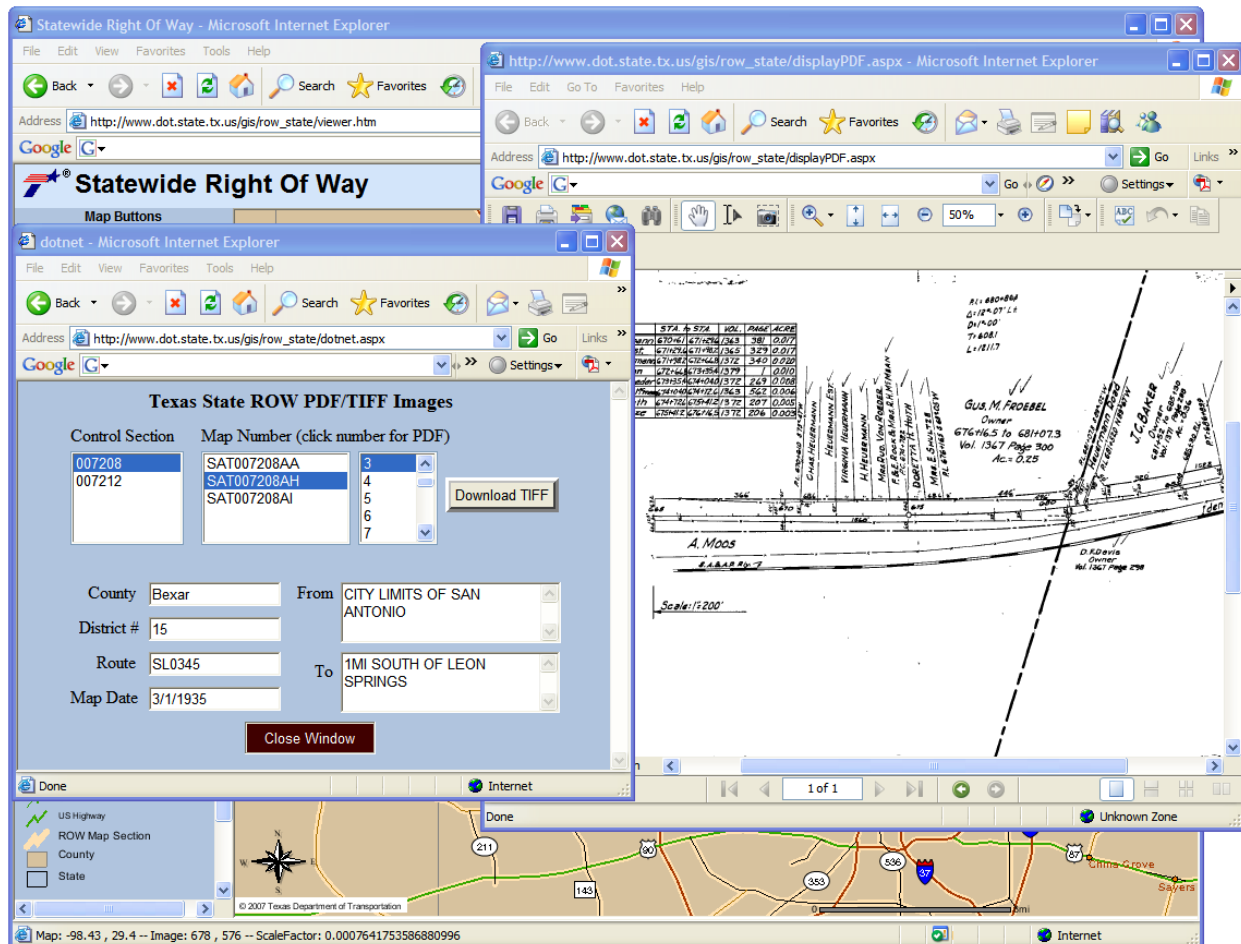
Figure 17. Right of Way Map Locator Interface (*44*).

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 (*45*). 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. Figure 18 provides screenshots of the application.
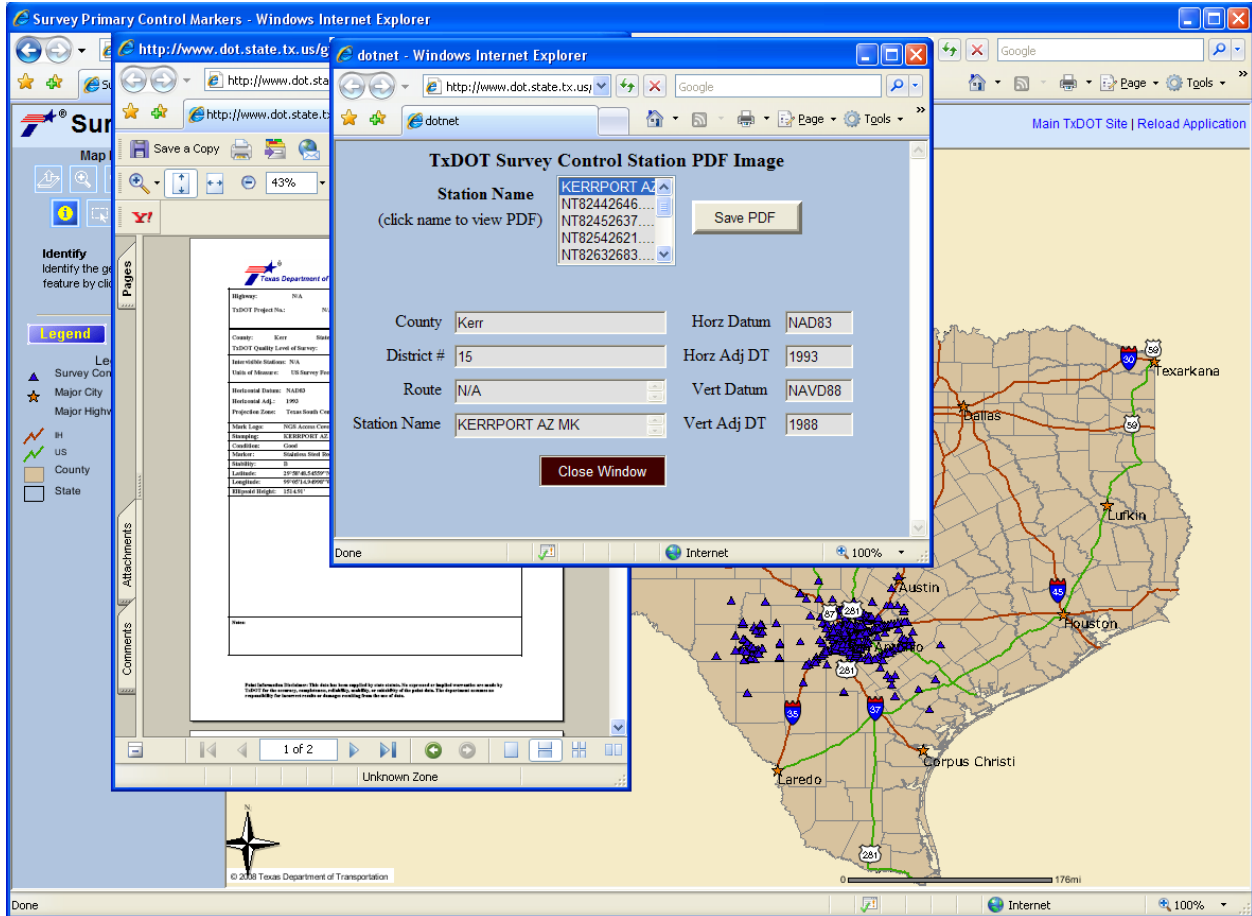
Figure 18. Survey Primary Control Markers Interface (*45*).

Utility Facility Database

For Project 5-2110-01, the research team refined an earlier version of a utility inventory data model and developed a utility facility database (UFD) to test the model (*46*). During the development of UACT, the research team ensured that UACT would be compatible with an implementation of the UFD structure. Compatibility focused on two main aspects:

- Ensure that data from the UFD can be imported into UACT.

- Ensure that utility data created within UACT follows the UFD structure, to facilitate the data export to an implementation of UFD.

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UACT's logical data model demonstrates the full compatibility of the system with the data structure provided by project 5-2110-01 by replicating several of UFD's utility feature tables. To ensure the two main aspects of compatibility between UACT and UFD, it was not necessary to recreate the complete UFD data model in UACT. As a result, UACT does not include all tables of the UFD structure. As of this writing, no TxDOT district has a working implementation of a UFD. However, it is likely that a future implementation of UACT could incorporate an implementation of the UFD data model.

Utility Installation Review System

The Utility Installation Review (UIR) System is a web-based application to support the management of requests for utility installations on the state right of way (*47*). UIR is being used by several districts and TxDOT is expanding the use in a current statewide implementation effort. UIR uses an implementation of ESRI Arc Internet Map Server (ArcIMS®) and Oracle DBMS.

UIR and UACT use the same Oracle database system and share several web applications. The research team designed the UACT data architecture with the intention to share data components in a UACT implementation to ensure integration of the two systems. Currently, UACT shares the table structure for user management with UIR to ensure that a future implementation will be able to link to these tables, which will enable UIR users to use UACT without a need to create a new user account.

CHAPTER 3. UTILITY COORDINATION ACTIVITIES OF PDP STAKEHOLDERS

INTRODUCTION

The researchers complemented the information provided by TxDOT's technical documentation by discussing utility relocation and coordination activities in the project development process with TxDOT officials in Austin (both at the district office and SH 130 project office), Dallas, Houston, and San Antonio. The researchers also met with representatives from utility companies and consultants to gain an understanding of their perspective about the utility coordination process.

UTILITY COORDINATION AT TXDOT DISTRICTS

During meetings with TxDOT officials, the researchers discussed the utility coordination process, utility coordination issues, and current utility tracking and conflict management strategies. The following summarizes the information and opinions that district officials provided to the research team.

Utility Coordination at the Austin District

Utility Coordination Process

The Austin District strives to follow the guidelines of the UCMP using a flexible utility coordination procedure that adapts to the needs of each project. In essence, the district uses the UCMP by selecting those activities that appear suitable for each particular project. In the districts' experience, the UCMP recommends too many meetings for a typical project and, as a whole, is better tailored toward large-size projects.

To involve utilities early on in the project, the Austin District attempts to send out notifications to utilities but recognizes that they are not always consistent in this practice. Communication between TxDOT and utilities is in general good, but could be improved in terms of following up on issues and sending out reminders and notifications if utilities get behind schedule.

According to district officials, utility coordination is often underestimated in terms of assigned human and fiscal resources. As a result, there are little labor or financial resources available for utility inspection, monitoring, and verification. Accordingly, the district strives to prioritize and optimize utility coordination activities. The district optimizes utility coordination for a particular project mainly by determining which activities are essential in the coordination process, which in turn determines when utility coordination activities begin. For example, there are often not enough resources to conduct utility coordination activities before the start of detailed design. In those cases, the project's geometric schematic is already complete when utility coordination activities begin. Utility coordination activities vary greatly depending on the project type and its unique dynamic features in terms of activities and processes performed. Some projects are regular developments; others are fast-tracked projects including toll projects. There are

traditional, design-build, developer-driven, and concessionaire type projects. Depending on the project, utility coordination may start at different times during the project development process and may include different sets of activities.

In the Austin District, area offices have been responsible for utility coordination since the 1980s when TxDOT reassigned utility coordination activities statewide from district offices to area offices. The majority of utility coordination activities deal with non-reimbursable utilities, which are much easier to deal with than reimbursable utility adjustments. Non-reimbursable adjustments require only a Utility Joint Use Acknowledgement (UJUA), Non-Reimbursable Utility Adjustment (form ROW-U-UJUAB) as compared to the far more extensive Standard Utility Agreement (form U35) that is a requirement for reimbursable utility adjustments. Austin District officials reported that in some cases, reimbursable utilities have started adjustments without signed agreements, which then cannot be reimbursed by TxDOT. From the district's experience, it can be a lengthy and time-consuming process to acquire signed utility agreements. For that reason, area offices preferred using the Date of Eligibility forms (DOEs) that specified the date after which the utilities activities are eligible for reimbursement without the immediate requirement to sign a utility agreement. However, the ROW Division intended DOEs for use on an exceptional basis and in emergency situations only, with the understanding that the utility would provide a utility agreement at a later time and as soon as feasible. DOEs, however, quickly evolved as the standard for utility coordination, and in many cases, the Austin District did not receive a utility agreement subsequently. In July 2005, the ROW Division clarified that DOEs are intended for emergency use, removed the forms, and replaced them by two new forms called U# Authorization Work Sheet – Pre-Highway Letting (form ROW-U-AWS), and Emergency Work Authorization – Post Highway Letting (form ROW-U-EWA). The Austin District has not used either form very often, and now spends more time to get signed utility agreements.

The Austin District makes an effort to stop issuing permits for utility installations once a construction project is in the planning stage. The district does not allow utilities to move in the right of way of a planned project unless the utility signs a letter of intent that it will move out of the right of way if necessitated by the planned project. If TxDOT determines utility conflicts early in a project, the Design Section employees may sometimes adjust their design. Occasionally, changes in the design appear feasible but the designers are not willing to redesign.

Utility Coordination Issues

The district's two major utility coordination issues are utilities that cannot adjust in time for letting, and utilities in conflict with proposed design that are only identified after construction has started. The Austin District acknowledges that all utilities should be identified, and preferably adjusted prior to letting. However, the district perceives that the level of detail required in standard utility agreements is growing steadily, which makes it increasingly difficult for utilities to prepare them and as a result, increasingly difficult for the district to get signed agreements in a timely manner. Some utility companies find the agreement process, in particular the detailed estimate, too complicated, too detailed, and too inflexible. Many utility companies only do a small share of their work in Texas, which in their view does not justify changing the way they do business, including providing detailed estimates. Detailed estimates take longer to

prepare and increase the liability for the utility companies since they could be held to their estimates. Although utilities have the current year plus two years to submit their bills to TxDOT, it is not enough time for some companies. From the district's perspective, these companies create significant problems and are less cooperative with the next utility adjustment. Some of these issues can be avoided if the district can include the utility adjustment in the highway contract. This is the Austin District's option of choice, although it is not always feasible. The district's experience is that utilities that are included in the highway contract produce fewer construction delays.

Utility easements and redesigns can also be a major problem. For example, frequently sidewalks and bike trails are only afterthoughts that can become a major problem if they are in conflict with existing utility lines. In other cases, utility installations weave in and out of easements, where a utility line is located only in part in the TxDOT-managed right of way with other parts in private easements. This situation makes it more difficult to adjust the utility.

To Austin District officials it appears that utilities are increasingly unwilling to begin design work on their adjustments until about 90 percent of TxDOT's design is completed. This may be a result of negative experiences with TxDOT and the UCMP that utilities had in the past. Such negative experiences may include projects that TxDOT canceled or where TxDOT determined that the utility did not need to move, after the utility already completed the design of the adjustment.

An area of concern to the Austin District is the overlapping of right of way parcels over multiple construction CSJs. This problem may occur if TxDOT splits up large projects in phases with different construction CSJs while maintaining one right of way CSJ. Officials mentioned that it is now a statewide mandate to adjust the right of way CSJ to match the construction CSJ, so this issue may become obsolete.

To Austin District officials it is unfortunate that a significant amount of utility information is either lost in the current business process or too difficult to access. For example, the Right of Way Section does not know what happens to new utility installations after as-builts are provided, nor does right of way know what happens to the utilities after construction is complete. In essence, only the Maintenance Section has some of that information. Austin District officials suggested keeping utility permits in a centralized location where both sections have access.

Current Utility Tracking and Conflict Management

The Austin District has limited internal utility conflict tracking or management capabilities. The area engineer determines the technologies to gather and track utility information, which may include spreadsheets and reports created by local public agencies. Some utility coordination consultants have more advanced utility tracking systems. One consultant uses an electronic data management system (EDMS) that tracks utility locations using x and y coordinates. A consultant for the SH 130 project developed its own utility tracking system called "Utility Tracker." This consultant provides monthly utility status reports consisting of three parts—(1) Identification, (2) Assembly and Agreement, and (3) Construction and Payment—for each

project segment of the SH 130 project. The Identification part is a listing with general information about the utility installation by utility agreement assembly number, including:

- line ID, segment, and section;
- utility owner;
- utility description, size, and material;
- baseline station;
- enter and exit right of way station and offset; and
- existing right of occupancy type (e.g., permit or easement).

The Assembly and Agreement part is a listing that shows agreement information by utility agreement assembly number, including:

- line ID, segment, and section;
- proposed action;
- responsible party;
- estimated adjustment amount; and
- several dates (executed by owner; executed by developer; Texas Turnpike Authority (TTA) approval; Utility Joint Use Acknowledgement executed by owner; Utility Joint Use Acknowledgement executed by TTA).

The Construction and Payment part is a listing that contains construction progress and payment information by utility agreement assembly number, including:

- line ID, segment, and section;
- several dates (scheduled and actual construction start, scheduled and actual construction completion);
- betterment in percent; and
- payment info (total payment amount, payment amount, payment type and date, partial and final payment).

Eligibility ratio and accrued depreciation credit are not tracked by the system. Although the system has been very beneficial to the district, some officials mentioned that this tracking system is too complex and requires too much data, and would therefore be too difficult for TxDOT to maintain. One suggestion was to track utilities using the utility agreement number (U-Number).

For other projects, the district does not have access to the tracking system described above. Without a similar system in place, and given the current staffing level and coordination demands, it is not feasible for the office to manually track all utility lines in a project. For these projects, the district office focuses on what it perceives as the essential task, which is tracking utility agreements of conflicts associated with reimbursable utilities. To track these agreements, the district uses a spreadsheet with color codes that distinguish the current agreement assembly status, such as "approved" (blue) and "finished" (green). The spreadsheet keeps track of several data items:

- U-Number;
- number of assemblies;
- number of adjustments;
- section number;
- status (approved, conditionally approved, or other comment) and reason;
- dates (returned to consultant, and consultant submittal);
- utility adjustment amount; and
- comments.

The spreadsheet contains the following sections:

- utility assemblies approved,
- utility assemblies forthcoming,
- TxDOT permits approved,
- TxDOT permits on hold/pending,
- advanced utility installations approved,
- advanced utility installations pending,
- rocks in the road,
- utility adjustments in progress, and
- completed utility adjustments.

Although the district tracks utility agreements of conflicts associated with reimbursable utilities, the district does not track any data elements of the utility conflicts (e.g., location, type, etc.) or the utility lines (e.g., location, type, material, etc.) Further, the district does not track any information about conflicts that are associated with non-reimbursable utilities. The majority of utility adjustments at the district are non-reimbursable contracts, and the district handles about 50 reimbursable contracts per year. On average, there are about four utility adjustments per utility agreement. However, a single large project can have 50 utility adjustments and more. In such a case, the project is broken up into phases, and U-Numbers are usually broken up by construction phasing.

The Austin District maintains a centralized list of utility industry contacts. However, given the turnover at utilities, it is not feasible for the district to keep that list current. Further, many utilities may not have utility adjustment projects for years. Occasionally, TxDOT updates that list when new projects start and as time permits.

Recommendations for a Future Utility Information Management System

Austin District officials recommended that the researcher keep the new management system as simple as possible. Utility coordinators are already overcommitted and cannot populate another complex database. One recommendation was to determine exactly what data is needed and what data elements should be stored. Austin District officials suggested six essential data elements for the utility data management system:

- U-Number,
- relocation cost estimate,
- payments and total cost,
- parcels,
- acquisition schedule, and
- automated notifications for critical dates.

They also provided several recommendations to consider in the development of the utility management system:

- Keep data input as simple as possible.

- Track project milestones.

- Track utilities and parcels in one place.

- Handle both reimbursable and non-reimbursable utilities.

- Handle both design-build and traditional contracts.

- Track utilities at the assembly level (such as from point A to point B) for each company.

- Provide mechanism to store and manage access to utility data gathered or generated throughout the project development process.

- Provide a mechanism to exchange a conceptual plan produced early during the preliminary design meeting or in a separate meeting. Utilities could use the plan to lay out their lines. This plan should be voluntary and disseminated concurrent to public meetings. Utilities could be overlaid on a map or a CAD drawing using U-Numbers.

Utility Coordination at the Dallas District Office

Utility Coordination Process

The Right of Way Section typically learns about new projects during annual meetings with each of the Design Sections and area offices that update what is on the Unified Transportation Program (UTP) and the Transportation Improvement Plan (TIP), and what the letting schedule is. Increasingly, the advanced planning group notifies right of way about upcoming projects. The Dallas District office essentially follows the UCMP as described in the Utility Manual. Depending on the size of the project, the district may only perform the steps and meetings of the UCMP that the district determines are important and reasonable.

The primary contact for utility coordination is the area office. Each area engineer is responsible for the utility coordination in his/her geographical area, and utility coordination practices vary by area office. The area engineer essentially determines who should conduct inspections and what

projects require inspection. Some area offices use a utility coordinator to do the coordination, while some use a maintenance inspector. Other area offices perform collection and processing of information as well as most of the coordination in-house.

Utility coordination includes a number of meetings based on the project size and complexity. At the annual meeting with utilities, all area offices hand out a project list to utilities. As projects come up during the year, the area offices send out notifications to utilities. Area offices coordinate utility relocations, both reimbursable and non-reimbursable. The focus of the effort is to accommodate utilities if possible, and to design around the utilities. The district office is more involved in reimbursable contracts, and reviews utility agreements and manages utility billings and payments. Each area office forwards both reimbursable and non-reimbursable contracts to the district office in hardcopy for approval. By reviewing both agreements, the Dallas District Right of Way Section perceives it improves consistency of handling agreements across the district and avoids miscommunication between the maintenance and Design Sections. For each utility agreement, the area offices submit four hard copies, one copy each for the district, area office, division, and utility. The area offices have been using utility permits for non-reimbursable installations in the past and are now transitioning toward Utility Joint Use Acknowledgements.

The typical process of adjusting utilities includes the following steps:

- Find out what utilities are installed within project limits.

- Determine ownership and contacts for utilities involved in the project.

- Determine which lines are in conflict and will have to move.

- Determine available space for utilities to move.

- Examine adjustment constructability and develop timeframe and set of plans.

- Determine who has to go where, who has to move first, and who has to go how deep.

In addition, reimbursable adjustments need a right of way release. Non-reimbursable adjustments typically do not involve the purchase of new right of way; therefore, they do not need a right of way release. The district office enters all reimbursable contracts into ROWIS. For non-reimbursables adjustments, the action depends on the form the district uses. Dallas is steering toward having both types of adjustments in ROWIS. Reimbursable adjustments sometimes adjust quicker than non-reimbursables but not in all cases.

Use of SUE depends on the project complexity and TxDOT's confidence in the data provided by utilities. Typically, a request from an area office initiates a contract with a SUE provider, or if the district office believes that a SUE contract is warranted for any other reason. The district has a continuous contract with a SUE provider that it can use for any project. There are no specific factors that automatically justify SUE. The real limitation to SUE contracts is the amount of SUE money available to the district, which is not directly related to a project. Because of the

limited funds, the Dallas office prioritizes SUE for projects. Usually, SUE consultants are tasked to pick up all utilities within the project limits at quality level B. Depending on the project, it may become necessary to survey at quality level A. Test holes become necessary if a utility is potentially "salvageable," meaning the utility may remain in place if TxDOT design can be modified. If quality level B is not needed, TxDOT can save some money using quality level C. However, occasionally even SUE does not detect all utilities, such as old materials like clay-tile pipe or other material that is not easily detectable using regular SUE techniques.

The Dallas District is in the process of implementing a requirement for a type of certification for as-built documentation to address the low quality of many as-builts. Ideally, the Dallas District would like to achieve the certification without having to make it mandatory for all types of projects. The district requires as-builts for some types of utilities, including gas, water, and sanitary sewer installations. For those types of utilities, the Dallas District usually receives at a minimum some type of plan that may become an as-built. In contrast, utility coordination consultants always submit as-builts because they are pay items, but in many cases, the accuracy of these as-builts has been questionable. In many cases, these as-builts are not tied to TxDOT controls, and occasionally do not reference the right of way map. Frequently, consultants provide locations by measurements with respect to the fence line or the edge of pavement, which are not fixed locations, may change during construction, and therefore are not adequate references for measurements as compared to the right of way line. Therefore, locations provided on as-builts may vary from actual locations of utility installations, and TxDOT's trust in these as-builts has been generally low. To improve the quality of the as-built documentation provided by consultants, the district has started to require utility coordination consultants to tie all inspection measurements and subsequent as-builts to the right of way line. If the right of way line is not staked out, consultants are required to hire a surveyor to determine the location of the ROW. The consultant provides MicroStation drawings and/or GPS coordinates of utility installations along with hard copies to the district office.

The Dallas District has a database of utilities and contacts with over 1000 records. However, the database is notoriously outdated, since most utilities have active adjustments only once every few years. By the time a utility in the database has a new active adjustment, the record is usually outdated: employees have moved on, phone numbers have changed, and even the utility name might have changed. It would take a serious effort to maintain a current database. Instead, the Dallas District updates the database whenever a utility calls or when agreements come in. The Dallas District uses the database contents only as a starting point for utility coordination activities.

Many projects include some local (e.g., county or city) participation. Local participation ranges typically from 5 percent to 10 percent of the total project cost. In those cases, the district leaves it to the local authority to decide who should take the lead on a project, i.e., who should become the acquiring agency. At the Dallas District, in almost all cases TxDOT becomes the acquiring agency.

The Dallas District sometimes hires consultants to perform utility coordination functions. The utility coordination contracts typically include provisions that require the consultant to monitor the utility installations to ensure that all installations are in according to the approved plans.

There are no set standards to when these contracts should be awarded; they are typically awarded upon recommendation by the design engineer. Good project candidates are areas that change from rural to urban (e.g., rural FM road to urban FM road) or highly complex projects. The area offices like these contracts in particular and typically try to maximize their use. Utility coordination contracts give the district office considerable flexibility, since the district or area offices typically do not have the resources to inspect all utility installations.

Utility Coordination Issues

District officials outlined a major difficulty in the utility coordination process, which is the level of expertise of utility company employees. Problems with utility coordination do not always arise because of unwillingness to cooperate but often because of lack of competence. Frequently, utility employees that handle the utility side of the coordination are not qualified, cannot read design plans, and do not understand basic engineering concepts such as cut and fill, stations, or offsets. Most utilities are primarily interested in reducing their costs and complain if Dallas District officials ask them to maintain basic design standards. To some utilities, an adequate design drawing may consist of only a few lines drawn on paper without any reference whatsoever. However, more and more utility companies use consultants, who produce drawings that are more satisfactory.

Another common problem according to district officials is that utilities do not provide reliable information about the horizontal or vertical location of their facilities. Drawings produced by utilities provide utility elevations, but frequently these drawings do not differentiate between existing and proposed elevations. This practice leads to unreliable construction drawings, which can cause further problems in the field: frequently utilities may relocate on time but to the wrong elevation. Unreliable references such as the fence line or the edge of pavement frequently cause utilities to relocate to the wrong horizontal location. In either case, utilities appear to be cleared and Dallas District officials include these utilities with a cleared status in the utility certification document. Since these utilities are in fact not cleared they often result in expensive highway contractor charges because of delays to highway construction that are payable by TxDOT. Dallas District officials mentioned that based on the documentation they receive, utilities appear to increasingly cut back on engineering and surveying and leave those activities to a contractor who only estimates the location of the new line. Those contractors benefit from the fact that most area office inspectors are usually tied up in construction jobs and very seldom have time to inspect utility jobs.

In the view of Dallas District officials, there are three common causes of utility adjustment and project delays:

- Utilities are notified late of a project.

- Utility conflicts are not identified.

- Utilities are non-responsive and uncooperative in providing utility information to the district or area office.

Dallas District officials pointed out a problem with the standard TxDOT deadline to submit final utility bills. Some utilities lose track of reimbursable contract payments until the deadline for submitting bills to TxDOT, which is the current plus two years, has passed. Utilities can then only file a claim to the state of Texas, which is a lengthy process with an uncertain outcome. The Dallas District does not send out reminders if the deadline is approaching, but it does let them know about the current plus two-year timeframe when the utility signs the contract.

Current Utility Tracking and Conflict Management

The effort of tracking utilities at the Dallas District office depends on the type of project. Typically, the Dallas District office uses spreadsheets and notebooks, and relies primarily on each area office to coordinate utility adjustments during a project. The district currently has a system with minimal capability to track status of agreements. The system is a Microsoft Office® program that the district developed internally and that has no reporting capability.

The Dallas District has been developing a project management system using DCIS data that has several reporting capabilities. Several offices in the district have access to the system and may make changes to a certain portion of the data. The system uses the DCIS data because all area offices enter data into DCIS, and the district wants to avoid multiple data entries and data inconsistencies. The management system is capable of projecting due dates based on an estimated timeframe. The system also has fields for estimated dates and timeframes for each project phase, including environmental clearance, right of way purchases, right of way map, approved schematics, etc. If the actual time needed to complete a project phase changes from the initial estimate, the system automatically adjusts all other timeframes and the total time needed to clear all utilities. The district plans to expand the system to include a utility tracking feature in a future version.

Recommendations for a Future Utility Information Management System

Dallas District officials recommended that the new system should have several reporting and tracking capabilities, including the following:

- time stamp for the initiation of the coordination process;

- time stamp for the submission of agreement to the district office;

- time stamp for the submission of agreement to the ROW Division or alternatively, time stamp for the approval of agreement at the district;

- mechanism to track any supplemental agreements;

- mechanism to estimate the utility adjustment completion time;

- mechanism to estimate total construction time; and

- mechanism to show the conflict location.

Utility Coordination at the Houston District Office

Utility Coordination Process

Utility and right of way certification is a vital part of the PS&E documentation that the district submits to the Design Division. For any given project, it is necessary to track the progress of utility adjustments because they become part of the utility certification. Utility certifications verify that all utility adjustments are complete except for those listed on the certification. For those utilities that have not been adjusted, the certification lists location station, description, owner, and expected completion (adjustment) date. The utility certification designates expected completion date by a letter (e.g., A, B, or C), which refers to certain conditions with regard to the expected adjustment time (60 or 90 days after right of way purchase, 30 days after the completion of an outstanding adjustment, etc.). The same list of outstanding utility adjustments may also appear in the PS&E documentation as a "Special Provision – Important Notice to Contractors." By comparison, right of way certifications certify that all right of way parcels have been acquired for a defined project section except for those listed on the certification. The right of way certification typically lists the anticipated acquisition date for those parcels that have not been purchased.

Providing and documenting utility certifications is a major task that the district has to complete in the utility coordination process. Essentially, the certification ensures that the contractor is aware of the status of all outstanding utility adjustments. By making the contractor aware of outstanding utility adjustments, it also protects TxDOT to some degree from contractor charges for suspension delay that occur if the contractor is delayed by utility conflicts that have not been adjusted at the time the project is awarded.

The utility coordination process at the Houston District office follows essentially all activities that are outlined in the UCMP. However, due to the volume of projects at the district, Houston has developed a modified version, which outlines five definitive milestones:

- Preliminary Design
- 30 percent Design
- 60 percent Design
- 90 percent Design
- Final Design

Depending on the complexity of the project, designers may not require or host all of the meetings recommended in the UCMP as long as the milestone objectives are met. For the annual meeting, TxDOT disseminates a list of planned projects to all stakeholders.

Typically, projects begin with a conceptual design that involves schematics and planimetrics (e.g., aerial imagery). Subsequently, the district determines the location of utilities, the utility's owner, and the utility's responsible contact, which involves a considerable amount of communications, e-mails, and phone calls. Once all the data are compiled, the district sends the information on utilities electronically to the utilities. The district has found that it is crucial to keep the utilities informed while the district leads the utilities through every step of the process; otherwise, the coordination effort may run into problems.

Further steps are budgeting, programming, and scheduling of public involvement. Next, the schematics are handed over to the Design Section, which has a certain amount of time to develop detailed plans and alignments. At this point, the Design Section may request utility information from utility companies. Some utilities require a formal request on special forms if TxDOT requests documentation from utilities. The Design Section then makes a decision on whether to hire a SUE consultant. If the district decides to hire a consultant for SUE or for utility coordination, it typically occurs after preliminary design. Hiring a SUE consultant later in the process may provide less benefit and may reveal a utility detail with a profound impact on design, leading to greater cost in terms of resources and effort. Nevertheless, SUE may be started at any point along the process. After all utility data have been received by TxDOT, the Design Section attempts to match the utility data with other available data and identify utility conflicts. If possible, the district will make an effort to accommodate the facility's design between 30 percent and 60 percent design by placing the new road design in the area of least impact. However, most utilities are only interested at what time the project will be let.

TxDOT can handle utility adjustments as stand-alone adjustments or they can be included in the highway contract. At the Houston District, water and sanitary sewer utilities are typically included in a highway contract; others can be included in the highway contract if all involved parties agree. For example, the district will try to include manholes into the highway contract if they are encompassed by pavement.

The Houston District uses consultants to provide SUE and utility coordination services. Utility coordination consultants cover all activities of utility coordination, including utility relocation inspection and surveying, and provide the district with signed utility agreements and as-built documentation of adjusted utility facilities.

The approach used to gather utility facility information depends on the complexity of the project and the amount of pre-existing utility data. For smaller size projects, it may be sufficient to perform a visual inspection at the project location and record the data in a field notebook. The use of SUE is at the discretion of the project designer and becomes more likely with increasing complexity of the project. For new projects, the district typically performs a preliminary, i.e., visual utility, inspection to determine if SUE is warranted. The visual inspection is important to get a good understanding of the utility situation and indicate important visible utility installations. The visual inspection may result in annotated schematics with approximate utility locations. District officials estimated that without a preliminary inspection, inexperienced SUE contractors would only locate about two-thirds of the existing utilities within project limits. The preliminary fieldwork is also critical to estimate the number of necessary test holes if SUE data at quality level A are required.

Utility Coordination Issues

There has been a major change in the way the district handles utility agreements. In the past, the district often used the DOE option. The DOE gave the utility the assurance that from the specified date forward it could accrue eligible costs for design work in advance of an executed utility agreement. Although DOEs initially authorized physical adjustment of the utility, eventually TxDOT removed this authorization from all DOEs. In addition, DOEs did not guarantee that all costs incurred by the utility were eligible for reimbursement. Over time, DOEs were used for more projects than they were intended for until the ROW Division replaced DOEs with Emergency Work Authorizations (EWAs) in July 2005. About half of the Katy Freeway utility coordination was completed using DOEs. The district uses EWAs very infrequently and now focuses on signed utility agreements. The utility agreements involve considerably more paperwork, and getting them signed by the utility is becoming increasingly difficult. As a result, the Houston District spends a substantial amount of time and resources on getting signed utility agreements/assemblies. The level of cooperation varies considerably from one utility company to the next. Occasionally, utilities provide all information necessary for the utility agreement but then refuse to sign it.

District officials noted that one problem with current conflict lists is that some lists do not provide information on which side of the roadway the utility conflict is located. Another issue is the accuracy of plans provided by utilities. Plans rarely contain positional references such as coordinates. In most cases, plans only show the approximate location that TxDOT then needs to verify by another process such as SUE. It also happens that utilities provide maps of their facilities but only include major facilities, such as transmission lines, but not minor facilities, such as service lines.

Although SUE provides great benefit to utility coordination and detection of utility conflicts, there are some issues associated with SUE. To assure that SUE data is reliable it is important to use experienced and dependable SUE contractors that are familiar with the requirements of standard TxDOT SUE contracts. Some district officials were concerned about the storage of SUE data after the district receives the data from the consultant. The district collects a wealth of utility data, but the data are not available to all parties within TxDOT that could use the data, partly because there is no centralized storage for the SUE data.

There are attendance and response problems with utilities at the 30 percent, 60 percent, and 90 percent meetings. If a utility does not attend a design meeting, it creates an additional burden for the district to schedule individual meetings with each utility that failed to attend. Although most utility companies appear for the 60 percent or 90 percent meetings, it is often unsatisfactory to the district because it is too late in the process to avoid major utility conflicts. If utility conflicts are detected early in the process, it is sometimes possible to accommodate utilities in the design. On the other hand, it is somewhat understandable that utilities want to get involved only at a later stage of the project because TxDOT design may change in the earlier stages, which then forces the utilities to redesign their facilities.

In the past, some utilities did not submit their final bills within the allowed timeframe. The Code of Federal Regulations (CFR) Title 23 Part 645 requires utilities to submit a complete billing of all costs incurred (or agreed lump sum) within one year following completion of the utility

adjustment (*48*). Federal-aid highway funds may also participate in billings that the state received at a later time, if the state desires to pay them. Texas state law requires the utility to provide a final bill of the adjustment within the current plus two years as a result of the biennial legislative funding appropriations (*49*). If a utility submits its final bill after the current plus two years time limit, TxDOT is not authorized to reimburse the utility, and the reimbursement is not subject to the "Prompt Payment Act" that requires payment for goods and services received by governmental agencies within 30 days (*50*). Although utilities can make a request for payment directly to the state legislature, it is a lengthy and time-consuming process that does not guarantee that the utility will be reimbursed. This issue has negatively affected the relationships between TxDOT and the utilities that have not been reimbursed, because these utilities believe they have been treated unfairly.

Current Utility Tracking and Conflict Management

The Houston District uses spreadsheets to manage utility contact and conflict information. Spreadsheets for contact information typically contain utilities ordered by installation in either private or public ROW, a contact name, company name, contact title, address, and phone number. Spreadsheets to manage utility conflicts typically contain an ID, name of utility company, contact info, utility type, conflict station and offset, proposed structure that is in conflict, adjustment date, remarks, and utility relocation needed (yes/no).

The Houston District also has the option to keep track of utility data using the Houston District Utility Conflict Tracking and Certification Database, which also includes a utility contact database. Keeping utility contacts current between projects is a difficult task because ownership of facilities changes frequently, high employee turnover at utility companies, and other changes such as names change of utility companies. Occasionally, utility ownership of facilities changes even during the adjustment process. Depending on the project, the district also has access to other sources of utility contact information. For example, the Katy Freeway project's general engineering consultant that has been charged with the utility coordination aspect of the project developed an online database system called "ProjectSolve" that contains utility contact information for utilities involved in the project. The consultant also tracks utility conflicts with utility matrices using Microsoft Excel®.

Recommendations for a Future Utility Information Management System

Officials at the Houston District stressed the importance to have all utilities at the 30 percent meeting and to investigate strategies that would facilitate the early participation of utilities. One suggestion was to hand out hard copies of the current state of coordination for each utility at all intermediate design meetings. The district could print a separate report for each utility owner showing the specifics of that utility such as conflict description, stationing, etc. Each time a utility would attend a meeting it would leave the meeting with detailed information. At the early meetings, TxDOT could share information with utilities in the form of print outs and then request the utility to review and verify that information. Toward the completion of design and PS&E, these printouts could become the basis for a type of agreement or commitment with utilities that have outstanding, non-reimbursable adjustments, with an indication of the time the utility will

adjust the facility. The agreement could consist of a Utility Joint Use Acknowledgement attached to the printouts that would be signed by the utility. This agreement would then become part of the utility certification and make utilities liable for the timely adjustment of their facilities. Currently, the district asks the utilities only for a written communication that they will complete the adjustment prior to construction. If the utility does not adjust as indicated, the district is liable for delay charges from the contractor. Researchers could investigate if it would be feasible to include all utilities (in conflict and adjusted, in conflict and not adjusted, and not in conflict) in the utility certification.

The new system should be designed to keep all engineers and technicians up-to-date. It should record all transactions, such as adding, change, or exchange of information and the username of the party responsible for that transaction. The system should also be capable of distributing meeting reminders and other notifications to system users. These events should become part of the utility status (e.g., 30 percent meeting notified, 30 percent meeting attended, etc.). The researchers should investigate how it would be possible to record and track easement interests in the system to indicate that there is a reimbursable interest.

The utility management system should also be capable of tracking commitment letters from utilities at the 30 percent meetings if such commitment letters would be implemented in the future. The system should also be able to generate reports that show utility and conflict locations that could become part of the commitment letters. The prototype developed by this research should also contain a feature that would automatically send out reminders to utilities about upcoming meetings, design changes, and deadlines for billings.

The Houston District has a defined format for utility coordination meetings including meeting agenda, standard topics, and protocol. The researchers should investigate what other criteria could be useful to improve utility coordination.

Utility Coordination at the San Antonio District Office

Utility Coordination Process

The San Antonio District Right of Way Section handles reimbursable agreements and joint bidding, i.e., utility projects included in the highway contract. Non-reimbursable agreements are handled by the Maintenance Section through the utility permitting process and UIR. The district then forwards the agreements to the division, which enters the information into ROWIS and assigns a U-Number. For utility adjustments, the San Antonio District follows a 10-step process:

- Right of Way Release and UCSJ Request (Design, Right of Way, and ROW Division)

- Alternate Procedure (Design, Right of Way, and utility)

- Determine Conflicts/Develop Utility Plans (Design, Right of Way, and utility)

- Agreement Assembly (Right of Way and utility)

- Agreement Assembly Review (Right of Way and utility)

- Agreement Assembly Review and Approval (ROW Division)

- Utility Adjustment (utility)

- Billing Assembly (Right of Way, ROW Division, and utility)

- Billing Assembly Review (Right of Way, ROW Division , and utility)

- Payment Process (Right of Way, ROW Division, and utility)

Essentially, the San Antonio District prepares the necessary documentation in coordination with the utility to enable reimbursement of the utility through the ROW Division.

The district becomes typically involved in a project at the initial design phase or initial project notification. The major tasks that the Right of Way Section needs to complete are:

- Develop the right of way map, which is often outsourced to consultants.

- Coordinate environmental clearance.

- Establish a right of way account in the ROWIS database.

- Coordinate project limits with design staff.

- Prepare Advance Funding Agreement.

- Prepare Local Funding Agreement, if necessary.

- Prepare initial cost estimate.

The preparation of the initial cost estimate can be very complicated since the design plans at this stage are typically vague. In many cases, actual project cost has increased severely over the initial cost estimate due to unforeseeable circumstances. From the experience of district officials, the estimated timeframe for utility adjustments is about 13 to 25 months, which includes:

- project notification and right of way release (about 3 to 6 months);
- alternate procedure (about 1 month);
- utility coordination and conflict determination, organized by Design Section (about 6 to 12 months);
- agreement assembly preparation, which coincides with coordination and conflict determination and should ideally start at the same time (about 6 to 8 months); and
- adjustment/construction time (about 3 to 6 months).

If the agreement assembly preparation occurs consecutively to utility coordination and conflict determination, the adjustment timeframe increases to about 19 to 33 months. After construction is complete, the billing process takes usually an additional 6 to 8 months.

Consultants typically become involved in the development of the right of way map at the start of a project. To develop the map, consultants need information on project limits and parcels, the existing right of way map, and information on existing utilities. District officials are usually satisfied if existing utilities are verified at a SUE quality level C. It is more important to know about existing utilities in general terms, what company is in the way and where they are approximately located, than knowledge of the exact location. More recently, the San Antonio District has started to use consultants to help with utility coordination. Contracts with consultants vary and may cover one or more of steps 3 through 7 (utility conflicts to utility adjustment) mentioned earlier. The district does not want these contracts to be involved in the preparation of the billing assembly package to avoid possible conflicts of interest. There are four types of utility coordination contracts:

- SUE category (contracts include the ASCE 38-02 standard);
- utility engineering;
- utility coordination; and
- utility verification (i.e., inspection).

Utility Coordination Issues

Occasionally, an issue at the San Antonio District has been utilities that do not submit their bills before the Texas state law mandated deadline. The current deadline, as mentioned earlier, is two years plus the current year after the completion of construction, which is a result of the biennial funding appropriations of the Texas Legislative Budget Board (*49*). If the billing is not submitted before the deadline, TxDOT cannot reimburse the utility for the adjustment, and the reimbursement is not subject to the "Prompt Payment Act" for governmental entities (*50*).

A further issue at the district that has surfaced in the past is a problem with construction and right of way CSJs. In the past, right of way CSJ and construction CSJ did not always align or have the same stationing, which was a source of confusion among TxDOT staff and utilities. Recently, the San Antonio District implemented a new use of right of way and construction CSJ numbers, mandated by the ROW Division. The district now uses one right of way CSJ for each construction CSJ number (Figure 19). According to the district, the change to one right of way CSJ for each construction CSJ has been well received by auditors, utilities, and TxDOT staff.
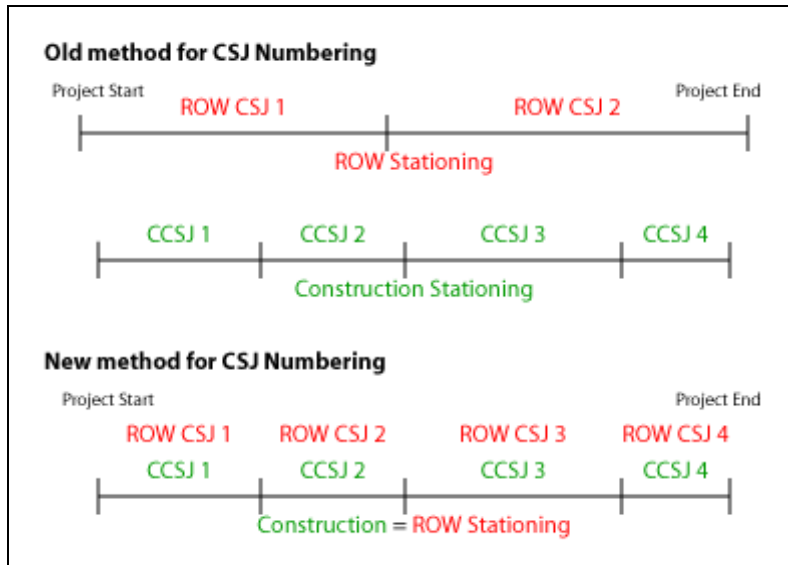
Figure 19. Use of Construction and Right of Way CSJ Numbers.

Current Utility Tracking and Conflict Management

The San Antonio District tracks the agreement assembly package and the billing assembly package but keeps them separate from each other. The San Antonio District keeps track of reimbursable utility adjustments using a spreadsheet in which each line represents one utility agreement. The spreadsheet keeps track of basic data elements such as:

- highway, county;
- project limits;
- right of way limits;
- utility company;
- U-Number;
- construction CSJ; and
- right of way CSJ.

The district indicates on the spreadsheet when steps of the utility coordination process are completed and the amount of the initial estimate and actual cost. The last column tracks the project letting date with a color code that indicates the escalation level of a particular contract:

- white: more than six months before letting, no escalation;
- yellow: three to six months before letting, escalate to levels 1 and 2;
- orange: less than three months before letting, escalate to level 3; and
- red: post letting.

The district tracks most communications through GroupWise. District officials have established a system by which they create e-mail folders for each project in GroupWise and a list of tasks

with estimated completion dates. By typing that information into each task, they keep track of phone calls, meetings, and e-mails to create a paper trail.

Recommendations for a Future Utility Information Management System

The Right of Way Section would like notifications about new projects as early as possible. Occasionally, the Right of Way Section hears about projects for the first time when design is already at the 60 - 90 percent design stage. At that point, it is usually impossible to adhere to the letting schedule, and project delays are unavoidable. Similarly, the environmental section occasionally is not notified of a new project. Ideally, the Right of Way Section would like to receive notifications every time a new project is entered into DCIS, which would ensure that it is aware of projects that may involve utility adjustments.

The Right of Way Section would prefer if the district would use only one permit for non-reimbursable utility installations. That could be the Utility Joint Use Acknowledgement and would require a change in the UIR system. Right of way personnel could get involved in the process, but they would rather have the Maintenance Section forward the agreement directly to the division, maybe using the existing UIR system. Signatures are an important part of the process at this point. If involvement by the Right of Way Section is necessary, it would need one set of plans, either paper or electronic copies through access to UIR.

In a new utility conflict management system, the district would prefer to have a feature to automatically notify the utility by e-mail if the billing is not completed before the deadline. The system should also be able to handle toll roads and new agreements such as CDAs. Public utility companies and utility consultants are partners of TxDOT in the UCMP. Although utility companies have many common business elements, e.g., provide a utility commodity to the public consumer, there is great variation among utilities in terms of company size, area of operations, resources available for relocation, familiarity with the UAR, and knowledge about TxDOT engineering and surveying standards. Although statewide operating utilities may frequently become involved with the UCMP, many smaller utilities are less often exposed to utility relocations and the UCMP. As a result, it is not surprising that especially small utilities are frequently not familiar with TxDOT's rules, requirements, and procedures. That does not mean, however, that smaller companies are cause for more delay in the project development process. In fact, in the view of several district officials, smaller utilities are usually more active in the earlier stages of the process, whereas larger utilities tend to prefer waiting until the later stages of the design phase when TxDOT's redesigns become less likely.

UTILITY OWNERS AND CONSULTANTS

Given the great number of utility companies that all have different business processes it is an unfeasible task to develop a detailed business process model that includes the business activities of all utility companies involved in utility adjustments. Nevertheless, it is critical to understand the perspective of utility companies and their consultants on the utility relocation process to ensure that the prototype utility data exchange system meets their needs. To understand the perspective of utility companies, the research team developed a survey focusing on utility

involvement in the project development process, utility agreements, as-built plans, utility location and conflict data, and several other items regarding exchange of information during the utility relocation process. A copy of the utility survey is provided in Appendix A. The TxDOT Houston District provided a list of utility contacts that the researchers used to conduct the survey. The team conducted the surveys over the phone or through e-mail.

Utility Survey

The utilities contacted for this survey came from a master list of utilities and utility consultants of the ongoing Katy Freeway project on IH 10 west of Houston. In total, the researchers contacted eight utility companies and three utility consultants. Four of the utility companies and one utility consultant completed the survey.

Utility Companies Contacted

- AT&T
- CenterPoint Energy Houston Electric
- TelCove
- Broadwing Communications
- Genesis Pipeline Texas L.P.
- Kinder Morgan Natural Gas Pipeline
- Optel TV Max Telecommunications
- Phonoscope LTD

Utility Consultants Contacted

- Cobb Fendley & Associates
- Binkley & Barfield Inc.
- Halff Associates

The focus of the survey was to obtain information about the activities, information exchange, and data needs of utilities during the UCMP. The researchers then used the information to develop a business process model of UCMP activities from the utilities' perspective. Given the variation in business practices of utility companies mentioned earlier, the survey was designed to provide the researchers with a general understanding of the utility and utility consultant business processes to supplement the PDP/UCMP business process model.

Utility Coordination Business Process Model

From the responses received by utility companies and utility consultants, the researchers developed a business process model that combined the companies' activity descriptions into one model. This business process model covers the complete timeframe in which utilities interact with TxDOT, which is from the time of notification by TxDOT through resolution of the conflict. The following paragraphs describe the business process model in more detail.

Utility Notification

Utility companies receive notification from TxDOT of a utility conflict or possible utility conflict. Some utility companies receive a letter notifying them of utilities in conflict while others receive notice to identify conflicts, depending on the preliminary utility research performed by TxDOT. After receiving the notification, which is usually a letter or e-mail, the utility company must make a decision on whether to perform utility conflict relocation with company forces or use a consultant. Company size and complexity of the project are influencing factors of this decision.

Use of Consultants

If the company decides to use a consultant, the utility company will send all available installation and as-built drawings to the consultant. Utility installation records can be scaled as-built information or simple, unscaled schematics, and occasionally there are no drawings available at all. The utility company or the consultant then requests and receives proposed design drawings from TxDOT.

The engineering consultant uses both the utility drawings and TxDOT design drawings to identify utility conflicts. The utility or consultant then "redlines" TxDOT design drawings, which places red lines of utility locations on TxDOT drawings. According to utility representatives, the level of accuracy for the redlining should be approximately equivalent to a level C or D SUE procedure. If the utility company's drawings are not to scale, a SUE provider locates the utilities in the field using a level B SUE procedure that involves geophysical measurements, which some utility companies also refer to as "designating" or "tone-locating."

If the utility company decides to complete the work with its own forces, it also requests a set of design drawings from TxDOT. The utility company then uses the design drawings to locate utilities in conflict and presents the results to TxDOT.

Utility Coordination Meeting

To avoid some or all of a utility's conflicts, TxDOT may consider a design change after reviewing a utility's conflict locations. The possibility to redesign depends greatly on the type of infrastructure that TxDOT is constructing and the timing of the request. At the 30 percent design state, design changes can be fairly easily accommodated compared to the 90 percent design state after which there is very little chance for a redesign. There are different strategies to avoid or remove conflicts. For example, wastewater lines can sometimes be moved vertically or horizontally to avoid a conflict. However, usually any large structure such as bridge pile and the roadway itself requires utility relocation and will rarely be redesigned. For reimbursable utilities, most of these decisions are based on cost, e.g., in most cases the utility lines are moved because it is cheaper than adjusting the roadway alignment. If TxDOT is able to accommodate the utility with a design change, the utility provides location information to TxDOT. If TxDOT cannot change the design, the utility must relocate.

Utility Conflict Resolution

If TxDOT is able to change the design to accommodate the utility, the utility or consultant provides the utility location to TxDOT for its records. If utilities use a consultant, a SUE provider will expose the utility with a test hole and tie the location to a TxDOT control point, which is a level A SUE procedure. If the utility does not hire a consultant, the utility typically will provide maps or existing utility drawings to document the location of the facility. In general, researchers found that utility companies who complete their own relocation work are reluctant to share survey data with TxDOT.

A relocation that involves reimbursement to the utility requires that the consultant or utility company complete a utility agreement. A utility agreement requires design drawings, cost estimate, schedule of work, and other documentation. Larger utility companies typically hire engineering consultants to prepare most or all of the required documentation. In other cases, the utility company prefers to prepare the documentation for TxDOT. Some larger companies actually have staff that deal only with utility agreements. A relocation that does not involve reimbursement to the utility only requires a set of relocation design drawings and a Utility Joint Use Acknowledgement. Either the consultant or the utility company can complete the agreement. The utility company submits the Utility Joint Use Acknowledgement either electronically or by hardcopy to TxDOT. A utility agreement is not required for non-reimbursable work. Once the design for the utility relocation is complete, and TxDOT and the utility sign the utility agreement, the relocation effort can proceed. To complete the utility relocation, utility companies use either in-house crews or bid out a contract.

Observations and Trends

Utility Conflict Notification to Utility Companies

TxDOT notifies utility companies by letter about upcoming projects. The researchers noted that those smaller utility companies typically receive a notice of conflict while larger companies receive a notice to identify conflicts. There was no clear indication for this trend, except that TxDOT may acknowledge that smaller utilities do not have the resources available to perform a utility survey. Similarly, larger companies appeared to be more likely to hire a consultant to complete SUE and identify conflicts.

Utility Consultants

Once TxDOT informs the utility company of future construction, the utility company must decide whether to hire a utility coordination consultant. Reasons for hiring a consultant revolved around the size and complexity of the project. From the survey, smaller companies appeared to prefer using their own forces to complete the work. Larger utility companies reported using consultants frequently for non-reimbursable projects, and virtually for all reimbursable projects. Utilities may use consultants to locate existing facilities, prepare utility agreements, and relocate facilities, but some utilities hire consultants for only one or two of these activities. Some utility companies prefer that the consultants attend the meetings in place of the utility representatives;

some prefer that both utility representative and consultant attend the meetings, and some prefer that consultant companies do not attend the meetings.

Aerial Utilities

Relocation of aerial utilities varies greatly from relocation of underground utilities. Multiple utility companies with aerial utilities often share utility poles that are owned by only one of the utility companies and leased by the others. If the poles need to relocate, utility companies that are attached to the poles must follow a hierarchy when relocating their facilities. Typically, the utility companies owning the poles install the new poles and move the lines that they own, and then companies with leasing rights attach their lines to these poles. The common order to re-attach utility lines is in the original order utility companies attached to the old poles, which is usually starting from the top and moving down. The utility attached at the bottom of the pole cannot move until all other utilities move their lines. If a utility attached higher on the poles requires a long time to move, it can cause issues among the utilities further down that are waiting to relocate. It also happens that a utility line that is attached above another line may be no longer in service or its ownership may be unresolved. Even in these cases, the protocol still requires that utility companies attached below a line must resolve any lines attached above them.

Early Involvement in the UCMP

A frequent comment from utility companies was that any work done before the 60 percent meeting could be a waste since TxDOT's design could still change. Several companies gave examples of projects where earlier involvement of the utility resulted in a wasted effort on behalf of the utility. One suggestion from a utility to encourage earlier involvement was to establish a policy of benchmark drawings that TxDOT would disseminate to utility companies, for example at the 30 percent design stage. The benchmark drawings would establish eligibility for reimbursement such that all work after the benchmark would be eligible for reimbursement, even if the TxDOT design would change and require additional design or construction.

Coordination of New Utility Location

Coordination with utilities to determine the location of their relocated facilities in the right of way is critical to avoid conflicts among relocated utilities. The location information of the new utility consists, in the majority of cases, of a measured offset from the right of way line and a depth below the new grade. Utility companies reported three approaches to determine a utility is offset from the right of way line:

- TxDOT determines and provides the suitable relocation offset location.

- TxDOT coordinates with the utility and agrees on a suitable relocation offset.

- TxDOT receives and agrees to a request from a utility for a certain relocation offset.

Utility Facility Tracking

Not all utility companies have a good understanding about the facilities they own, and not all utilities have methods to track them. For those utilities that do track their facilities, researchers observed a widespread use of spreadsheets as a way to track facilities. Other methods utilities mentioned were customized, stand-alone, and frequently proprietary applications and procedures. One utility gave the researchers detailed insight into its utility conflict tracking system. The utility uses a color-coordinated mapping system and a 4-foot by 8-foot map that shows the company's utility routes throughout Houston and its vicinity. If the project manager receives a notification about future construction from TxDOT, he marks the location on the map. The utility uses a color code to distinguish types of utility facilities and conflicts:

- reimbursable facilities,
- non-reimbursable facilities with a conflict,
- reimbursable and non-reimbursable facilities with a conflict that will be paid mostly at the expense of another party, and
- reimbursable and non-reimbursable facilities with currently no conflict.

The utility also marks "caution areas" on the map that signify locations of known potential future routes.

Utility Coordination Issues

Most companies claim to have a good understanding of the TxDOT utility relocation process, although they may not have heard of the term "utility cooperative management process." However, there are a few issues that utilities brought up during the surveys. For example, one utility company felt that TxDOT does not inform its contractors that utilities are not in physical conflict. Sometimes lines are not in physical conflict but perhaps a construction conflict, and contractors call utility companies asking them to move or relocate the line. Smaller utility companies mentioned issues with payments on reimbursable projects. Some utilities have an impression that TxDOT takes too much time to reimburse utilities and does not have backup personnel to process payments. If a TxDOT employee handling payments goes on vacation, the reimbursable payment process is significantly delayed.

A recurring utility complaint was that TxDOT wants to adjust utilities too quickly and/or sets construction dates before any construction can begin. Some utilities complained that often there are many design changes, and frequently these changes occur at a late stage in the design process. A further complaint was that utilities are subject to increased cost and effort if TxDOT cannot acquire necessary right of way on time, and the utility must move its lines, portions at a time.

Recommendations for a Utility Data Exchange System

All surveyed utility companies welcomed the idea of an online system to manage utility data and offered recommendations for such a system. The critical element of such a system that utilities

mentioned most frequently was the accuracy of the data. Utilities repeatedly pointed out that errors in the available data are a common cause for delays in construction. One company illustrated this point by giving an example of a competitor that started a utility relocation based on an incorrect set of design drawings. Although the contractor caught and corrected the mistake in the field, it cost the utility time and money.

Consultants frequently suggested providing online access to topographic data to transpose utility locations from records onto TxDOT plans. Consultants would also like the system to provide information on test holes that other companies completed as well as data depicting elevation, size, and type of all located facilities. A smaller company requested access to contact information of other utilities in order to coordinate the attachment of its lines to leased utility poles owned by other utilities. Many consultants and utility companies recommended that coordination would improve if they knew the status of other utilities involved in the relocation process. To encourage early utility involvement, one utility company suggested making participation in utility coordination meetings a requirement and including in the utility agreement that utilities must be aware of other utilities around them.

CHAPTER 4. DEVELOPMENT OF TXDOT UTILITY RELOCATION BUSINESS PROCESS MODEL

INTRODUCTION

The TxDOT *Data Architecture Manual* describes the integrated methods for the data design process of a data architecture (*51*). According to the manual, a data architecture is "the manner in which data components are organized and integrated" (*51*). The manual outlines a data design process that begins with broad user requirements resulting from real-world objects and ends with detailed technical requirements for database design. This data design process includes the following six 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.

- **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. The Technology Services Division at TxDOT (TSD) creates and maintains TSIDs.

This chapter describes the activities of the research team to develop a business process model to create a graphical representation of business processes that describe the activities of right of way coordination focused on utilities in the PDP and their interdependencies. Following the Data Architecture Manual's recommendation to provide a conceptual data model, the business process model identifies entities and entity associations and in addition provides a detailed overview of process activities and the responsibilities, precedence and/or concurrence, and inputs/outputs of these activities. The development of logical and physical data models in addition to the data dictionary are described in detail in Chapter 5.

BUSINESS PROCESS MODEL DEVELOPMENT

Sources of Information

To develop a business process model of utility coordination activities in the project development process, the research team had access to two main sources of information: TxDOT manuals and TxDOT officials. As a starting point, the researchers reviewed the PDP Manual with a focus on utility and right of way activities. The researchers found that in many cases, the PDP Manual lists activities that a project may entail but includes only limited information on how these activities relate to each other, when they should occur, and for what types of projects they apply. There is also little information on how TxDOT entities should interact and at what times. In addition, there are several other manuals (Utility Manual [10], Survey Manual [35], Right of Way Manual [17], etc.) that describe activities in more detail but occasionally provide inconsistent information. As a result, a major task of the business process model development was to reconcile information from several manuals into a single business process model.

Depending on the type and size of a project, there can be an extreme range of required activities to develop a project from concept to completion. Due to the variation in complexity, TxDOT rarely documents business processes at a detailed level. The range of requirements also makes it a tremendous challenge to produce a manual that covers all possible scenarios that projects may encounter in the project development process. Consequently, the style of the PDP Manual is such that it leaves much of the process open to the judgment of the project manager. In general, this approach is not bad considering the alternative would be volumes of process descriptions that would require enormous resources to maintain and keep current. However, due to the open style of the PDP Manual, it is not surprising that there are differences in the way districts interpret activities described in the PDP Manual. The unifying authority in this process is the ROW Division, which communicates minimum standards and requirements to the districts, and provides guidance on required activities.

From the start of the model development, it was clear to the researchers that much of the detailed process information could not be found in manuals but would reside with the TxDOT professionals that perform the activities on a daily basis. This information is unfortunately for the most part undocumented, and gathering this information requires numerous meetings and discussions with process stakeholders. What complicates the development of the business process model is that information is distributed among a large group of individuals. In addition, the researchers found that most professionals have either a modest understanding of a large portion of the process, or an excellent understanding of a very small portion of the process. Finally, there may be different options available to achieve the same goal and different opinions on which alternative would be most beneficial. As a consequence, another major task in the business process model development was to reconcile opinions and interpretations of all stakeholders.

Integrated Computer-Aided Manufacturing Definition Language Notation

TSD did not require the use of a specific software or modeling language to develop the business process model, but did require using ERwin, at the time the standard data modeling tool at

TxDOT, for the development of the logical and physical data models. Because of the requirement for the data models, the researchers developed the first business process model using Computer Associates AllFusion Process Modeler, which is a companion to ERwin and provides some integration during the conversion of the business process model to the logical data model. Process Modeler uses the Integrated Computer-Aided Manufacturing (ICAM) Definition Language (IDEF), specifically the Integration Definition for Function Modeling (IDEF0) for business process models and the Integration Definition for Process Description Capture Method (IDEF3) for process flow models. IDEF0 is a technique that models systems as a set of interrelated activities or functions for a specific purpose and from a selected viewpoint, also called a "function model" (*52*). In IDEF0 diagrams, boxes represent functions, and arrows represent either inputs, controls, outputs, mechanisms, or calls, depending on their position relative to the function box (Figure 20).
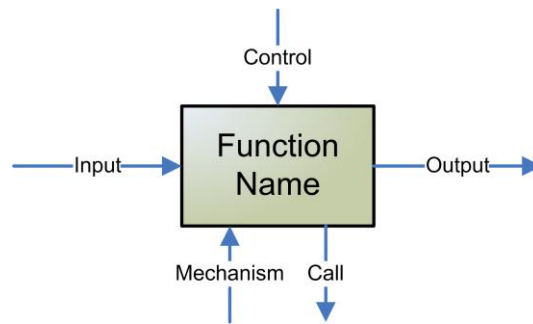
Figure 20. Function Box and Data/Objects Arrows.

IDEF0 consists of a top-level context diagram, which is a function that is represented by a single box. For example, Figure 21 shows the top-level context diagram for "Develop Project."
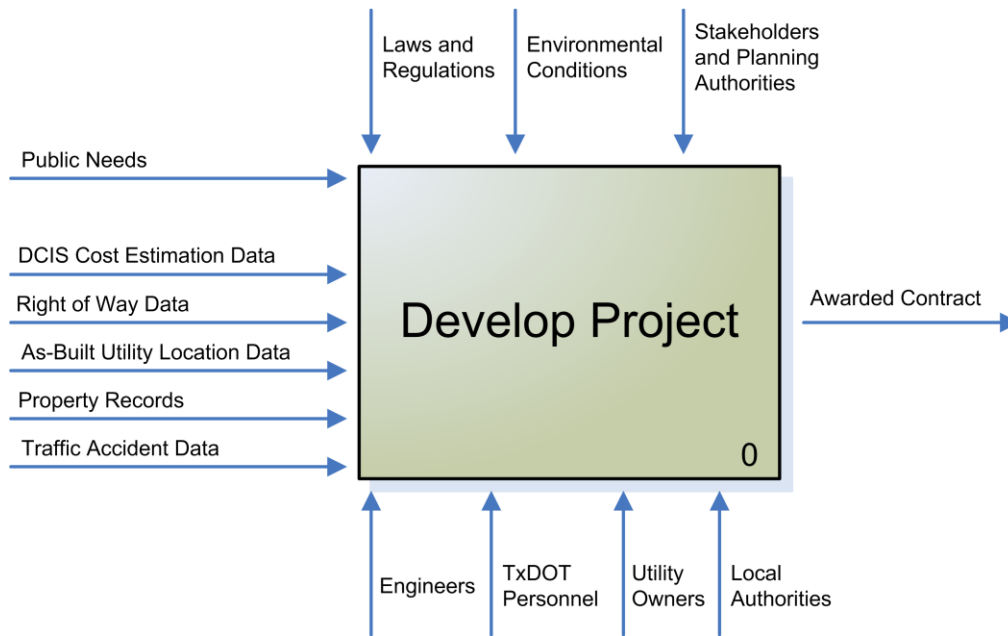
Figure 21. TxDOT PDP Top-Level Context Diagram.

The top-level context diagram is then decomposed into subfunctions on child diagrams, which may in turn have further subfunctions, etc. Each child diagram that entails another decomposition or child diagram is also a parent diagram for its child diagram. Figure 22 illustrates how the top-level context diagram "Develop Project" could be decomposed into six subfunctions.
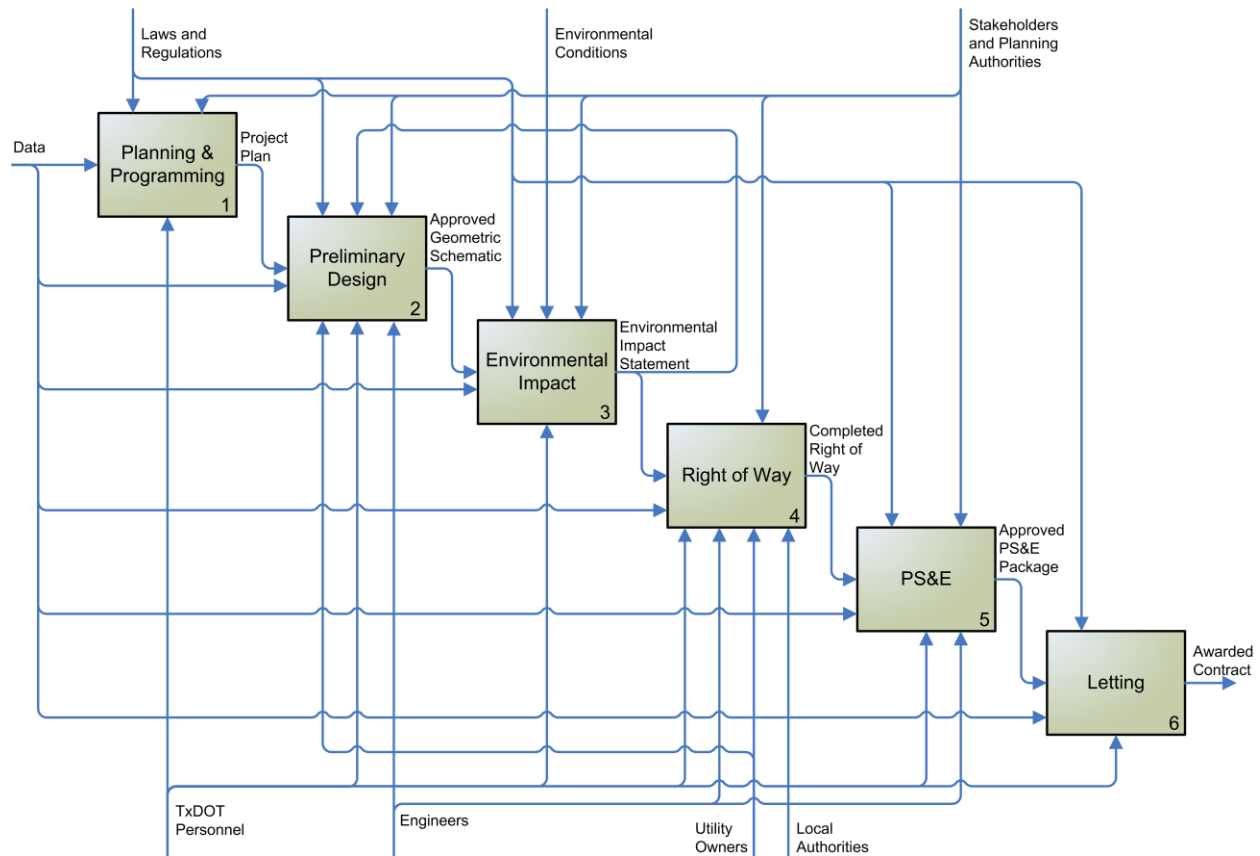
Figure 22. TxDOT PDP Decomposition Child Diagram.

By comparison, IDEF3 is a technique to capture, manage, and display process-centered knowledge in a form of scenarios that are displayed as process schematics (*53*). IDEF3 can be used to describe a process as an ordered sequence of events along with objects that participate in those events. AllFusion Process Modeler uses IDEF3 to support IDEF0 models when more detail and conditional information is available that can be expressed in junctions between activities, such as "all following processes must start/end," "one or more following processes must start/end," or if the user wants to analyze different scenarios of the same process.

A characteristic of the IDEF business process modeling notation is that all diagrams fit on letter-sized sheets. Although this format makes it very easy to physically handle and reproduce the model, the researchers quickly realized that the notation is very technical and less useful to discuss business process model details with practitioners that are unfamiliar with the notation. For example, the researchers developed a preliminary business process model of the project development process in IDEF0 format that consisted of about 70 letter-size pages. Researchers noted that many practitioners became quickly lost in the hierarchical structure of parent and child diagrams and were unable to provide useful feedback on the model. A part of the problem is that model reviewers see only a small portion of the model at a time, which makes it difficult to picture the whole network, verify existing relationships, or draw new relationships. The researchers also found that the integration between AllFusion Process Modeler and AllFusion ERwin Data Modeler provided little benefit to the development of the data models.

Business Process Modeling Notation

As a result of the difficulties with the IDEF notation, the researchers evaluated other options for business process modeling. One of the options under consideration was the Business Process Modeling Notation (BPMN), which depicts the end-to-end flow of a business process and has a process-oriented approach to application modeling (*54*). BPMN provides three basic types of models, which are private (internal), abstract (public), and collaboration (global) business process models. The collaboration business process model depicts interactions between two or more business entities as sequence of events, activities, and gateways that are arranged in "pools" and "swimlanes" along with data objects. After several experiments, the research team found that practitioners intuitively understood the BPMN's collaboration business process model and were able to provide useful feedback to researchers. Figure 23 shows a collaboration business process model in BPMN using the example of the utility agreement approval process.
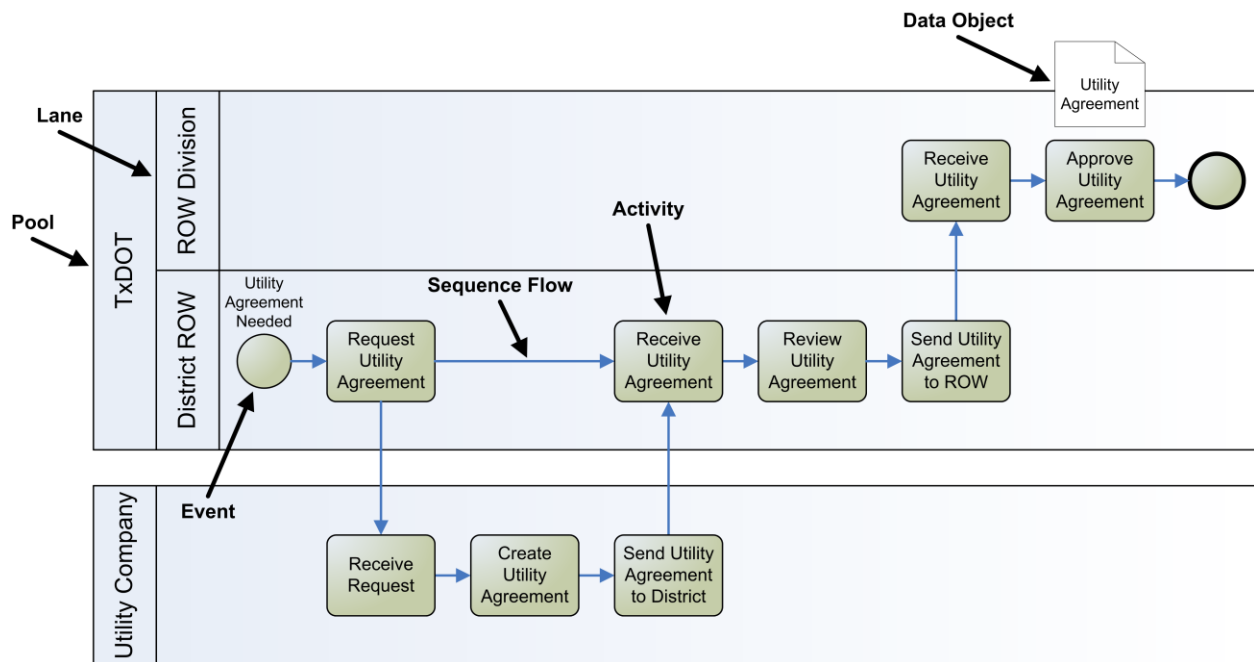
Figure 23. Example of Collaboration Business Process Model Using BPMN.

Collaboration business process models are also called "swimlane" diagrams, because they associate ownership of or responsibility for an activity with an entity that is represented by the swimlane. In other words, a swimlane diagram displays activities sorted by the entities, such as offices or sections within an organization that perform the activities. These entities, sometimes referred to as roles, have an assigned horizontal space across the length of the model for activities that these entities perform. As a result, the model takes on a different shape as compared to the "standard" business process model that simply arranges activities by precedence to display a chain of events. Because of the activity sorting, swimlane diagrams tend to stretch horizontally, which may create the impression of a more complex model. However, the swimlane diagram is simply a different view of a standard business process model. The advantage of a swimlane diagram is that activities are sorted into the horizontal swimlane of the

entity that performs the activity, and it becomes immediately evident when and how a certain entity becomes involved in the process.

Business Process Model Development Using BPMN

The research team used Microsoft Visio to produce the BPMN business process models, which allowed them to show the whole business process model on one sheet of paper. This strategy proved to be beneficial during meetings with TxDOT officials because they were able to see the whole process at once and draw lines and link activities from one area of the model to another.

Once the researchers determined the appropriate notation for the business process model, the next step was to determine the focus of the model or diagram point of view. This step is critical because the business process model includes several participants, and each participant may view the diagram in a different way, specifically, how the process applies to them. BPMN does not currently specify any graphical mechanisms to highlight the point of view, so the research team included this information along with further limitations and clarifications in the following disclaimer text that is shown on the main business process model:

> "This business process model describes the TxDOT Utility Coordination Process between TxDOT and other involved entities, such as utility companies, contractors, and consultants. The Utility Coordination Process is a set of activities that is part of the larger TxDOT Project Development Process. The activities of the utility coordination process are arranged in swimlanes that represent groups or organizational units that are involved in the utility coordination process. Each process activity is located in the swimlane of the organizational unit that has the responsibility to complete that activity. Activities are connected by arrows that signify precedence. As such, a preceding activity must be completed before the following activity can begin, or an output from a preceding activity is required as an input by a following activity. The process model is based on TxDOT's standard model of project delivery, design-bid-build (DBB). Alternate methods of project delivery such as comprehensive development agreements (CDAs) and facility concession agreements (FCAs) may exhibit significant differences from this process model. This business process model was developed using information from the TxDOT Utility Cooperative Management Process (UCMP) outlined in the TxDOT Utility Manual, the TxDOT Project Development Process (PDP) Manual, and feedback from TxDOT officials, utility company officials, and utility consultants.
> Texas Transportation Institute, 2008."

A major challenge in the development of the business process model was to define the model's appropriate level of detail. The researchers found that there was an optimum level of information that provided enough context for a productive discussion with practitioners without overburdening the participants with too much detailed information. This level of detail was roughly at the PDP task level, as described in Chapter 2. Although the researchers attempted to maintain a uniform level of detail throughout the model, it proved beneficial to increase the level of detail slightly in some areas by including some of the subtasks described in the PDP manual.

The researchers began the business process model development by translating a majority of the approximately 200 tasks in the PDP Manual into an extensive business process model. To determine activity sequence, relationships, and dependencies, the researchers reviewed the task and subtask descriptions of all tasks. Unfortunately, the PDP Manual does not provide a wealth of information on task sequence, and statements such as "tasks are provided in approximately chronological order" are typical. Due to this lack of information on activity sequence,

relationships, and dependencies, the model in its first version displayed long chains of activities with little concurrency and few links between different TxDOT groups. Clearly, this first version was not an accurate reflection of the actual TxDOT project development process, which is not a linear process but rather exhibits several activities occurring concurrently at any given time. Through several meetings with process stakeholders, the research team was able to move from a strictly sequential model to a model with many concurrent activities that provides a better representation of the actual TxDOT project development process.

Concurrently, the researchers reviewed the Utility Manual and developed an updated UCMP flowchart that integrated the Local Utility Procedure (LUP), the State Utility Procedure (SUP), and the Federal Utility Procedure (FUP) into one chart. With the help of the research advisory panel, the researchers were able to validate the chart activities and relationships, identify dependencies, and outline activity prerequisites. The researchers integrated all tasks from the PDP process chart with any relation to utility coordination and/or relocation processes. The result of this effort was an integrated PDP/UCMP utility relocation business process model.

UACT BUSINESS PROCESS MODEL DESCRIPTIONS

Local District Business Process Models

Starting with the initial PDP/UMCP model, the research team developed separate business process models for the Houston and the San Antonio Districts that focused on precedence of activities but did not show responsibilities for the activities. In the next step, the research team created a swimlane diagram of the models, and finally combined the two models into a single model titled "Utility-Focused Right of Way Coordination in the Project Development Process." The researchers also created an overview diagram and alternative process model for utilities choosing to participate in utility relocation prepayment funding agreements, as authorized by Senate Bill (SB) 1209 (*55*). The three business process models were submitted to the research panel as product P3. The short titles for these models are as follows:

- Detailed Business Process Model
- Overview Diagram
- SB 1209 Business Process Model

The following sections provide an overview of these business process models.

Detailed Business Process Model

The detailed business process model (BPM) is a BPMN swimlane diagram that provides a view of activities related to utility-focused right of way coordination in the project development process. The detailed BPM uses the following model elements:

- **Pool.** A pool represents an organization within the BPM. This BPM consists of two pools, "TxDOT" and "utility company." In the BPM, pools are implied but not designated using graphical elements.

- **Swimlane.** A swimlane is a subcomponent of a pool that associates ownership of or responsibility for an activity with an entity that is represented by the swimlane. A swimlane is the highest level of organization in the business process model that has a graphical representation.

- **Subswimlane.** A subswimlane is a component of a swimlane that is used to further break down ownership of or responsibility for activities.

- **Secondary Subswimlane.** A secondary subswimlane is a component of a subswimlane that is used to further break down ownership of or responsibility for activities.

- **Activity Group.** An activity group represents an aggregation of activities that is useful for a high-level view of the model. All activities in the business process model are part of an activity group. The overview diagram shows only activity groups.

- **Activity.** Activities are descriptions of actions or tasks that stakeholders of the business process carry out. Each activity is located in a swimlane that indicates ownership or responsibility for that activity. Activities are shown as boxes with an activity name, a UCMP process or subprocess code (if available), a PDP task number (if available), and a business process model code. The research team created the business process model code to label several new activities that the researchers defined as a result of discussions with stakeholders, which consequently do not have a UCMP or PDP code.

- **Subactivity.** A subactivity is a disaggregation of an activity, which the researchers created in cases where the activity did not provide an adequate level of detail.

- **Secondary Subactivity.** A secondary subactivity is a disaggregation of a subactivity, which the researchers created in cases where the subactivity did not provide an adequate level of detail.

The PDP Manual and the UCMP in the Utility Manual use different elements to describe processes. Table 10 provides an overview of how the elements of the detailed business process model approximately relate to business process elements in the PDP Manual and the Utility Manual:

Table 10. Detailed Business Process Model Elements and TxDOT Manual Equivalents.

BPM Element	Approximate PDP Manual Equivalent	Approximate UCMP Equivalent
Pool	-	-
Swimlane	Chapter (most)	-
Subswimlane	Chapter (some)	-
Secondary Subswimlane	-	-
Activity Group	Section	-
Activity	Task	Process Activity
Subactivity	Subtask (most)	Process Activity or Subprocess Activity
Secondary Subactivity	Subtask (some)	Subprocess Activity

In the business process model, each swimlane, activity group, activity, and subactivity has a business process model code that consists of up to five numbers separated by periods. In order to limit the business process model codes to five numbers or less, the researchers decided to exclude subswimlanes or secondary subswimlanes from the code structure. As a result, users can only infer the swimlane from the business process model code. Table 11 gives an overview of the code structure used for the detailed business process model:

Table 11. Detailed Business Process Model Code Overview and Example.

BPM Element	BPM Code	BPM Code and Activity Description Example
Swimlane Number	x	1 Advanced Transportation Planning
Activity Group Number	x.x	1.1 Project Programming and Funding
Activity Number	x.x.x	1.1.5 Obtain Input from Local Entities and Others
Subactivity Number	x.x.x.x	1.1.5.4 Annual (Utility) Meeting
Secondary Subactivity Number	x.x.x.x.x	1.1.5.4.1 Discuss STIP with Utilities

The current version 12 of the business process model consists of six swimlanes, 36 activity groups, 174 activities, 100 subactivities, and two secondary subactivities. Of the 174 activities in the business process model, 104 are new activities the researchers defined during discussions with stakeholders without a PDP or UCMP code. Of the 104 new activities, 49 describe utility company activities in the utility company swimlane and 55 describe TxDOT activities. For the purpose of this research, it was not necessary to create detailed descriptions of the 55 new TxDOT activities. However, a future implementation of the business process model as a training tool or reference should consider the creation of detailed descriptions for all new tasks, which could include updates to the PDP and Utility Manual, and possibly the creation of a separate guideline for utility companies.

In the business process model, activities are connected by arrows that identify inputs or outputs for an activity. Arrows within swimlanes are blue; if they cross swimlanes, they are color-coded using the color of the originating swimlane. The business process model also displays documents that an activity produces or modifies. In the data flow diagram, these documents are used to represent the flow of data in the project development process. Table 12 provides a listing of the business process model's activity groups and activity group codes for each swimlane and subswimlane in the model. For a complete listing of activities, subactivities, and secondary subactivities, refer to Appendix B.

A challenge in the creation of the business process model was to deal with the multitude of TxDOT project types. TxDOT projects vary substantially in duration (from several months to several years) and complexity. Given the limitations in time and resources for this project, the team did not attempt to create separate business process models for different project types. Instead, the research team asked process stakeholders to focus on the "worst case scenario," the most time-consuming and complex project. As such, the business process model should include activities that may not be required for all types of projects.

At the beginning of the modeling phase, the researchers attempted to model the status quo of utility coordination activities in the project development process at every district the researches visited. Following this approach, the researchers intended to create status quo models for each district, and then follow up with the district to create a model of how the process should be carried out. Again, the research team quickly realized that this approach was not feasible, given restraints in time and resources for this project. As such, the researchers focused the discussions with district and division representatives on how the utility coordination activities should be carried out in the project development process, and how the utility conflict tracker could best support this process.

Table 12. Detailed Business Process Model Activity Group Codes and Names by Swimlane.

Swimlane	Subswimlane	Activity Group Code	Activity Group Name
Advanced Transportation Planning	-	1.1	Project Programming and Funding
		1.2	Obtain PLAN Authorization
		1.3	Assign ROW-CSJ
		1.4	Obtain DEVELOP Authorization
		1.5	Obtain CONSTRUCT Authorization
Advanced Project Development	Schematic Design	2.1	Data Collection and Preliminary Utility Coordination
		2.2	Preliminary Design (Schematic Design)
	Environmental	2.3	Environmental Documentation
		2.4	Environmental Clearance
Design	-	3.1	PS&E Development (Detailed Design)
		3.2	PS&E Assembly/Design Review
Right of Way	Utilities	4.1	Preliminary Utility Coordination
		4.2	Preliminary Right of Way Research
		4.3	SUE Level C and D (Visual and Records)
		4.5	Obtain Right of Way Release
		4.6	SUE Level C (and Some B)
		4.8	Locate Utilities (SUE Level B and Some A)
		4.10	Utility's Consultant Contract Approval
		4.11	Agreements with Utilities
		4.12	Locate Utilities (SUE Level A)
		4.13	Adjustment Monitoring and Reimbursement Before Letting
		4.14	Utility and Right of Way Certifications
		4.17	Adjustment Monitoring and Reimbursement After Letting
	Right of Way Mapping	4.4	Right of Way Mapping Before Letting
		4.15	Right of Way Mapping After Letting
	LPA Coordination	4.7	Secure Federal, State, and Local Funding Agreements
	Acquisition and Special Projects	4.9	Right of Way Acquisition Before Letting
		4.16	Right of Way Acquisition After Letting
Letting Authority	-	5.1	Final Processing and Letting
Utility Company	-	6.1	Initial Utility Involvement
		6.2	Preliminary Design Meeting
		6.3	Initial Coordination and Markup
		6.4	Conflict Determination
		6.5	Utility Design
		6.6	Utility Adjustment Before Letting
		6.7	Utility Adjustment After Letting

Version 12 of the business process model identifies 17 milestones, which are model elements that mark the completion of a significant document, activity, or phase in the process. For each milestone, the model lists the documents that are required to complete the milestone and the resulting product of the milestone. Note that some of the milestones may occur repeatedly in the process, whereas other milestones only occur once for each project. For example, the milestone "PLAN Authorization" occurs only once per project, whereas the milestone "Executed Utility Agreement" occurs once for each utility agreement needed in a project. Table 13 provides a listing of the business process model's milestones in chronological order including document requirements and milestone products. Note that due to great variations in project requirements not all projects have the same document requirements.

Through many iterations of the model, the diagram continued to grow in size and is now about 18 feet long, which prohibits the inclusion of the detailed business process model in this report. The researchers submitted the complete business process model separately in print and electronic format as product P3. For inclusion in this report, the research team created an overview diagram that displays the swimlane activities at a very high level, as follows.

Table 13. Detailed Business Process Model Milestones.

Milestone	Required Documents (May Depend on Project Type)	Product
PLAN Authorization	• Transportation Commission Approval (Minute Order) • Construction CSJ	• Authorization to perform planning, preliminary design, environmental, right of way determination, route study, and public involvement activities
Design Concept Conference	• Partial Design Summary Report • Advanced Planning Risk Analysis	• Meeting Notes
Preferred Geometric Alignment	• Preliminary Level of Service (LOS) analysis • Horizontal and vertical alignments for all feasible route alternatives • Typical sections • Landscape and aesthetic assessment • Bicycle and pedestrian accommodation concept • Analysis of corridor alternatives	• Preferred geometric alignment alternative
Final Geometric Schematic	• Geotechnical survey • Pavement design report • Refined typical sections • Report on impact of historic structures • Detailed LOS analysis • Guide signal and operational controls report • Preliminary planning for weigh stations, bridges, retaining walls and noise walls • Hydrologic study • Hydraulic analysis • Right of way and access needs analysis • Location of existing utilities report • Preliminary illumination locations • Constructability review • Project scope update • Value engineering study • Updated cost estimate • Design waivers and design exceptions approval • Public involvement notes and comments • Project stakeholder comments	• Final geometric schematic

Environmental Clearance	• Environmental document
	  o Public involvement notes and comments
	  o Purpose and Need statement
	  o Natural resources study
	  o Cultural resources study
	  o Section 4(f) evaluation
	  o Hazardous materials assessment and investigation
	  o Socioeconomic/environmental justice analysis
	  o Right of way relocation impacts
	  o Noise analysis
	  o Air quality analysis
	  o Environmental consequences assessment
	  o Landscape recommendations
	  o Environmental mitigation plans
	  o Public comments and responses
		• Approved environmental document (ENV only/ENV and FHWA)

DEVELOP Authorization	• Ranked project listing
	• Final geometric schematic
	• Transportation Commission Approval
	  o Inclusion in UTP
	  o Minute Order (if not in UTP or if facility or a portion of it has control of access)
		• Authorization to prepare PS&E and acquisition of ROW

Table 13. Detailed Business Process Model Milestones (Continued).

Milestone	Required Documents (May Depend on Project Type)	Product
Approved Right of Way Map	• Right of way map checklist • Final right of way map	• Right of way map approved by ROW Division
Design Conference	• Partially completed Design Summary Report (DSR) • Project data including maps, aerial photography, and schematics. • Advance Planning Risk Analysis assessment	• Design Conference notes • Updated DSR
Funding Secured	• Federal Project Authorization and Agreement (FPAA) • Alternate Procedure Approval (APA) from FHWA • Agreement to Contribute Funds • Contractual Agreement for Right Of Way Procurement • Advance Funding Agreements	• Approved funding agreements with LPAs/project stakeholders
Right of Way Project Release	• Approved final geometric schematic • District approved right of way map • Right of way cost estimate • Environmental clearance • Approved funding agreements with LPAs, FHWA, and other project stakeholders if applicable	• Authorization for all right of way activities including adjustments of utilities and reimbursements.
30% PS&E (Detailed Design) Complete	• Preliminary PS&E documentation	• PS&E documentation 30% complete
60% PS&E (Detailed Design) Complete	• Preliminary PS&E documentation	• PS&E documentation 60% complete

Executed Utility Agreement*	• Standard utility agreement signed by TxDOT and utility owner, including:
	  o Attachment A, PS&E documentation
	  o Attachment B, utility's accounting method
	  o Attachment C, utility's schedule of work and estimated date of completion
	  o Attachment D, statement covering contract work, if applicable
	  o Attachment E, Utility Joint Use Acknowledgement
	  o Attachment F, eligibility ratio calculation
	  o Attachment G, betterment calculation and estimates
	  o Attachment H, proof of property interest, if applicable
	  o Attachment I, including utility advance funding agreement (if included in highway contract)
	  o Additional documentation as appropriate
	• Compensable interest certificate
	• Utility adjustment checklist
		• Executed utility agreement

90% PS&E (Detailed Design) Complete	• Preliminary PS&E documentation	• PS&E documentation 90% complete
CONSTRUCT Authorization	• Ranked project listing • Design and right of way acquisition at least 75% complete • Transportation Commission Approval • Inclusion in UTP • Minute Order (if not in UTP or if facility or a portion of it has control of access)	• Authorization to complete PS&E documentation, utility adjustments, and roadway construction
Project Letting	• State letter of authorization (LOA) • FPAA, if applicable • Financial clearance analysis • Earthwork construction cross sections	• Final bid proposal
Adjustment As-Builts*	• Not available	• Utility owner as-built documentation

Note: Milestones with a * may occur repeatedly in the project development process.

Overview Diagram

The overview diagram provides an overview of utility-focused right of way coordination in the project development process. It displays the activity groups of the detailed business process model, the swimlanes, and a select number of input/output arrows and milestones. Relationships crossing swimlanes do not differentiate between input and output, and relationships between activities within a swimlane are not shown to prevent the diagram from being too cluttered. The only milestones shown are "Design Concept Conference," "Design Conference," and "Letting." The location of the activity groups relates to the approximate location in the detailed business process model. Finally, the diagram includes vertical separations for the three levels of project authority, "PLAN," "DEVELOP," and "CONSTRUCT."

The purpose of this diagram is to provide a starting point in the business process model discussions with process stakeholders. The diagram provides a quick reference that gives stakeholders an approximate orientation for discussion of process activities at a more detailed level. In an implementation of the prototype, the diagram could be used as a high-level process display to provide stakeholders access to areas of interest in the detailed business process model. As such, each activity group should be a clickable area on a web interface that would link to a view of the activities in that activity group. In turn, each activity box could then be linked to a detailed description of the activity as provided by TxDOT manuals. Figure 24 shows version 12 of the overview diagram.

Data Flow Diagram

Some of the activities that the research team described in the detailed business process model have data or documents attached to them that are created, read, updated, or deleted. The data flow diagram (DFD) is a different view of the detailed business process model that shows only the flow of data or documents between activities. Similar to the IDEF0 notation, a DFD models systems as a network of activities connected by arrows that represent the movement of data between activities. As such, arrows display the flow of data and are labeled according to the data that flows from on activity to the next. The data flow diagram is useful for the development of the requirements of the information system architecture. Figure 25 shows the DFD of the system prototype.

Utility-Focused Right Of Way Coordination in the Project Development Process: Overview Diagram

Project 0-5475 • Version 12 • August 2008
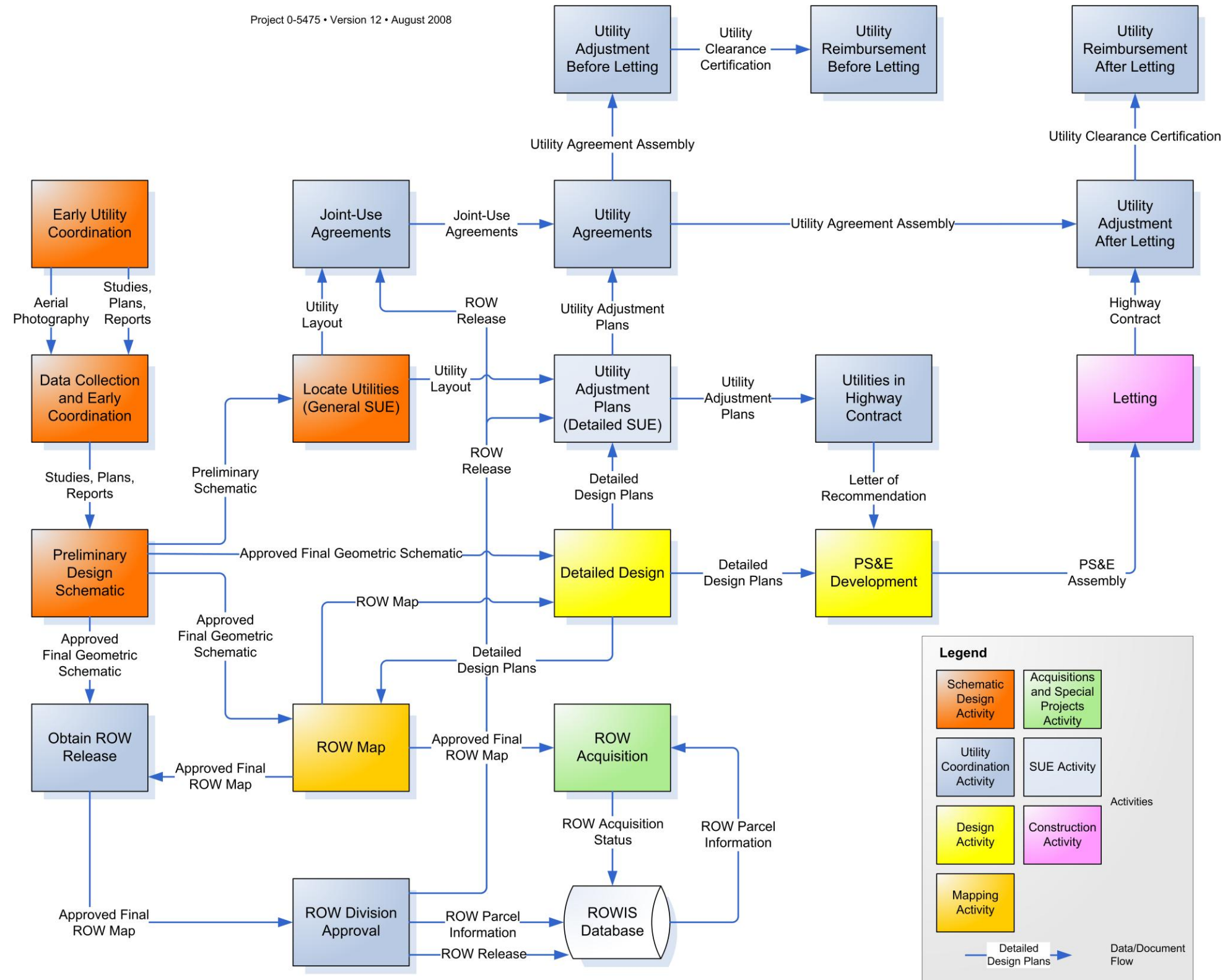
Texas Transportation Institute

Figure 24. Overview Business Process Model of Utility Relocation in the TxDOT Project Development Process.

Utility-Focused Right Of Way Coordination in the Project Development Process: Data Flow Diagram

Figure 25. System Prototype Data Flow Diagram.

Business Process Model for Utility Relocation with Prepayment Funding Agreements

The 80th Texas Legislature passed Senate Bill 1209, which added section 203.0922 to the Texas Transportation Code (*56*). This section authorizes TxDOT, at the request of a utility company, to enter into a prepayment funding agreement with the utility to reimburse the utility for direct and related indirect costs of a utility relocation project. The bill provides a process in which the utility signs a master agreement with TxDOT and then pays an annual prepayment amount for at least six years and if elected, a multiple of three years after the initial six-year period. The bill further provides that the annual prepayment amount for the initial three-year period should be equal to 75 percent of the (non-reimbursable) annual average of the utility's direct and related indirect costs incurred for relocation of the utility's facilities on the state highway system during the preceding three-year period. If a TxDOT project requires a utility to move that has a master agreement in place and otherwise would not be eligible for cost reimbursement, the utility can enter into a project utility agreement with TxDOT to receive cost reimbursement from TxDOT.

As a result of SB 1209, the Texas Transportation Commission appointed a rules advisory committee of seven members of the utility community to meet with TxDOT staff and render advice, review drafts, and make specific recommendations. In November of 2007, the rules advisory committee unanimously recommended the adoption of a new set of rules that were published in the Texas Register for comment, and adopted by the Texas Transportation Commission Minute Order 111255 in February of 2008 (*57, 58*). The new rules became effective March 20, 2008, as Subchapter P, Utility Relocation Prepayment Funding Agreements, of Chapter 21 in the Texas Administrative Code (*59*). The rules, which are essentially an implementation of the statutory law that will control the operation of the new program, cite that the annual prepayment amount will be equal to 75 percent of the averaged annual relocation/adjustment costs incurred or paid for the relocation of utility facilities.

The research team developed a subprocess model for the detailed business process model to capture changes to the business process as a result of SB 1209. The SB 1209 business process model covers alternative activities that may occur due to the provisions of the new rules in the Texas Administrative Code. It consists of two swimlanes, TxDOT and utility company, several activities and activity groups, decision points, and milestones. It also shows required documents for activities in the subprocess. The purpose of the subprocess model is to allow the prototype management system to manage utility conflicts under the provisions of the new rules. The subprocess model is too large to include in this report. The research team submitted the complete model as a part of product P3.

CHAPTER 5. DEVELOPMENT OF DATA MODELS FOR A PROTOTYPE UTILITY CONFLICT MANAGEMENT SYSTEM

INTRODUCTION

The business process and data flow models described in Chapters 3 and 4 provided the foundation for a logical model of the utility conflict management system prototype's database. The team then translated the logical model into a physical model for the Oracle database environment and developed a first version of the prototype in the Microsoft .NET™ environment. Concurrently, the researchers identified requirements of the utility conflict data management system. Specifically, the researchers identified user, functional, and other system requirements. This chapter starts with a summary of the system requirements and subsequently discusses the logical data model structure of the prototype in its current form and anticipated improvements to the model in the beta development phase.

USER, FUNCTIONAL, AND OTHER SYSTEM REQUIREMENTS

UACT User Requirements

The research team created a list of user requirements from feedback received from TxDOT officials, utility companies, and consultants. Potential future users of the system suggested the following system features:

- Provide a simple, consistent, and accessible interface with user group-based customization. TxDOT administrators should be able to customize the scope and level of detail viewable by external users.

- Provide web-based user access through the Internet or the TxDOT intranet.

- Provide secure, permissions-based document management. Keep a complete record of changes and deletions made by system users.

- Allow for the exchange of documents between system users.

- Allow users to restrict access to documents.

- Accommodate flexible workflows for the management of utility-related tasks.

- Allow scheduling and management of meetings and events using a project calendar that is accessible online.
- Provide a directory of TxDOT and utility companies and representatives.

- Provide a mapping component that allows visualization of utility, design, and right of way data.

- Provide a help system and a list of frequently asked questions (FAQs) about the software and current TxDOT utility procedures, and link to important references.

- Send billing reminders to utility companies involved with reimbursable projects.

- Print CAD files that users upload to the system to PDF.

- Allow users to query data and generate reports based on user input.

UACT Functional Requirements

Based on user requirements and input that researchers received from the project advisory panel, the team developed a list of functional requirements. The researchers developed functional requirements for the system interface, document exchange and storage, communications, reporting, visualization, and compatibility with future and existing TxDOT information systems.

System Interface

- Provide a contact directory for TxDOT and external users and allow users to update their profile.

- Provide a customized interface for both TxDOT and external user groups.

- Provide a user access permissions system with several access levels that allows administrators or designated users to restrict access to view, edit, or delete documents and project information.

- Provide a project summary screen that shows the progress of the selected utility project, including past and upcoming milestone dates.

- Manage and view utility facilities within the limits of a construction project, including assignment of documents or schematics to a utility facility, association of owner and representative information with each utility facility, and maintenance of conflict and adjustment status for each utility facility.

Document Exchange and Storage

- Upload, manage, and display CAD files, such as design plans and schematics, surveying data, and utility plans and schematics.

- Convert uploaded files to PDF.

- Allow the exchange and coordination of utility-related documents and schematics between utility companies and TxDOT officials.

- Provide support for the creation of utility agreements associated with reimbursable utility adjustments.

Communications

- Allow users to leave comments about documents or utility facilities.

- Provide a project calendar that outlines important project dates and milestones.

- Provide customizable e-mail notifications of upcoming events, new messages, and new documents that TxDOT users can send to project stakeholders automatically.

- Provide a management system for meetings, including meeting scheduling.

- Association of documents such as agendas, meeting minutes, attendance list, etc.

Reporting

- Provide automated document generation of reports, including utility conflict list, letter of no conflict, reimbursable utility adjustment billing reminders, utility clearance certifications, and triple-zero special provisions.

Visualization

- Allow visualization of MicroStation plot/composite files with attached reference files, such as design schematics, utility adjustment plans, and current and proposed right of way limits using a GIS component.

- Allow creation, modification, and deletion of utility conflict outlines representing the location of utility conflicts using a GIS component.

Compatibility with Existing and Future TxDOT Information Systems

- Design a data architecture compatible and integratable with applicable TxDOT RDBMS applications such as ROWIS and UIR using relational logical/physical database models and consistent metadata fields (e.g., dates, authors, etc.); consistent data types (e.g., integer, string, date, etc.); consistent file folder naming conventions; and consistent entity, relation, and attribute naming conventions. Maintain compliance with TxDOT data architecture standards and CAD level and cell libraries.

- Maintain compatibility of the data architecture with TxDOT GAIP.

- Design a data architecture consistent with applicable TxDOT legacy applications such as DCIS using consistent naming, metadata fields and data types for data entities and associated attributes.

- Consider the use of data warehousing for data updates and downloads of legacy application data.

UACT Other System Requirements

Based on the list of functional requirements for the prototype data exchange system and feedback from the advisory panel, the researchers developed a list of system requirements for software, hardware, and interfaces.

Software

- Microsoft Windows Server 2003® standard operating system

- Microsoft IIS with .NET Framework 2.0 web server

- Oracle database

- ESRI Arc Geographical Information System Server™ (ArcGIS™ Server) and ArcSDE mapping components

- Adlib Software® Adlib Express Server® PDF conversion software

- Cimmetry® AutoVue® 2D Desktop CAD file viewer

Hardware

- Database server with Intel® Xeon® 3.2 GHz processor, 2 GB random access memory (RAM), 1 terabyte (TB) serial advanced technology attachment (SATA) storage, and Microsoft Windows Server 2003 R2 Standard

- Web server with Intel Xeon 3.6 GHz processor, 2 GB RAM, 1 TB of SATA storage, and Windows Server 2003 R2 Standard

Interface

- Compliant with Hypertext Markup Language (HTML) or Extensible Hypertext Markup Language (XHTML).

- Compliant with World Wide Web Consortium (W3C) Cascading Style Sheet Level 2 Specification (CSS2).

- Consider W3C web content accessibility guidelines.

For the development of this prototype, the researchers made use of existing hardware and software purchased through other projects including UIR (project 5-2110-05), the development of an online system for utility permits.

Additional Considerations and Recommendations

The research team received additional recommendations from the research advisory panel throughout the development of the prototype system. A summary of key recommendations follows:

- The ROW Division is committed to the use of ROWIS for the tracking of utility payments at this point. Since ROWIS does not allow creation of utility conflicts or agreements, users create parcels in ROWIS to represent utility agreements. Payment information should not be duplicated in UACT; therefore, UACT would need to connect to parcel information in ROWIS to obtain billing and payment information for a utility agreement.

- A U-Number is an identifier for a utility adjustment, utility agreement, or a Joint Use Acknowledgement. The U-Number is a unique identifier statewide in combination with the right of way CSJ. A U-Number can cross different CSJs using percent allocations. A problem with U-Numbers spanning multiple CSJs is that some construction CSJs might not have environmental clearance. If a utility works outside the CSJ limits, the work must be necessary and justified by the work in the first CSJ. If it is a convenience to continue outside the limits, it should be charged to the second CSJ. After project completion, the Joint Use Acknowledgement is retained and the utility agreement info is discarded. U-Numbers for utility agreements should not be generated by the system. Instead, UACT should provide field where the ROW Division could enter the U-Number manually.

- Supplemental agreements to utility agreements may complicate matters further. Supplemental agreements affect a percentage allocated per right of way CSJ, so one supplement may be associated with many right of way CSJs.

- There should be a process on the interface to facilitate the relation of utility conflicts to multiple roadway CSJs. For example, if a utility company submits documentation for a single utility line that spans several highway projects, the utility line should be associated with several highway CSJs. It may be necessary to use the "project name" field or another code to cover several highway projects.

- ROW Division officials mentioned that the right of way CSJ in DCIS sometimes is incorrect. In this case, a business process that involves TPP is in place to correct the CSJ number. For UACT, it would be useful to introduce a quality control procedure to verify DCIS data and to highlight potential cases where DCIS data in UACT is not up-to-date when data is imported into UACT.

- The ROW Division encourages the use of a one-to-one relationship between CSJ and right of way CSJ. However, there may have been projects where a CSJ has two right of way CSJs or a right of way CSJ spanned more than one CSJ. It would be preferable to allow a many-to-many relationship between CSJ and right of way CSJ to provide additional flexibility.

LOGICAL DATA MODEL DEVELOPMENT

The researchers developed a logical model for the UACT system using ERwin Data Modeler. The development of the logical and physical model as well as the data dictionary followed the standards that TxDOT provided in version 4.0 of the TxDOT Data Architecture Manual (*51*). In particular, the logical model

- displays entities, attributes, and relationships;
- uses Information Engineering notation;
- identifies primary, foreign, and alternative keys;
- is designed to third normal form; and
- includes a data dictionary.

In addition to the above, the logical data model also includes format or datatype definitions. Specifically, the researchers assigned a datatype for each attribute in the data model. This is an iterative process, where the data designer assigns a datatype to the best of her knowledge at the time the attribute is created. In a later stage, the designer may revisit the attribute's datatype definition as more information about the physical implementation of the attribute becomes known and make modifications to the datatype. For example, a company identifier may initially have the datatype "number," until it becomes known that the company identifier should be a combination of numbers and letters, which suggests the use of the datatype "varchar." To provide a starting point for assigning datatypes and promote the consistent use of datatypes in the model, the researchers developed a list of common and default data types (Table 14.)

Table 14. Standard UACT Logical Data Model Datatypes.

Attribute	Datatype
Address	VARCHAR(100)
Amount	NUMBER(X,X)
ESTIMATE AMOUNT	NUMBER(14,2)
Code	NUMBER, NUMBER(X)
FEATURE CLASS CODE	VARCHAR(30)

Table 14. Standard UACT Logical Data Model Datatypes (Continued).

Attribute	Datatype
Date	DATE
Flag	NUMBER(1,0)
ID	NUMBER, NUMBER (10), NUMBER (10,0)
COMPANY ID	VARCHAR(30)
COMPANY USER ID	VARCHAR(30)
DOT UNIT ID	VARCHAR(5)
Feature Ids	NUMBER (10,0)
Login Ids	VARCHAR(30)
OBJECTID	INTEGER
OFFICE ID	VARCHAR(30)
OFFICE PLACE ID	VARCHAR(30)
PERMIT ID	VARCHAR(30)
PLACE ID	VARCHAR(30)
PRIVILEGE ID	NUMBER (2,0)
SESSION ID	VARCHAR(30)
STATE ID	VARCHAR(2)
STATUS ID	NUMBER(2,0)
SYSTEM USER ID	VARCHAR(30)
TABLE UNIQUE ID	NUMBER (10)
TxDOT UNIQUE ID	NUMBER (10)
USER PLACE ID	VARCHAR(30)
Measurement	NUMBER, VARCHAR(30)
Names	VARCHAR(100)
Text fields	VARCHAR(X)
Comment	VARCHAR(1000)
Description	VARCHAR(1000)
Disclaimer Text	VARCHAR(1000)
NOTE TEXT	VARCHAR(4000)
NOTE TITLE	VARCHAR(100)
SCOPE OF WORK TEXT	VARCHAR(1000)
Number	NUMBER(X,X)
PHONE NUMBER	VARCHAR(30)
PARCEL NUMBER	VARCHAR(30)

Table 14. Standard UACT Logical Data Model Datatypes (Continued).

Attribute	Datatype
CONTROL SECTION JOB NUMBER	NUMBER (9,0)
Percent	NUMBER
Quantity	NUMBER(10,0)
Shape	LARGE BINARY
String	VARCHAR(1000)
Timestamp	TIMESTAMP

Core UACT Data Elements

To manage utility coordination data, the UACT data model is centered on four core data elements, which are "Feature," "Project," User," and "Document." "Feature" is a representation of a great variety of objects that have boundaries in both space and time. Features can be represented by points (e.g., poles, signs, and pedestals), lines (e.g., centerlines, project limits, and utility lines), and polygons (e.g., parcels, paved areas, and building footprints). "Project" represents data about projects, "Document" represents data about a variety of documents, and "User" represents data about the people who interact with the system and manipulate the data. As Figure 26 shows, the relationship between these entities is many-to-many. For example, a feature may be associated with many projects, many users, and many documents. Similarly, a project may be associated with many users, many documents, and many features. The same applies for users and documents. This UACT core data model is an expansion of the data model developed for project 0-5246, which includes the entities "Feature," "Project," and "Document" (*60*).
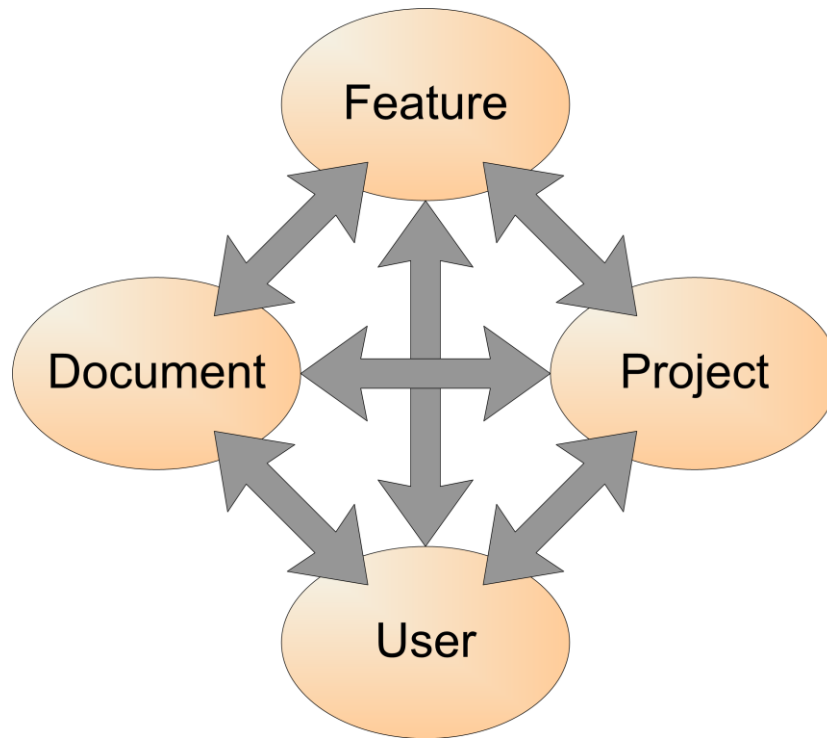
Figure 26. UACT Data Model – Core Data Elements.

In the logical data model, the four main data elements are represented by the entities FEATURE, UACT PROJECT, SYSTEM USER, and DOCUMENT. A more formal definition of the four main entities follows:

- **DOCUMENT**. A DOCUMENT is a tangible product in printed or electronic form produced from, resulting from, or documenting a TxDOT Project Development Process activity. A DOCUMENT can be indexed or catalogued in terms of business process operations or activities. Examples include forms, chapters, technical memoranda, invoices, and reports (provided the entire report is represented by a single file; otherwise the report would need to be represented using document sets). A document may have several files or versions (in a variety of formats) associated with it (through DOCUMENT VERSION).

- **FEATURE**. A FEATURE is an object (real or virtual) that has boundaries in space and time. In the model, a feature can be represented by points, lines, or polygons. 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.

- **SYSTEM USER**. A SYSTEM USER is a person that has an account and the authority to use the UIR and/or UACT system. The system allows two types of users: DOT USERs and COMPANY USERs (e.g., installation owners). Both types of SYSTEM USERs are assigned with different levels of system access for both permitting and user management within the system.

- **UACT PROJECT**. A UACT PROJECT is a TxDOT roadway improvement project that is managed and tracked in the UACT application. The data of a UACT PROJECT is mostly derived from a DCIS PROJECT.

In most cases, there are existing information systems at TxDOT that support business processes to create data for these entities. For example, DCIS and ROWIS are repositories for project-related data, FileNet is a TxDOT system for document-related data, and MST is a system to provide GIS feature data in a GAIP-compatible format. The challenge in the design of the UACT logical data model was to minimize data redundancy and maximize the use of existing data. As such, the data model facilitates the use of existing data from TxDOT systems wherever possible. The many-to-many relationships in this data model enable a mapping of data in UACT and existing systems and therefore minimize data redundancy.

Figure 27 is a data model that shows the UACT core data elements in Figure 26 and additional entities including entities from other TxDOT systems to provide an overview of the UACT data model at a high level. The figure shows entities without attributes to facilitate the understanding of the model. To avoid potential design issues, the researchers resolved the many-to many relationships between the core data elements in the logical data model using associative entities or linking tables. In Figure 27, the core entities are shown in orange, and the associative entities are shown in blue.

Figure 27 also shows several green entities, which represent entities from systems that TxDOT is currently using or are under development for future use. To minimize data duplication and redundancy, the researchers designed the logical model to make use of the data provided by these systems, and to follow existing data structures to allow in-turn sharing of UACT data as much as possible.
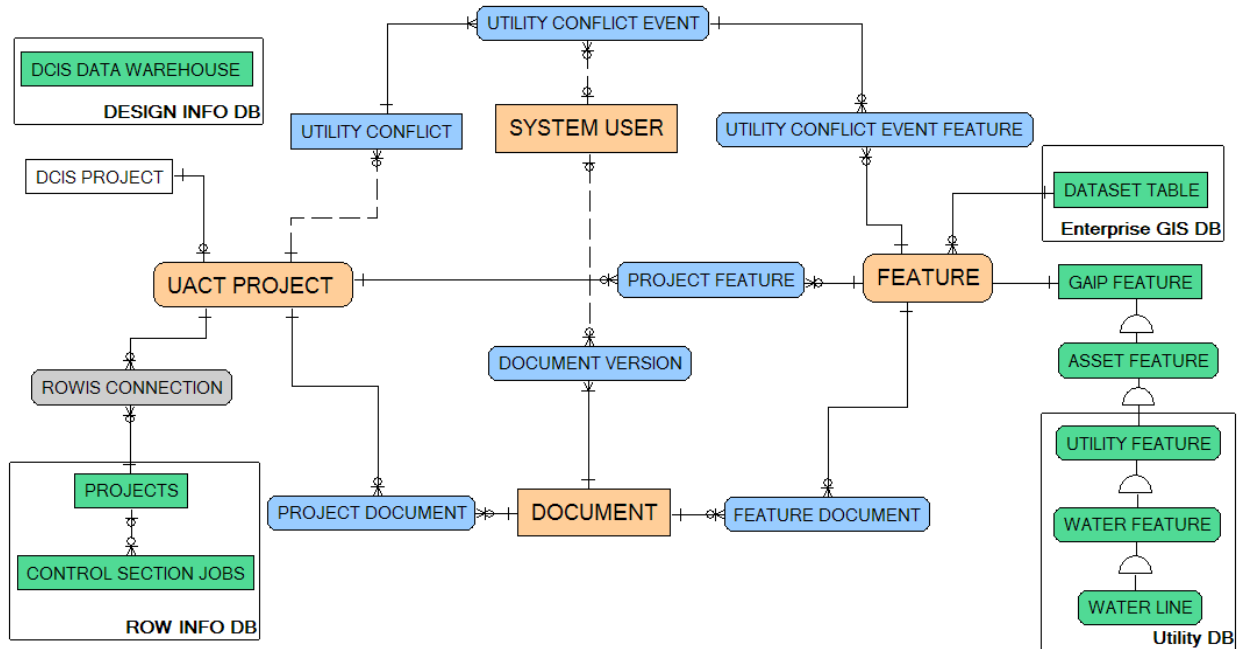
Figure 27. UACT Data Model – High-Level Logical Data Model.

The logical data model consists of a large number of entities. To make the data model easier to manage and to distinguish between entities of UACT and other systems, the researchers divided the model into 16 groups of entities, or subject areas: ArcSDE, DCIS, Document, Feature, FileNet, Main Street Texas, Meeting, Permission, Project, ROWIS, System, Utility Agreement Assembly, Utility Facility Database, Utility Installation Review, User, and Utility Conflict. The use of subject areas also facilitates the data updating process since database scripts can be generated separately for each subject area. The following provides a description of the main entities and relationships in each subject area. Subject areas that show entities and attributes are included in Appendix B. A complete data dictionary of the UACT prototype including attribute definitions and datatypes is included in product P2.

The logical model shows entities that represent tables in the physical data model. With the exception of a few entities that only exist in the logical model, all entities in the logical model become tables in the physical model. Although tables have the same attributes as their respective entities, table names and tables attribute names are different from entity names and entity attribute names to conform with data modeling standards and database requirements. A complete physical model of UACT as well as pdf files of physical model subject areas is included in product P2.

ArcSDE Subject Area

The ArcSDE Subject Area consists of the entities PROJECT LINE, UTILITY CONFLICT OUTLINE, TXDOT DISTRICT POLYGON, TXDOT COUNTY POLYGON, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 28, Table 15.) The entities in this subject area are spatial features that are stored in the ArcSDE tablespace of

the Oracle database. ArcSDE is a primary component of ArcGIS Server that provides multi-user access to spatial data, associated attributes, and metadata stored in the Oracle database. UACT's data model includes other spatial entities that are not stored in the ArcSDE tablespace but in personal geodatabases. For the testing of this prototype, the researchers only added those spatial entities to ArcSDE where there was a likely need to support versioning and multi-user support. The researchers used the data stored in personal geodatabases for display purposes only.
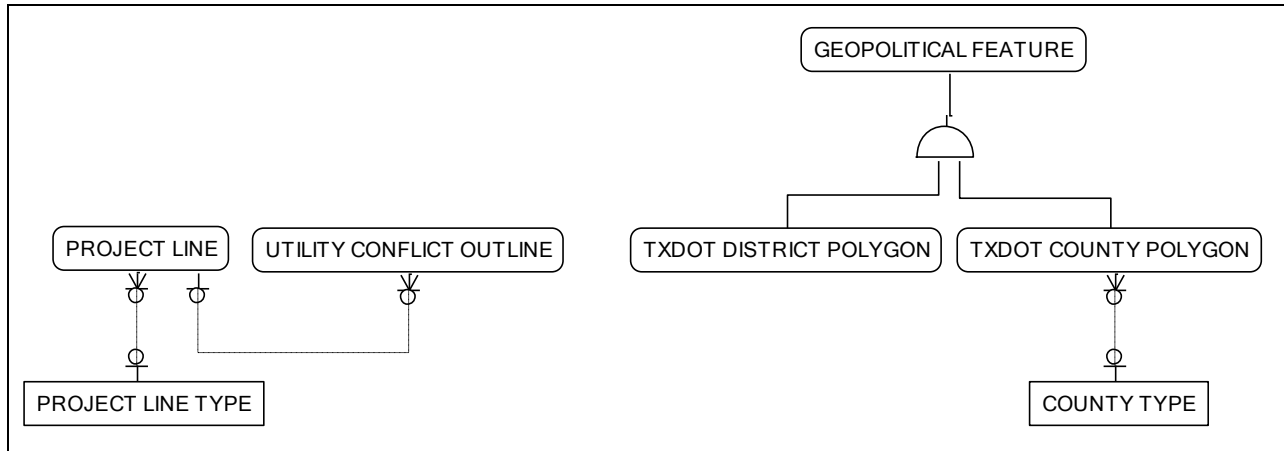
Figure 28. UACT Data Model – ArcSDE Subject Area.

The PROJECT LINE, UTILITY CONFLICT OUTLINE, TXDOT DISTRICT POLYGON, and TXDOT COUNTY POLYGON are GAIP-compatible features. As such, they share a number of attributes, and their primary key is TXDOT UNIQUE ID, which is a unique identifier for records in each table. In combination with the TABLE UNIQUE ID, which identifies each table in the TxDOT enterprise, these two attributes become a unique identifier for a feature in the enterprise. The Feature Subject Area provides a more detailed background on the subject of GAIP features and indexing spatial entities in the TxDOT enterprise.

PROJECT LINE represents linear features in a project that may be of use to linear reference other features such as utility conflict polygons. Examples of a PROJECT LINE feature are an existing route centerline, a proposed main project centerline, a proposed frontage road centerline, and a direct connector centerline. In UACT, if a system administrator has authorized the use of the PROJECT LINE, a UACT user can select the centerline as a reference for the location of a utility conflict.

UTILITY CONFLICT OUTLINE is the spatial entity that represents polygon shapes of utility conflicts. When a user creates a new utility conflict in UACT, the user must create a visual representation of the utility conflict using the integrated GIS mapping component. The purpose of the UTILITY CONFLICT OUTLINE is to provide a simple method to quickly locate the approximate location of the conflict within the project limits. The UTILITY CONFLICT OUTLINE references a PROJECT LINE, and a user must provide start and end station measurements as well as offsets from the PROJECT LINE to the utility conflict. UACT stores these measurements in the UTILITY CONFLICT OUTLINE record. The UTILITY CONFLICT OUTLINE also references the UTILITY CONFLICT ID, which is the primary identifier for each

utility conflict, and UTILITY CONFLICT EVENT NUMBER, which tracks changes to each utility conflict and the UTILITY CONFLICT OUTLINE.

TXDOT DISTRICT POLYGON and TXDOT COUNTY POLYGON are entities maintained and owned by TxDOT. TXDOT COUNTY POLYGON 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. The research team obtained copies of these features to allow queries of features by district and county. For the implementation of the prototype, the researchers will link to these entities in the TxDOT enterprise table space.

The GEOPOLITICAL FEATURE is a supertype without any attributes of its own (see ArcSDE Subject Area in Appendix B). As a result, this entity only exists in the logical model. In the physical model, the supertype/subtype roll down transform must be applied before the physical data model schema is generated, which removes the entity and links to TXDOT DISTRICT POLYGON and TXDOT COUNTY POLYGON.

Table 15. ArcSDE Subject Area Entities.

Name	Definition
COUNTY TYPE	A COUNTY TYPE is a property that categorizes the type of COUNTY. Valid values are rural, urban, and metropolitan.
GEOPOLITICAL FEATURE	A GEOPOLITICAL FEATURE is an entity that represents a virtual boundary defined by a jurisdictional agency that exists in a spatial or spatiotemporal domain modeled consistent with the TxDOT GAIP standards.
PROJECT LINE	A PROJECT LINE is a spatial representation of a highway improvement project represented as a roadway centerline segment bounded by project limits.
PROJECT LINE TYPE	A PROJECT LINE TYPE is an entity that classifies PROJECT LINES. For example, centerline, frontage road centerline, etc.
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." Examples of counties include Bexar, Travis, Harris, and Dallas. Source: TxDOT Production GIS Data, March 2006.
TXDOT DISTRICT POLYGON	A TXDOT DISTRICT POLYGON is an entity that represents the boundary of a TxDOT DISTRICT in the state of Texas that exists in a spatial or spatiotemporal domain modeled consistent with the TxDOT GAIP standards.
UTILITY CONFLICT OUTLINE	A UTILITY CONFLICT OUTLINE is a spatial representation of a UTILITY CONFLICT in the field. A UTILITY CONFLICT OUTLINE is created using the station and offset information provided by a user of the UACT system.

DCIS Subject Area

The DCIS Subject Area consists of one entity, DCIS DATA WAREHOUSE (Figure 29, Table 16). Figure 29 also lists the attributes of DCIS DATA WAREHOUSE to facilitate the discussion of this subject area.

DCIS DATA WAREHOUSE

CONTROL SECTION JOB NUMBER

ACTUAL LETTING DATE
ADDITIONAL ROW AMOUNT
ANCESTOR CSJ 1
ANCESTOR CSJ 2
ANCESTOR CSJ 3
ANCESTOR CSJ 4
ANCESTOR CSJ 5
BEGINNING REFERENCE MARKER DISPLACEMENT NUMBER
BEGINNING REFERENCE MARKER NUMBER
CONTRACT CSJ
COUNTY NUMBER
DATE LAST REVISION
DISTRICT LETTING DATE
ELIGIBLE FEDERAL FUNDING FLAG
ENDING REFERENCE MARKER DISPLACEMENT NUMBER
ENDING REFERENCE MARKER NUMBER
ENGINEER NUMBER
ESTIMATED CONSTRUCTION COST AMOUNT
ESTIMATED CONSTRUCTION COST AMOUNT DATE
ESTIMATED ROW COST
ESTIMATED ROW COST DATE
HIGHWAY NUMBER
LAYMAN DESCRIPTION1
LAYMAN DESCRIPTION2
LETTING SCHEDULE 1
LIMITS FROM
LIMITS TO
LOCAL CONTRIBUTIONS AMOUNT
PROJECT NUMBER
ROADWAY FUNCTIONAL CLASS CODE
ROW CSJ
TIME LAST REVISION
TIP FISCAL YEAR
TOTAL OBLIGATED AMOUNT

Figure 29. UACT Data Model – DCIS Subject Area.

As mentioned previously, DCIS is a non-relational legacy system that TxDOT uses to store critical project information, such as location, highway, CSJs, available funding, etc. To manage utility conflicts effectively, several data items from DCIS File 121 should be available for display in UACT. Figure 29 shows the subset of File 121 attributes that the researchers selected to characterize sample projects.

The researchers encountered some difficulty when accessing the data in DCIS. Due to its non-relational structure, it was not possible to design a direct connection between UACT and DCIS to provide a read access of the DCIS data in UACT. After discussion of several options, the

research team decided to create the DCIS DATA WAREHOUSE entity to act as a data repository for a recurring download of DCIS File 121 data into the UACT database. DCIS DATA WAREHOUSE maintains the same structure of DCIS File 121, which ensures compatibility with DCIS File 121 and allows a mostly unmodified download of the data. As a result, DCIS DATA WAREHOUSE is not normalized and does not follow TxDOT data architecture standards (*51*). Normalization of the data in DCIS DATA WAREHOUSE occurs in DCIS PROJECT, which is part of the Project Subject Area. This process is described in detail in the Project Subject Area discussion of the report.

Table 16. DCIS Subject Area Entities.

Name	Definition
DCIS DATA WAREHOUSE	A DCIS DATA WAREHOUSE is a TxDOT roadway improvement project whose data is entered into the TxDOT DCIS database and imported into this table.

Document Subject Area

The Document Subject Area consists of the main entities DOCUMENT, DOCUMENT VERSION, DOCUMENT SET, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 30, Table 17.)
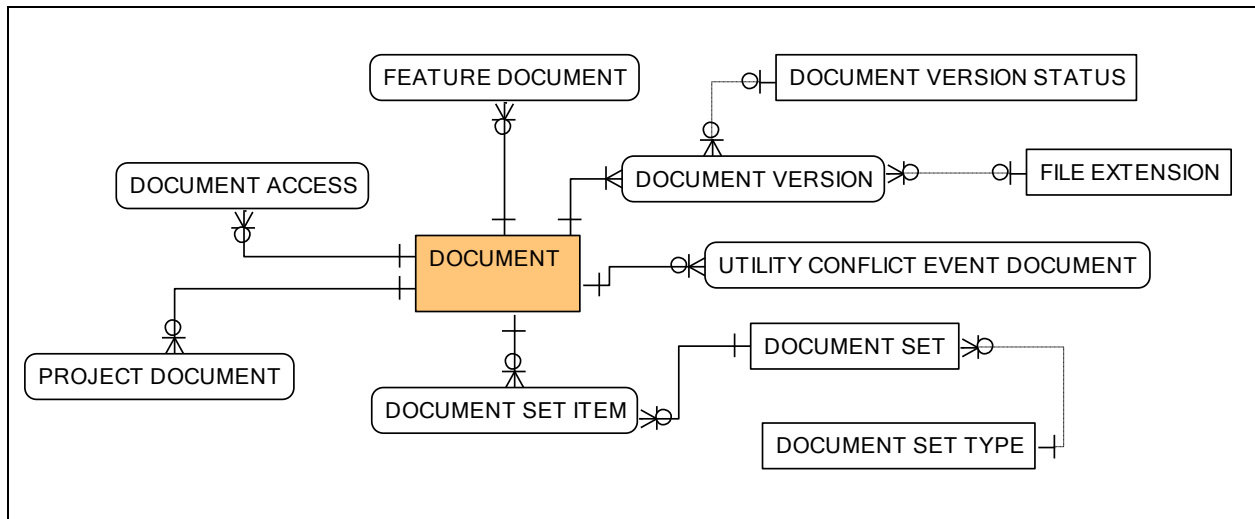
Figure 30. UACT Data Model – Document Subject Area.

A DOCUMENT is the representation of a single logical document. For example, meeting attendance lists, construction change orders, or environmental assessments can be a DOCUMENT. A DOCUMENT always consists of and is limited to a single file. In some cases, a user may wish to link multiple files together, e.g., if a user submits a MicroStation CAD file along with several reference files. The user can link the reference files to the main file by creating a DOCUMENT SET and marking all DOCUMENTS that are part of the set. Another

example for a DOCUMENT SET would be a list of approved change orders or a list of historical right of way surveys.

When a user uploads a DOCUMENT, UACT requires the user to provide some information about the document such as title, description, status, and FileNet data types. The user may also provide a comment, which is not mandatory. Internally, document information is stored within the DOCUMENT and the DOCUMENT VERSION entity. DOCUMENT VERSION contains the data elements that may change between versions of the same document. To differentiate a new version of the same document from a completely new document, UACT requires that the document title, document description, and FileNet data types not be changed. If any of these attributes change, the user should create a new document. For a new version of an existing document, the user can change only the document status (such as "Draft," "Final," "Superseded," "Obsolete," or "Other") or document comments.

Several attributes of DOCUMENT VERSION are created automatically when the user uploads or makes changes to a document, including the creation date, modification date, and physical document name, which is a unique, system-generated filename. UACT also checks the file extension (e.g., ".doc," ".xls," or ".pdf") of the uploaded file and compares it to a list of file types in the entity FILE EXTENSION, which lists file types that the system software is able to convert to PDF. If a user attempts to upload a file that UACT cannot convert it will disallow the upload and provide an error message to the user.

A DOCUMENT also has document type data, which correspond to document attributes set forth in the TxDOT Information System's Content Services Library Standards, which is stored in DOCUMENT FILENET TYPE (*22*). This entity allows a mapping between the UACT document management system and the TxDOT FileNet document management system.

UACT allows the association of DOCUMENTS directly to other entities such as PROJECT, UTILITY CONFLICT, or FEATURE. The data model construct that allows this connection are mapping tables such as PROJECT DOCUMENT and UTILITY CONFLICT EVENT DOCUMENT, and FEATURE DOCUMENT. Using these tables, UACT allows the direct document associations; for example, an environmental assessment document may be directly associated with a project, and a utility agreement document may be directly associated with a utility conflict.

Table 17. Document Subject Area Entities.

Name	Definition
DOCUMENT	A DOCUMENT is a tangible product in printed or electronic form produced from, resulting from, or documenting a TxDOT Project Development Process activity. A DOCUMENT can be indexed or catalogued in terms of business process operations or activities. Examples include forms, chapters, technical memoranda, invoices, and reports (provided the entire report is represented by a single file; otherwise the report would need to be represented using document sets). A document may have several files or versions (in a variety of formats) associated with it (through DOCUMENT VERSION).
DOCUMENT ACCESS	A DOCUMENT ACCESS is the permission for a COMPANY to view, revise, and delete a DOCUMENT. In other words, DOCUMENT ACCESS is a mapping between a DOCUMENT and a COMPANY.
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 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 between the entities FEATURE and DOCUMENT. It identifies all FEATURES associated with a DOCUMENT and all DOCUMENTS associated with a FEATURE.
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. In a Microsoft Windows environment, a three-letter code at the end of a file name separated by a period represents the FILE EXTENSION.
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.
UTILITY CONFLICT EVENT FEATURE	A UTILITY CONFLICT EVENT FEATURE is a collection of features involved with a given UTILITY CONFLICT EVENT.

Feature Subject Area

The Feature Subject Area consists of the main entities FEATURE, FEATURE SET, FEATURE PROPERTY RIGHT, FEATURE DEPRECIATION, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 31, Table 18.)
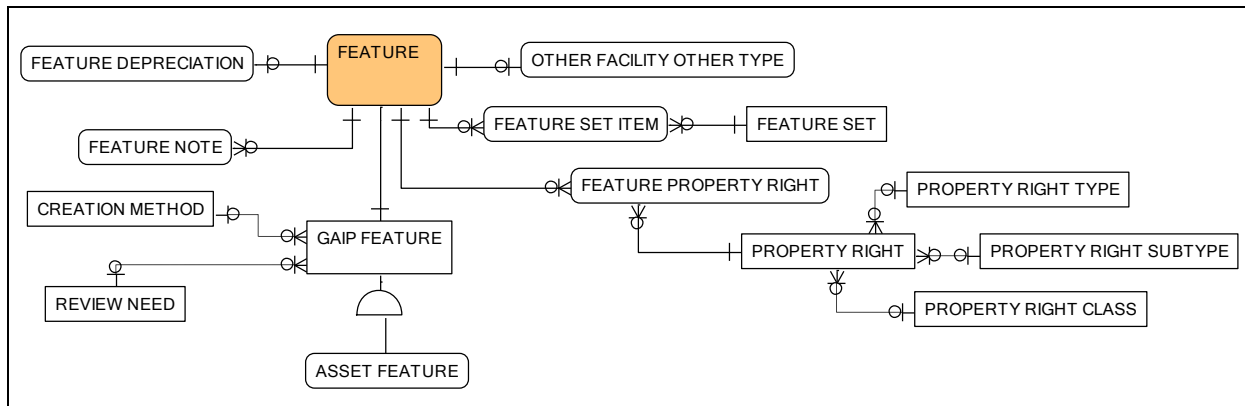
Figure 31. UACT Data Model – Feature Subject Area.

The FEATURE entity is a comprehensive index of features in the database that consists of the attributes TABLE UNIQUE ID and TXDOT UNIQUE ID that in combination uniquely identify any feature in the enterprise. FEATURE references TABLE UNIQUE ID from the entity DATASET TABLE in the MainStreet Texas Subject Area, and TXDOT UNIQUE ID uniquely identifies records from each feature class, e.g., COMMUNICATION LINE. Both keys are required because different feature classes could share the same TXDOT UNIQUE ID values. For example, potential TXDOT UNIQUE ID values within the COMMUNICATION LINE feature are 1, 2, 3, and 4. These values are also potential TXDOT UNIQUE ID values within the ELECTRIC LINE feature.

In an earlier version of the UACT data model, the researchers modeled FEATURE as a supertype of GAIP FEATURE, which seemed appropriate since all features should be compatible to the GAIP standards and therefore should be GAIP features. However, the testing of the prototype found that a supertype/subtype relationship between FEATURE and GAIP FEATURE is not feasible because the FEATURE table would disappear in the physical model along with GAIP FEATURE, ASSET FEATURE, and all further subtypes that do not have attributes of their own. This is not a viable solution because the FEATURE table is the TxDOT index for all GAIP compatible features in the enterprise and has already been implemented on TxDOT servers. In an implementation of UACT, the system would need to link to that existing FEATURE table. To solve this, the researchers modeled the relationship between FEATURE and GAIP FEATURE as one-to-one, with FEATURE being the parent table to GAIP FEATURE. As a result, in the physical model the FEATURE table remains while all subtypes without their own attributes disappear in the supertype/subtype roll down transform. In the physical model, this creates a direct link of the FEATURE table with all feature class tables such as COMMUNICATION LINE. However, further testing of this model revealed that an implementation of a one-to-one relationship is also not a practicable solution. This relationship would require that FEATURE would reference the TXDOT UNIQUE ID from multiple tables,

essentially all feature class tables such as COMMUNICATION LINE and ELECTRIC LINE. This relationship would resemble a child with multiple parents, which prevents the enforcing of referential integrity when a new record is created in FEATURE. For example, say COMMUNICATION LINE has the TABLE UNIQUE ID "22" and a user attempts to create the first record in that table. UACT would assign the TXDOT UNIQUE ID "1," and attempt to create a record in FEATURE that would read "22, 1." To ensure referential integrity, the database would then check whether there is actually a record "1" in table "22," which it would find, but then proceed to check the tables COMMUNICATION POLE, COMMUNICATION DUCT BANK, and all other feature classes for a TABLE UNIQUE ID "1." A similar dilemma would occur during deletion of records. In summary, it would be impossible to ensure database consistency. As a solution, the research team kept the one-to-one relationship between FEATURE and GAIP FEATURE but removed all referential integrity requirements in the logical data model and removed the option to generate the relationship in the physical model. In UACT, the referential integrity between FEATURE and all feature tables is maintained through code.

Certain types of features are combinations of other features. For example, a utility pole may have multiple utility features. In UACT, 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.

ASSET FEATURE provides geographic representations of assets located within the TxDOT ROW. In UACT, ASSET FEATURE includes only the subtype UTILITY FEATURE, which the report describes in more detail in the Utility Facility Database Subject Area. It may be worth mentioning that research project 0-5788 is developing data models for the management of right of way data that includes additional ASSET FEATURE subtypes such as ROADWAY FEATURE, STRUCTURE FEATURE, and ENCUMBRANCE FEATURE, although it is not a comprehensive inventory of asset features.

PROPERTY RIGHT provides information about the legal circumstances that allow a utility owner to occupy and use real property for a utility facility. The related entities PROPERTY RIGHT CLASS, PROPERTY RIGHT TYPE, and PROPERTY RIGHT SUBTYPE form a hierarchical structure to classify the real property interest that a utility owner may hold. PROPERTY RIGHT CLASS is the highest level in this hierarchy, which distinguishes between the following:

- **Statutory Right.** A right to occupy state right of way that originates from provisions in the legal statutes of the state of Texas.

- **Compensable Interest.** A right or interest in real property and/or utility facilities placed upon real property that qualify under state law for reimbursement for some or all of the cost of the relocation of the utility facilities as necessitated by TxDOT.

- **Encroachment.** The use or occupancy of real property in absence of a right to occupy or use the property. Encroachments are typically fixed private properties (e.g., buildings, signs, or other fixtures) that are located in the public right of way or intruding into or invading upon the public right of way from an adjoining private property.

The PROPERTY RIGHT TYPE is the next level in the property right hierarchy that further classifies a PROPERTY RIGHT CLASS. For example, the compensable interest may be further classified as "fee simple interest," "license agreement," or "easement." PROPERTY RIGHT SUBTYPE is the lowest level in the property right hierarchy to further distinguish a PROPERTY RIGHT TYPE. For example, PROPERTY RIGHT SUBCLASS can specify the type of easement, such as "private easement" or "public utility easement."

The prototype makes use of FEATURE DEPRECIATION to store information about features that are reimbursable and depreciate in value over time to determine eligibility of utility adjustment costs. The entity is used to determine the loss of value over time of large structures such as buildings and plants to arrive at the current value that may be reimbursable. The loss of value or depreciation credit to TxDOT is not reimbursable and can be determined using a straight line or linear depreciation method that assumes a value of zero at the end of the feature's service life.

Table 18. Feature Subject Area Entities.

Name	Definition
ASSET FEATURE	An ASSET FEATURE is a real-world or virtual phenomenon associated with a model that exists in a spatial or spatiotemporal domain modeled consistent with the TxDOT GAIP standards and can be surveyable. Examples include bridges, recreation facilities, utilities, water systems, waste management, public facilities, rest areas, canals, signs, and airports.
CREATION METHOD	A CREATION METHOD is the process that was used to create a feature database record as described in Table 27 of the manual "TxDOT Graphic Data Standards, August 2004."
FEATURE	A FEATURE is an object (real or virtual) that has boundaries in space and time. In the model, a FEATURE can be represented by points, lines, or polygons. 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.
FEATURE DEPRECIATION	A FEATURE DEPRECIATION is a FEATURE with a depreciating value that is being tracked by the entity using a straight line or linear depreciation method that assumes a value of zero at the end of the service life. FEATURE DEPRECIATION tracks the depreciation value of a subset of features to determine eligibility of utility adjustment costs.
FEATURE NOTE	A FEATURE NOTE is a mapping between a FEATURE and corresponding set of NOTES.
FEATURE PROPERTY RIGHT	A FEATURE PROPERTY RIGHT is a mapping between a FEATURE and a PROPERTY RIGHT.
FEATURE SET	A FEATURE SET is an entity that represents a collection or aggregation of FEATURE entities. Examples include signposts with multiple signs or poles with multiple utility features.

Table 18. Feature Subject Area Entities (Continued).

Name	Definition
FEATURE SET ITEM	A FEATURE SET ITEM is an entity that identifies which FEATURE entities are associated with a FEATURE SET entity. This relationship allows a FEATURE entity to be associated with more than one FEATURE SET entity and a FEATURE SET entity to be associated with more than one FEATURE entity.
GAIP FEATURE	A GAIP FEATURE is an object (real or virtual) that has boundaries in space and time and is modeled in accordance with the TxDOT GAIP standard. In the model, a GAIP FEATURE can be represented by points, lines, or polygons.
OTHER FACILITY OTHER TYPE	An OTHER FACILITY OTHER TYPE is a user-defined category that further describes a certain kind of OTHER FACILITY, such as the type of a COMMUNICATION OTHER FACILITY or a WATER OTHER FACILITY, where the user has selected the OTHER FACILITY TYPE "Other."
PROPERTY RIGHT	A PROPERTY RIGHT is an entity that provides information about the legal rights of a utility installation that allow it to occupy the land where it is installed.
PROPERTY RIGHT CLASS	A PROPERTY RIGHT CLASS is a definition of rights associated with a UTILITY FEATURE that provides the utility owner the legal right to occupy land with a utility installation. In UACT, it is the highest level in the hierarchy of property rights. A PROPERTY RIGHT CLASS provides information about the underlying property rights that enable a utility owner to occupy land, for example, the property rights of a utility company for a utility facility in a particular location on the state ROW. A PROPERTY RIGHT CLASS may have several types to distinguish the property right further. Examples of PROPERTY RIGHT CLASS include "statutory," "compensable interest," and "encroachment."
PROPERTY RIGHT SUBTYPE	A PROPERTY RIGHT SUBTYPE is a subdivision of a PROPERTY RIGHT TYPE. Examples include "private easement" and "public utility easement" for the PROPERTY RIGHT TYPE "easement."
PROPERTY RIGHT TYPE	A PROPERTY RIGHT TYPE is a subdivision of a PROPERTY RIGHT CLASS. A PROPERTY RIGHT TYPE may have several subtypes to distinguish the property right further. Examples include "lease agreement," "license agreement," and "easement" for the PROPERTY RIGHT CLASS "compensable interest."
REVIEW NEED	A REVIEW NEED is an entity that describes the need for a TxDOT database administrator to review a record in the UACT utility facility inventory because of a potential error or omission.

FileNet Subject Area

The FileNet Subject Area consists of the entities DOCUMENT FILENET TYPE, FILENET DOCUMENT CLASS, FILENET RECORD TYPE, and FILENET DOCUMENT TYPE (Figure 32, Table 19.)
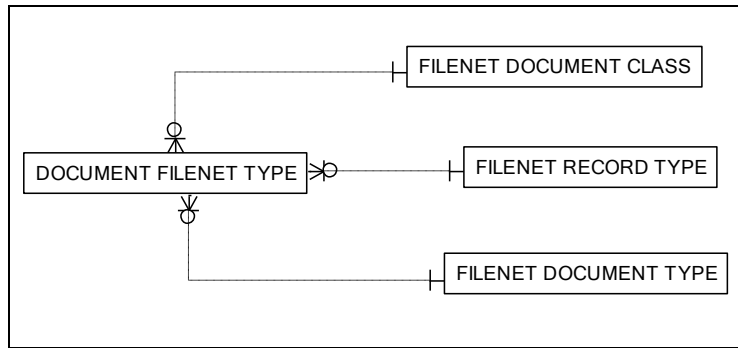
Figure 32. UACT Data Model – FileNet Subject Area.

As mentioned earlier, FileNet is an electronic document management system that TxDOT is implementing statewide. Currently, it appears that an implementation of UACT would begin at the completion of the FileNet implementation. To ensure that documents produced by UACT will be compatible with the current FileNet data structure, the researchers added these entities as "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 UACT data model match the corresponding entities in FileNet. Therefore, it may be necessary to modify some of the entities in this subject area and possibly additional entities in the Document Subject Area during implementation, particularly at the physical level. This limitation is not likely to be critical because, at the logical level, the model in Figure 32 explicitly considers the main data elements necessary to characterize FileNet document classes, records types, and document types. Therefore, all documents created in UACT can be classified using the FileNet document standards provided in the TxDOT EDTIS library structure (*22*). For consistency with the UACT data model, these entities comply with TxDOT data architecture standards, both in terms of content and entity and attribute naming conventions (*51*).

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 4). 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, the FILENET DOCUMENT CLASS ID matches the index of document classes in Table 3. 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 4.

Table 19. FileNet Subject Area Entities.

Name	Definition
DOCUMENT FILENET TYPE	A DOCUMENT FILENET TYPE is a unique combination of a FileNet document class, record type, and document type that follows TxDOT's EDTIS Content Services library standards. In the standards, a file code represents this unique combination. For example, file code 13.2.3 represents a drainage easement document (document class = "Right of Way," record type = "Easement," and document type = "Drainage Easement.")
FILENET DOCUMENT CLASS	A FILENET DOCUMENT CLASS is a category of documents within the EDTIS Content Services library standards that corresponds to the highest level of aggregation of TxDOT business functions. 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 a FILENET RECORD TYPE included in the EDTIS Content Services library standards. 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 a FILENET DOCUMENT CLASS included in the EDTIS Content Services library standards. For example, the FILENET RECORD TYPE "Plans Specifications and Estimates" is a document subclass within the FILENET DOCUMENT CLASS "Project Design."

MainStreet Texas Subject Area

The MainStreet Texas Subject Area consists of the entities DATASET CONNECTION, DATASET FIELD, and DATASET TABLE (Figure 33, Table 20.) With the exception of FEATURE CLASS, they are entities that reside on TxDOT servers and are maintained by TxDOT.
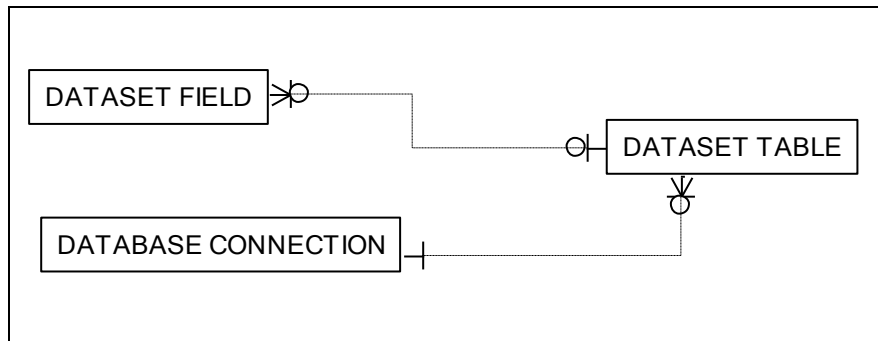
Figure 33. UACT Data Model – MainStreet Texas Subject Area.

DATASET TABLE includes a listing of all the entity logical names and table physical names in the TxDOT enterprise. 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 entities within MST, which is the online implementation of GAIP.

DATASET TABLE provides one of the dual primary key that identifies all features in the TxDOT enterprise, which is TABLE UNIQUE ID. Essentially, it is an index of all feature tables in the enterprise and as such identifies the table of a feature. The FEATURE entity references this attribute and in combination with TxDOT UNIQUE ID provides an index of all features in the enterprise.

Table 20. MainStreet Texas Subject Area Entities.

Name	Definition
DATABASE CONNECTION	A DATABASE CONNECTION is the definition of all of the connect strings that are needed to retrieve data from the tables listed in DATASET TABLE. The connect string can be formatted for either ActiveX® Data Object (ADO) or ArcSDE connections. (Main Street Texas table)
DATASET FIELD	A DATASET FIELD is a storage table for field information for each table listed in DATASET TABLE. (Main Street Texas table)
DATASET TABLE	A DATASET TABLE is a table that lists all of the tables that are available within the enterprise. The table can be a standard business table or an ArcSDE layer. (Main Street Texas table)

Meeting Subject Area

The Meeting Subject Area consists of the entities MEETING, MEETING ATTENDANCE, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 34, Table 21.)
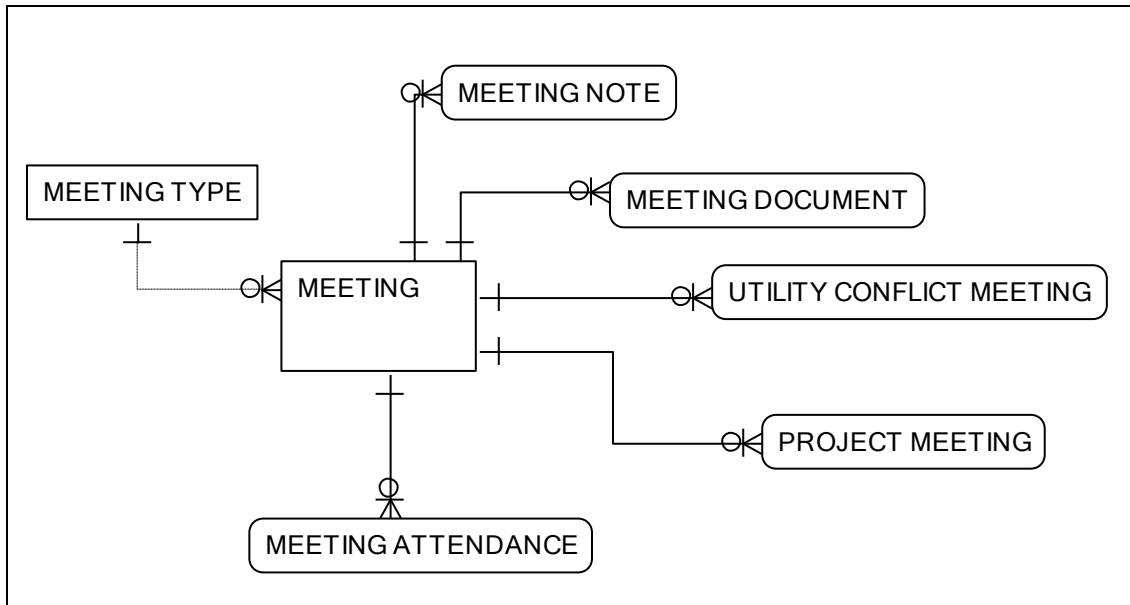
Figure 34. UACT Data Model – Meeting Subject Area.

MEETING provides the ability to store information about meetings in UACT. A user that creates a new meeting in UACT must provide a meeting name, description, start date, end date, location, and type. The system automatically assigns a meeting ID, creates a timestamp, and stores the user ID with each meeting. MEETING NOTE allows the association of notes with a meeting, and similarly MEETING DOCUMENT, UTILITY CONFLICT MEETING, and PROJECT MEETING allow association of a meeting with documents, utility conflicts, and projects, respectively. MEETING ATTENDANCE is a mapping between a meeting and UACT users to facilitate the association of UACT users with a meeting. For example, this entity would be useful when a meeting organizer wants to invite all utility owners that are stakeholders of a project to a utility coordination meeting. PROJECT MEETING would associate the meeting with a project, and MEETING ATTENDANCE would track the participants of that meeting.

Table 21. Meeting Subject Area Entities.

Name	Definition
MEETING	A MEETING is a gathering of TxDOT employees and/or other project-related companies at a predetermined date and time for the purpose of discussing project-related matters.
MEETING ATTENDANCE	A MEETING ATTENDANCE is the requirement or the recommendation that a SYSTEM USER attend a MEETING. MEETING ATTENDANCE maps MEETINGs to SYSTEM USERs.
MEETING DOCUMENT	A MEETING DOCUMENT is a mapping between the entities MEETING and DOCUMENT to associate all MEETINGS with a DOCUMENT and all DOCUMENTS with a MEETING.
MEETING NOTE	A MEETING NOTE is a mapping between a NOTE and a MEETING allowing a SYSTEM USER to provide additional information about a MEETING.
MEETING TYPE	A MEETING TYPE is a category that defines a certain kind of MEETING.
PROJECT MEETING	A PROJECT MEETING is a mapping between PROJECT and MEETING that describes a MEETING containing discussion about a PROJECT.
UTILITY CONFLICT MEETING	A UTILITY CONFLICT MEETING is a mapping between UTILITY CONFLICT and MEETING for the purpose to associate a MEETING with a UTILITY CONFLICT and vice versa.

Permissions Subject Area

The Permissions Subject Area consists of the entities ROLE, PERMISSION, CAPABILITY, BUSINESS AREA, BUSINESS AREA SECTION, and mapping tables (Figure 35, Table 24.)
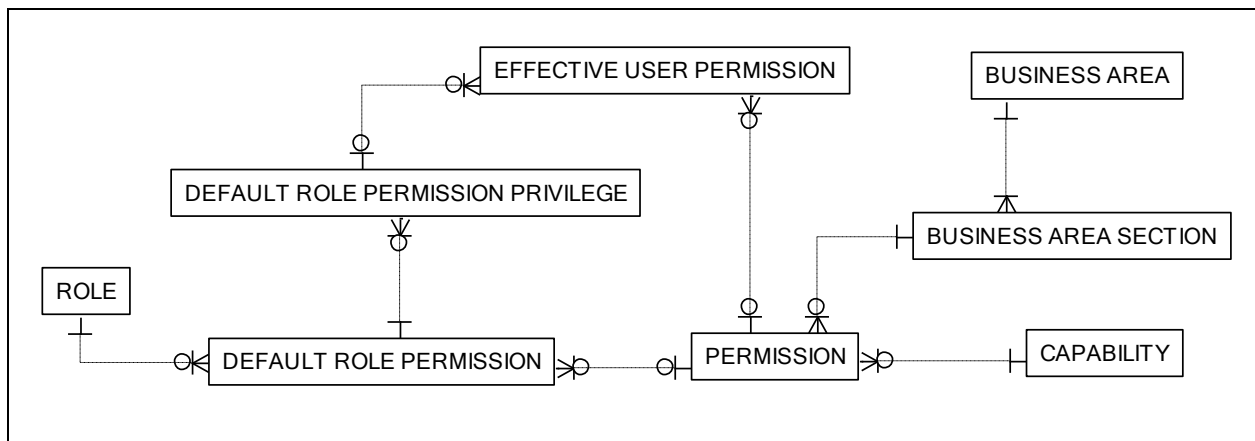
Figure 35. UACT Data Model – Permissions Subject Area.

Experience with the implementation of the UIR system has shown that maintaining a strict workflow-control system for the specific tasks supported by UACT would result in an unfeasible level of administrative overhead. Instead, the researchers designed a permissions-based system that allows any user to make changes at any time that are within his or her level of access. The

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UACT permissions model provides highly detailed user access levels, mapping of companies, functions in the Project Development Process, and user groups that the system combines to a user-specific set of application capabilities.

In the UIR system, permissions and access to documents are controlled by individual users that are part of a pre-defined workflow. Only the user with current control of a document can make modifications to that document. To enable another user to modify a document, a user must relinquish control of the document and send it to the second user who then gains control of the document. The UIR system controls access to documents by controlling the user's document distribution options at any given point in the workflow. The UACT system varies from this method in a way that it does not contain a strict workflow but access to a document or an area/function of the system is based on strictly defined permissions that are combinations of a capability with a business area section. Capabilities are the system's basic user actions, which are:

- view,
- add,
- edit,
- delete, and
- upload.

In UACT, business areas are zones that the researchers defined to restrict user access to portions of the prototype. Business areas have subdivisions called business area sections that the researchers used to further restrict user access. Table 22 shows UACT's business areas and business area sections:

Table 22. UACT Business Areas and Business Area Sections.

Business Area	Business Area Section
Project	Project Listing
	New UACT Project
	Project Details
	Project Status
	Project Stakeholders
	Project Documents
Utility Inventory	Project Utility Listing
	Enterprise Utility Listing
	Utility Details
	New Utility
Conflict Tracking	Conflict Listing
	Conflict Details
	Conflict Documents
	Conflict Notes
	New Conflict
Agreement Assembly	Agreement Listing
	Agreement Details
	New Agreement
Reports	Reports
Contacts	Contacts Listing
Other Resources	Other Resources
	New Resource
Users	User Listing
	User Details
	New User
Access Control	System Permissions
	Role Permissions
	Privilege Permissions

In UACT, a permission must be defined before it can be associated with a user because not every business area section has all capabilities. To create a UACT permission, a system administrator must associate a capability with a business area section, for example capability "view" with business area section "Project Summary." Once a permission is defined, it can be associated with a user. To assign several permissions to a user in one step, a system administrator can define a UACT role, which describes a function that a system user or company may perform in the TxDOT PDP, e.g., "Utility Owner." The administrator can then associate several permissions with that role. When a company creates a new account in the UACT system, a system administrator can assign the role to the account, which defines all permissions for the

account in one step. The UACT Access Matrix shows 16 roles with associated access permissions that the UACT prototype currently defines along with business area sections and capabilities (Table 23). Figure 36 shows how the roles utility owner, SUE provider, and TxDOT encompass subsets of UACT permissions, some of which are shared (overlapping areas).
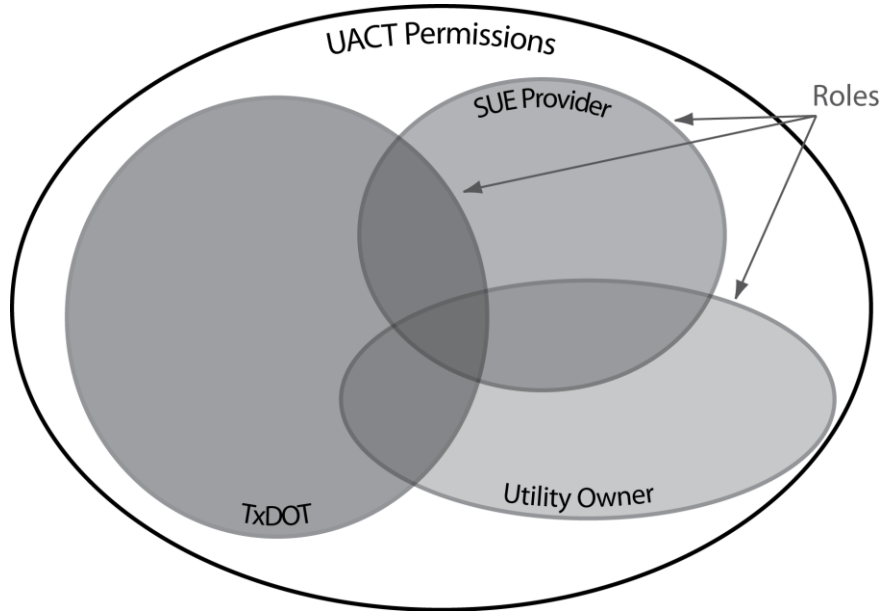
Figure 36. Relationship of Roles and Permissions in UACT.

The permissions of a UACT user are limited by the user's role. They can be further restricted by the company administrator using a privilege. A privilege is a subset of permissions that a role has. For example, a utility owner may want to set up three levels of access for his employees: "Administrator," which includes all permissions of the utility owner role, "User," which includes most of the utility owner permissions, and "Guest," which includes only the view permissions of a utility owner role. Figure 37 shows how the privileges Administrator, User, and Guest define subsets of permissions within the role TxDOT.
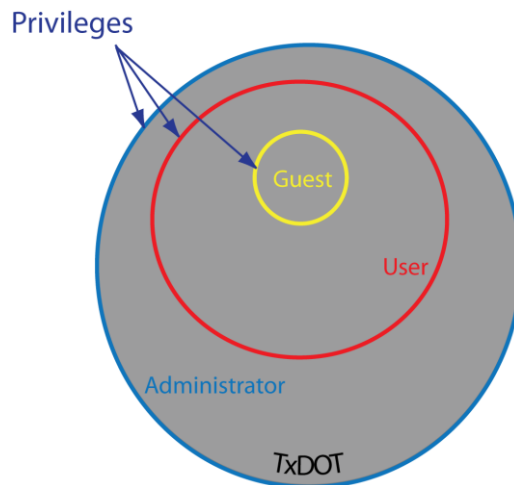
Figure 37. Relationship of Roles and Privileges in UACT.

In the data model, CAPABILITY stores a listing of capabilities, ROLE stores a listing of the system's roles, and BUSINESS AREA SECTION stores a listing of business area sections associated with a business area. Permissions that are associated by default with a role are stored in DEFAULT ROLE PERMISSION. DEFAULT ROLE PERMISSION PRIVILEGE stores the association of any default role permission with a privilege, in other words, which of the permissions associated with a certain role belong to a certain privilege within that role.

To give the system additional flexibility, the researchers created the table EFFECTIVE USER PERMISSION, which is the main table that defines a user's permissions and access to UACT (Figure 35). The table references four keys, which are CONTROL SECTION JOB NUMBER, DEFAULT ROLE PERMISSION PRIVILEGE ID, PERMISSION ID, AND SYSTEM USER ID and then assigns an EFFECTIVE USER PERMISSION ID. Essentially, only DEFAULT ROLE PERMISSION PRIVILEGE ID and SYSTEM USER ID would have been required to identify a system user's access. However, adding the reference to PERMISSION ID allows a system administrator to assign any permission to any user if there is a need for it. By adding the reference to CONTROL SECTION JOB NUMBER, the system administrator can limit any additional permission to one or more specific projects. Since DEFAULT ROLE PERMISSION PRIVILEGE ID is not part of the primary key, it is also possible for a system administrator to provide all permissions for a specific user directly without specifying a role or privilege. In summary, this data model design allows for a convenient mechanism to assign default permissions to certain types of users while providing the greatest possible flexibility of assigning permissions to user when needed.

Table 23. UACT Access Matrix.

Business Area	Business Area Section	Cap.	Perm. ID	UACT System Administrator	TxDOT District ROW Administrator	TxDOT ROW Division Reviewer	TxDOT District Utility Coordinator	Consultant Utility Coordinator	TxDOT District Design Project Manager	TxDOT District Designer	TxDOT Surveyor	Consultant Surveyor	SUE Consultant	Utility Owner	Utility Consultant	LPA	Utility Contractor	Highway Project Contractor	ROW Acquisition Consultant
Project	Project Listing	View	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	New UACT Project	View	2	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No
		Add	3	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No
	Project Details	View	4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Edit	5	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
		Delete	6	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
	Project Status	View	7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
	Project Stakeholders	View	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Edit	9	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Add	10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
		Delete	11	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Project Documents	View	12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Edit	13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Add	14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Delete	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Utility Inventory	Project Utility Listing	View	16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Utility Details	View	17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Edit	18	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
		Delete	19	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
	Enterprise Utility Listing	View	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Add	21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
	New Utility	View	22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
		Add	23	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Conflict Tracking	Conflict Listing	View	24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Conflict Details	View	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Edit	26	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
		Delete	27	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
	New Conflict	View	28	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Add	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	Conflict Documents	View	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Edit	31	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Add	32	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Delete	33	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Conflict Notes	View	34	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Edit	35	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Add	36	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Delete	37	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Agreement	Agreement Listing	View	38	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
	Agreement Details	View	39	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
		Edit	40	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	No	No	No
		Delete	41	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	No	No	No
	New Agreement	View	42	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No
		Add	43	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No
Reports	Reports	View	44	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Contacts	Contacts Listing	View	45	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Resources	Other Resources	View	46	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	New Resource	View	47	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Edit	48	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Add	49	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
		Delete	50	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Users	User Listing	View	51	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	User Details	View	52	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Edit	53	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
		Delete	54	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
	New User	View	55	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Add	56	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Access Control	System Permissions	View	57	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Edit	58	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Add	59	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Delete	60	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Role Permissions	View	61	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Edit	62	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Add	63	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Delete	64	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Privilege Permissions	View	65	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Edit	66	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Add	67	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
		Delete	68	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No

Table 24. Permissions Subject Area Entities.

Name	Definition
BUSINESS AREA	A BUSINESS AREA is a grouping of BUSINESS AREA SECTIONS according to their functionality and common business purpose, e.g., Project, Conflict, Utility Agreement, etc.
BUSINESS AREA SECTION	A BUSINESS AREA SECTION is an area of the application that is made up of a collection of processes or tasks (like adding, importing, or deleting).
CAPABILITY	A CAPABILITY is an individual action that a SYSTEM USER can perform in the application. Examples of a CAPABILITY are Add, Edit, Delete, Import, or Upload.
DEFAULT ROLE PERMISSION	A DEFAULT ROLE PERMISSION is a specification of the capabilities that a ROLE has by default. In other words, it is a mapping of ROLE and PERMISSION to provide default permissions for a ROLE.
DEFAULT ROLE PERMISSION PRIVILEGE	A DEFAULT ROLE PERMISSION PRIVILEGE is a mapping between DEFAULT ROLE PERMISSION and PRIVILEGE to define the permissions of a user account with a certain PRIVILEGE within a certain ROLE. This entity allows an administrative user of a certain role to assign permissions to a PRIVILEGE within that ROLE.
EFFECTIVE USER PERMISSION	An EFFECTIVE USER PERMISSION defines the permissions of a SYSTEM USER within the system. This entity allows a TxDOT administrator to modify the default permissions of a SYSTEM USER and to add any PERMISSION to a SYSTEM USER, either for all projects or only certain projects.
PERMISSION	PERMISSION is a joining of BUSINESS AREA SECTION and CAPABILITY, which results in a set of functions that can be performed in UACT. For example, "Edit Project" is a PERMISSION that is a combination of the CAPABILITY "Edit" and the BUSINESS AREA SECTION "Project."
ROLE	A ROLE is a function that a SYSTEM USER or a COMPANY may perform for TxDOT in the Project Development Process. Examples of a ROLE include "Project Manager," "Surveyor," "SUE Provider" and "Utility Coordinator."

Project Subject Area

The Project Subject Area consists of the main entities DCIS PROJECT, UACT PROJECT, PROJECT EVENT, ROW PROJECT, ALIGNMENT, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 38, Table 25.)
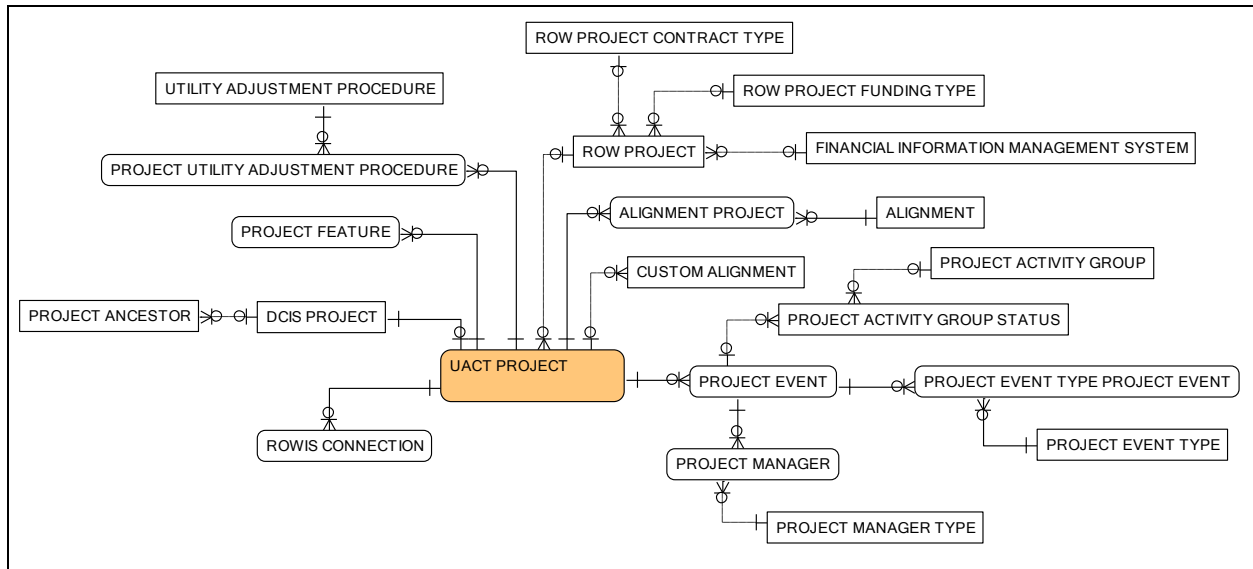
Figure 38. UACT Data Model – Project Subject Area.

DCIS PROJECT is the normalized data repository for data that the system receives from DCIS. The primary key of DCIS PROJECT is CONTROL SECTION JOB NUMBER. Typically, TxDOT projects start out with a planning or temporary CSJ number until the project is authorized. After authorization, TxDOT assigns a permanent CSJ number to the project. Occasionally, a project may be combined or split, which may create a number of parent CSJ numbers. To track these changes, the DCIS File 121 includes five attribute fields (ANCESTOR CSJ1 – ANCESTOR CSJ5) that track up to five changes to CSJs that are also included in DCIS DATA WAREHOUSE.

As mentioned in the discussion of the DCIS Subject Area, DCIS DATA WAREHOUSE serves as the non-normalized data repository for data from DCIS File 121 (see Figure 29). Once a download is complete, data is copied through UACT code from DCIS DATA WAREHOUSE into DCIS PROJECT and PROJECT ANCESTOR and normalized in the process. For example, LAYMAN DESCRIPTION1 and LAYMAN DESCRIPTION2 in DCIS DATA WAREHOUSE are combined to DCIS PROJECT DESCRIPTION in DCIS PROJECT. Further, the fields ANCESTOR CSJ1 through ANCESTOR CSJ5 are copied to PROJECT ANCESTOR and stored in CSJ PARENT NUMBER and associated with a project through CONTROL SECTION NUMBER referenced from DCIS PROJECT. Providing a dual-storage for project data also allows the comparison of the data from one data download to the next. Since the data in DCIS DATA WAREHOUSE is overwritten with every download, DCIS PROJECT allows a check for changes of the new data download. The researchers envision that during an implementation, a quality control mechanism will alert the system administrator of changes to the DCIS before committing changes to DCIS PROJECT.

DCIS is the repository for project data of all TxDOT projects. Because not all projects are impacted by utilities, it is necessary to identify the projects that do have a utility component and track only those projects in UACT. The entity UACT PROJECT entity is a filter of projects that are impacted by utilities and should be managed in UACT, which makes UACT PROJECT one

of the core entities of the UACT data model. UACT PROJECT also allows the designation of a project alias, and provides a linkage to several other subject areas such as ROWIS CONNECTION, which links to ROWIS, PROJECT DOCUMENT, which links projects to document, PROJECT FEATURE, which links projects to features, and PROJECT COMPANY, which links projects to companies.

ROWIS CONNECTION is a mapping between UACT PROJECT and the PROJECTS table in ROWIS that resolves a many-to-many relationship between the two tables. ROWIS CONNECTION associates a CONTROL SECTION ID from UACT PROJECT with a PROJECT ID from the PROJECTS table. As such, it should be possible to query any ROWIS data associated with a project in ROWIS as long as the primary project identifier or CSJ is known in UACT, provided that there is a physical connection between the two systems. This connection is the most basic form of integration between the two systems. During an implementation, it may be feasible to pursue a deeper level of integration between the two systems using additional associative tables or foreign-key constraints in UACT entities.

Similar to ROWIS CONNECTION, PROJECT DOCUMENT is a mapping between UACT PROJECT and DOCUMENT that resolves a many-to-many relationship between the two tables. Through PROJECT DOCUMENT, it is possible to associate a project with many documents and one document with many projects. PROJECT FEATURE and PROJECT COMPANY serve analogous roles to resolve many-to-many relationships between projects and features as well as projects and companies.

The ALIGNMENT entity provides the names of possible alignments in a project such as "Proposed Centerline" that may be used in combination with the alignment's stationing as a reference for the location of utility conflicts. ALIGNMENT presents an alternative to the PROJECT LINE feature described in the ArcSDE Subject Area if the project does not have a suitable project line feature available at the time a utility conflict is created (see Figure 28). In that case, a system administrator may create a record in ALIGNMENT to use as a non-spatial reference for utility conflicts.

Table 25. Project Subject Area Entities.

Name	Definition
ALIGNMENT	An ALIGNMENT is a pre-defined horizontal reference line to determine the relative location of a conflict, as compared to user-defined horizontal reference lines, which are stored in CUSTOM ALIGNMENT. Examples of ALIGNMENT are "Proposed right of way line" and "Existing main lane centerline."
ALIGNMENT PROJECT	An ALIGNMENT PROJECT is a mapping between the entities ALIGNMENT and PROJECT to resolve a many-to-many relationship between these two entities.
CUSTOM ALIGNMENT	A CUSTOM ALIGNMENT is a user-defined horizontal reference line to determine the relative location of a conflict, as compared to pre-defined horizontal reference lines, which are stored in ALIGNMENT. The purpose of CUSTOM ALIGNMENT is to store project-specific alignments. An example of a CUSTOM ALIGNMENT is "Southbound IH-10 frontage road centerline."
DCIS PROJECT	A DCIS PROJECT is a TxDOT roadway improvement project whose data is entered into the TxDOT DCIS WAREHOUSE, is normalized, and then imported into this table.
FINANCIAL INFORMATION MANAGEMENT SYSTEM	A FINANCIAL INFORMATION MANAGEMENT SYSTEM is a TxDOT accounting system maintained by the Finance Division and made up of approximately 35 segments and 700 programs. Source: TxDOT Glossary 02-2006.
PROJECT ACTIVITY GROUP	A PROJECT ACTIVITY GROUP is a collection or aggregation of activities in the project development process. Examples include "Right Of Way Acquisition" and "Detailed Design."
PROJECT ACTIVITY GROUP STATUS	A PROJECT ACTIVITY GROUP STATUS is the state of a PROJECT ACTIVITY GROUP at any given point in time. Examples include "30% Right Of Way Acquisition complete, " "60% Detailed Design complete, " etc.
PROJECT ANCESTOR	A PROJECT ANCESTOR is a mapping between a CONTROL SECTION JOB NUMBER and one or more CSJ PARENT NUMBERs, if the parent CSJ number exists.
PROJECT EVENT	A PROJECT EVENT is a creation or modification of a PROJECT.
PROJECT EVENT TYPE	A PROJECT EVENT TYPE is the category that describes a certain kind of PROJECT EVENT.
PROJECT EVENT TYPE PROJECT EVENT	A PROJECT EVENT TYPE PROJECT EVENT is a mapping between the entities PROJECT EVENT TYPE and PROJECT EVENT to resolve a many-to-many relationship between these two entities.
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 MANAGER	A PROJECT MANAGER serves as a record of all managers who manage a PROJECT.
PROJECT MANAGER TYPE	A PROJECT MANAGER TYPE is the job description of a PROJECT MANAGER.

Table 25. Project Subject Area Entities (Continued).

Name	Definition
PROJECT UTILITY ADJUSTMENT PROCEDURE	A PROJECT UTILITY ADJUSTMENT PROCEDURE is an association of a PROJECT with a UTILITY ADJUSTMENT PROCEDURE. The purpose of this association entity is to resolve a many-to-many relationship between the two entities.
ROW PROJECT	A ROW PROJECT is a TxDOT roadway improvement project that involves the TxDOT ROW Division.
ROW PROJECT CONTRACT TYPE	A ROW PROJECT CONTRACT TYPE is a property that categorizes the type of ROW PROJECT CONTRACT.
ROW PROJECT FUNDING TYPE	A ROW PROJECT FUNDING TYPE is a property that categorizes the type of ROW PROJECT FUNDING.
ROWIS CONNECTION	A ROWIS CONNECTION is a mapping that represents the many-to-many relationship between a DCIS PROJECT and a ROWIS PROJECT. ROWIS CONNECTION links zero, one, or more CSJs to zero, one, or more ROWIS PROJECT IDs and so enables the identification of project-related information from ROWIS.
UACT PROJECT	A UACT PROJECT is a TxDOT roadway improvement project that is managed and tracked in the UACT application. The data of a UACT PROJECT is mostly derived from a DCIS PROJECT.
UTILITY ADJUSTMENT PROCEDURE	A UTILITY ADJUSTMENT PROCEDURE is a process to accomplish the adjustment and accommodation of reimbursable utility facilities on TxDOT projects. Source: TxDOT Utility Manual

ROWIS Subject Area

The ROWIS Subject Area consists of the entities PROJECTS, CONTROL SECTION JOBS, PARCELS, and a related mapping table CONTROL SECTION JOBS PARCELS (Figure 39, Table 26.)
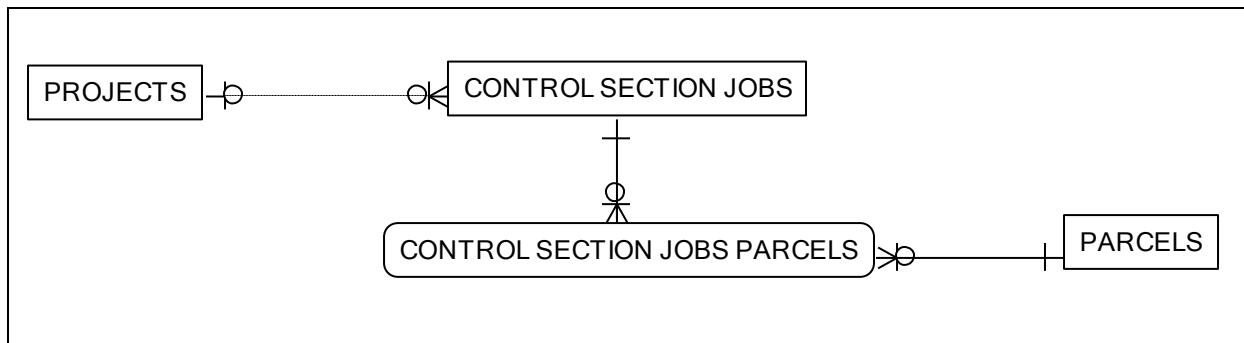
Figure 39. UACT Data Model – ROWIS Subject Area.

All tables in this subject area are components of ROWIS and maintained by TxDOT. For simplicity, the researchers only included some of the attributes in the data model that are relevant to UACT.

During an implementation of UACT, it would be critical to access and display data in UACT that are maintained in ROWIS. The data in ROWIS are stored in a RDBMS using an implementation of Microsoft SQL Server. As such, accessing data from ROWIS and displaying the data in UACT is conceptually much less difficult as compared to data that originated from DCIS. The logical model allows the linking of data in UACT and ROWIS through an associative entity called ROWIS CONNECTION as described in the Project Subject Area.

Table 26. ROWIS Subject Area Entities.

Name	Definition
CONTROL SECTION JOBS	No definition found in the ROWIS data model (ERwin format) TxDOT provided. Apparently, a CONTROL SECTION JOBS is a table that provides a linkage between different types of CSJ numbers (Construction, ROW) and a project, and for each CSJ assigns a different unique CSJ identifier for the system. (ROWIS table)
CONTROL SECTION JOBS PARCELS	No definition found in the ROWIS data model (ERwin format) TxDOT provided. Apparently, a CONTROL SECTION JOBS PARCELS is a linking table between CONTROL SECTION JOBS and the PARCELS table for the purpose of identifying which parcels are located on a control section job and which control section jobs a parcel is located on, to satisfy the many-to-many relationship between PARCELS and CONTROL SECTION JOBS. (ROWIS table)
PARCELS	No definition found in the ROWIS data model (ERwin format) TxDOT provided. Apparently PARCELS is a listing of parcel information that pertains to a right of way property parcel including, number, release date, possession date, etc. (ROWIS table)
PROJECTS	No definition found in the ROWIS data model (ERwin format) TxDOT provided. Apparently, PROJECTS is a listing of project information that pertains to TxDOT right of way project, including right of way release date, environmental clearance date, total authorized state funds, etc. (ROWIS table)

System Subject Area

The System Subject Area consists of the entities MESSAGE, MESSAGE TYPE, and UACT ENTITY (Figure 40, Table 27.)
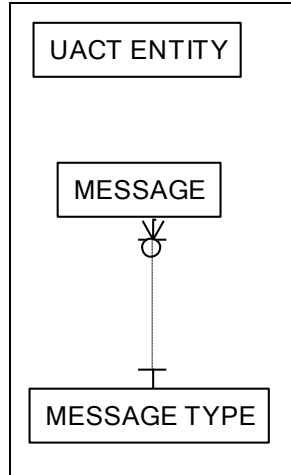
Figure 40. UACT Data Model – System Subject Area.

UACT ENTITY is a listing of all entities in the UACT data model including the definition of the entity. The purpose of UACT ENTITY is to make entity definition accessible to the system. The definitions are stored in the entity properties of the ERwin data model file but cannot be exported during database schema creation. UACT ENTITY provides an easy access to the entity definitions, which allows for the creation of Extensible Markup Language (XML) files that can be used for the context-relevant help that UACT displays in several areas of the system.

MESSAGE and MESSAGE TYPE are UACT system tables that allow UACT system designers to store standard error messages for various pages and processes.

Table 27. System Subject Area Entities.

Name	Definition
MESSAGE	A MESSAGE is a phrase or sentence used in the UACT application to convey information to users.
MESSAGE TYPE	A MESSAGE TYPE is a category that describes a certain kind of MESSAGE. Examples of a MESSAGE TYPE are "error message" and "warning message."
UACT ENTITY	A UACT ENTITY is a representation of a table in the UACT data model.

Utility Agreement Assembly Subject Area

The Utility Agreement Assembly Subject Area consists of the main entities UTILITY AGREEMENT, UTILITY AGREEMENT ASSEMBLY, UTILITY AGREEMENT ASSEMBLY EVENT, UTILITY JOINT USE ACKNOWLEDGEMENT, PAYMENT, UTILITY BILL, related lookup tables, and mapping tables that provide linkages to other subject areas (Figure 41, Table 29.)
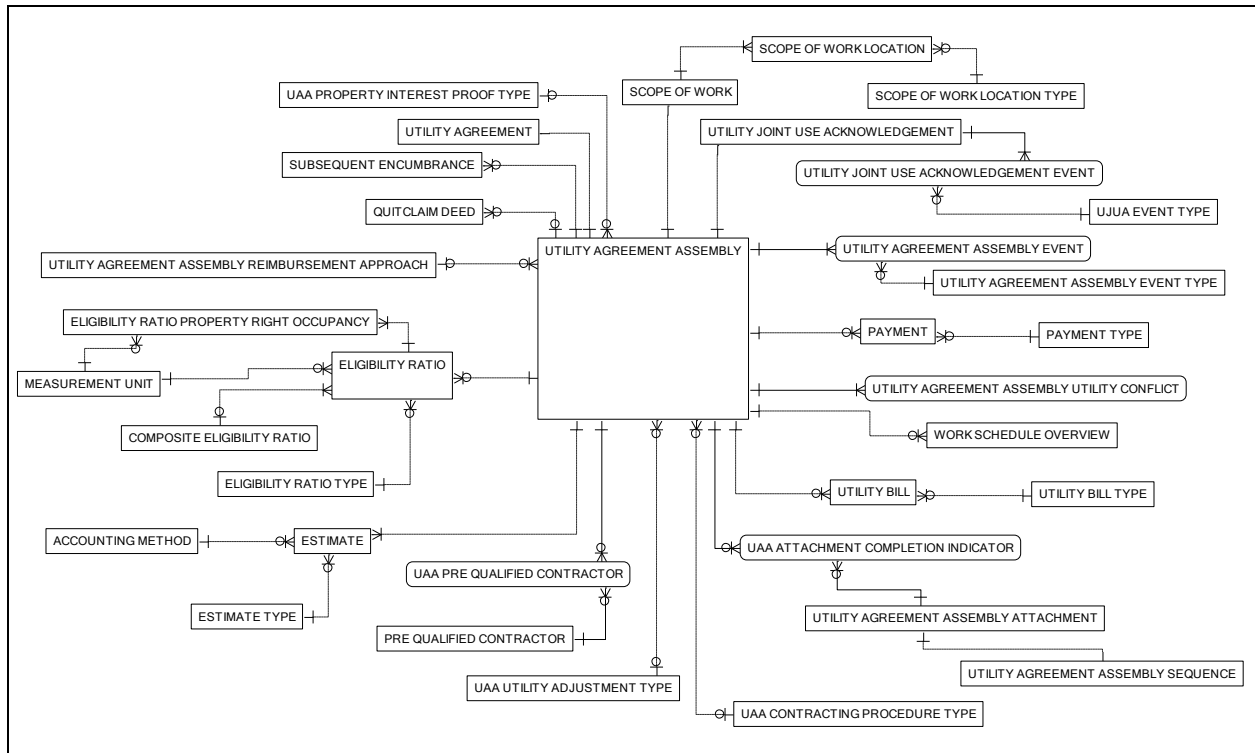
Figure 41. UACT Data Model – Utility Agreement Assembly Subject Area.

The Utility Agreement Assembly Subject Area has the largest number of entities of all UACT subject areas. These entities are required to store and provide data about utility agreement assemblies and the cost reimbursement process following a reimbursable utility adjustment. The design of this portion of the data model resulted from an initial data model design based on feedback from stakeholders that the researchers combined with the functionality of the ROW Division's UAD. Based on an analysis of the UAD data architecture, the researchers created a normalized UAD data model and then created several new UACT entities to reproduce the functionality of the UAD within the UACT data model. An implementation of the UACT prototype should allow for a complete migration of the UAD data into UACT and allow UACT to replace the UAD.

UTILITY AGREEMENT ASSEMBLY is the central entity of the subject area. Its purpose is to store information about the agreement assembly pertaining to property interest and reimbursement contract. For example, UTILITY AGREEMENT ASSEMBLY includes flags for quitclaim deeds, inclusion of the utility in the highway contract, and the need for a Utility Joint Use Acknowledgement. UTILITY AGREEMENT ASSEMBLY also references the contracting procedure type, reimbursement approach, property interest proof type, utility adjustment type, and documents. Although UTILITY AGREEMENT ASSEMBLY includes the utility agreement U-Number, its primary key is UAA ID because of concerns that the U-Number may have been re-used in the past. UTILITY AGREEMENT references the UAA ID and stores the utility agreement's statement of work. The primary key of UTILITY AGREEMENT is the UTILITY AGREEMENT ID.

UTILITY JOINT USE ACKNOWLEDGEMENT provides the type of Utility Joint Use Acknowledgement that may be attached to a utility agreement, and provides a reference to UTILITY JOINT USE ACKNOWLEDGEMENT EVENT. The latter entity tracks information such as when TxDOT requested or received a Utility Joint Use Acknowledgement.

UTILITY AGREEMENT ASSEMBLY EVENT tracks any change to the status of the utility agreement from the creation through modification, submission, and approval by creating a new record for each change to the agreement that is linked to the UAA ID and the event type. All event types are stored in the entity UTILITY AGREEMENT ASSEMBLY EVENT TYPE. Table 28 provides an overview of UACT utility agreement event types.

Table 28. UACT Utility Agreement Event Types.

ID	Name
0	Agreement created
1	Agreement edited
2	Agreement deleted
3	Agreement submitted to district
4	Quitclaim need determined
5	Quitclaim requested
6	Quitclaim received
7	Utility Joint Use and Occupancy need determined
8	Utility Joint Use and Occupancy requested
9	Utility Joint Use and Occupancy received
10	District agreement review start
11	District agreement approval
12	District agreement rejection
13	Division agreement review start
14	Division agreement approval
15	Division agreement rejection

If a utility adjustment is reimbursable, TxDOT reimburses the utility for eligible expenses either through a lump sum payment at the completion of the adjustment or through one or more payments for work completed. For a utility agreement, a utility must select either the lump sum or actual cost method of accounting, which UACT stores in the ACCOUNT METHOD entity. All payments to a utility are stored in the entity PAYMENT along with an ID, date, amount, and type. PAYMENT references the type of a payment from the entity PAYMENT TYPE, which includes values such as partial payment and final payment. Before TxDOT makes a payment to a utility, it must receive a bill from the utility for either the agreed lump sum or actual costs incurred. Information about these bills are stored in the entity UTILITY BILL including amount, record number, receive date, response date, and bill type. UTILITY BILL TYPE is a lookup

entity to specify the bill type, such as final bill (lump sum), incremental bill (actual cost), and final bill (actual cost).

Table 29. Utility Agreement Assembly Subject Area Entities.

Name	Definition
ACCOUNTING METHOD	An ACCOUNTING METHOD is a process to account for costs incurred during the adjustment of a utility facility, such as the category cost approach or the unit cost approach.
COMPOSITE ELIGIBILITY RATIO	A COMPOSITE ELIGIBILITY RATIO is a percentage that describes the relative amount of multiple estimated utility adjustment cost that is eligible for reimbursement by the state. A COMPOSITE ELIGIBILITY RATIO is calculated by dividing the sum of the eligible costs of the adjustments by the sum of the costs of the adjustments.
ELIGIBILITY RATIO	An ELIGIBILITY RATIO is a percentage that describes the relative amount of an estimated utility adjustment cost that is eligible for reimbursement by the state.
ELIGIBILITY RATIO PROPERTY RIGHT OCCUPANCY	An ELIGIBILITY RATIO PROPERTY RIGHT OCCUPANCY is an association of an ELIGIBILITY RATIO with a PROPERTY RIGHT OCCUPANCY. The purpose of this association entity is to resolve a many-to-many relationship between the two entities.
ELIGIBILITY RATIO TYPE	An ELIGIBILITY RATIO TYPE is a category that describes a certain kind of ELIGIBILITY RATIO.
ESTIMATE	An ESTIMATE is an approximation of costs for a utility adjustment that a utility provides to TxDOT that is part of a UTILITY AGREEMENT ASSEMBLY in the form of an attachment.
ESTIMATE TYPE	An ESTIMATE TYPE is a category that describes a certain kind of ESTIMATE.
MEASUREMENT UNIT	A MEASUREMENT UNIT is an agreed upon standard for expressing distance.
PAYMENT	A PAYMENT is a monetary compensation provided by TxDOT to a utility for the reimbursement of costs incurred during a utility adjustment.
PAYMENT TYPE	A PAYMENT TYPE is a category that describes a certain kind of PAYMENT.
PRE QUALIFIED CONTRACTOR	A PRE QUALIFIED CONTRACTOR is a utility contractor that is known to the utility to be qualified to perform the work that is required by a utility adjustment. All PRE QUALIFIED CONTRACTORs must be listed on TxDOT's form ROW-U-48 Statement Covering Utility Construction Contract Work if the utility selects procedure B as the procedure to be used in contracting work.
QUITCLAIM DEED	A QUITCLAIM DEED is a type of deed that TxDOT receives from a property owner in which the property owner bargains, sells, releases, and forever quitclaims his rights, title, interest, claim, and demand to a tract of land. Source: TxDOT form ROW-N-30 Quitclaim Deed

Table 29. Utility Agreement Assembly Subject Area Entities (Continued).

Name	Definition
SCOPE OF WORK	A SCOPE OF WORK is a detailed description of the work that the utility will perform as part of the utility agreement. A SCOPE OF WORK becomes part of a UTILITY AGREEMENT ASSEMBLY as an attachment.
SCOPE OF WORK LOCATION	A SCOPE OF WORK LOCATION is a description of the location where the utility adjustment will be performed.
SCOPE OF WORK LOCATION TYPE	A SCOPE OF WORK LOCATION TYPE is a category that describes a certain kind of SCOPE OF WORK LOCATION.
SUBSEQUENT ENCUMBRANCE	A SUBSEQUENT ENCUMBRANCE is an addendum to a utility agreement subsequent to the agreement's approval, typically consisting of an additional pay item. An example of a SUBSEQUENT ENCUMBRANCE is an addendum to a previously approved agreement due to a TxDOT design change.
UAA ATTACHMENT COMPLETION INDICATOR	A UAA ATTACHMENT COMPLETION INDICATOR is a temporary value to convey if a UACT user has completed all required information for a UTILITY AGREEMENT ATTACHMENT. The system uses this information to check if a UACT user has completed all UTILITY AGREEMENT ASSEMBLY ATTACHMENTS to determine if the user may submit the agreement assembly to TxDOT.
UAA CONTRACTING PROCEDURE TYPE	A CONTRACTING WORK PROCEDURE is a description of the work procedure used by a utility to adjust its facility that is part of a UTILITY AGREEMENT ASSEMBLY in the form of an attachment.
UAA PRE QUALIFIED CONTRACTOR	A UAA PRE QUALIFIED CONTRACTOR is an association of a UTILITY AGREEMENT ASSEMBLY with a PRE QUALIFIED CONTRACTOR. The purpose of this association entity is to resolve a many-to-many relationship between the two entities.
UAA PROPERTY INTEREST PROOF TYPE	A UTILITY AGREEMENT ASSEMBLY PROPERTY INTEREST PROOF TYPE is a list of methods by which a UTILITY can prove its ownership or by extension an interest in the land it occupies. For example, a utility may own a deed declaring its ownership or a railroad document that provides proof of an agreement for interest in the said property.
UAA UTILITY ADJUSTMENT TYPE	A UTILITY ADJUSTMENT TYPE is a list of methods by which a utility can choose to relocate or remove its facility. For example, a utility can choose a contract method, which specifies that if the utility does not have the right resources to relocate it will bid for a contractor to relocate its facilities.
UJUA EVENT TYPE	A UJUA EVENT TYPE is a category that describes a certain kind of UJUA EVENT.
UTILITY AGREEMENT	A UTILITY AGREEMENT is a contract between TxDOT and a utility that specifies costs, timing, methods of installation, and other information of utility facilities that need to be adjusted. TxDOT uses a standard form ROW-U-35 for all UTILITY AGREEMENTs. The standard form specifies a number of mandatory attachments with supporting information for each UTILITY AGREEMENT. The standard UTILITY AGREEMENT form plus all required attachments form the UTILITY AGREEMENT ASSEMBLY.

Table 29. Utility Agreement Assembly Subject Area Entities (Continued).

Name	Definition
UTILITY AGREEMENT ASSEMBLY	A UTILITY AGREEMENT ASSEMBLY is a document set that includes all documents that are needed for a UTILITY AGREEMENT between TxDOT and other agencies in connection with a utility adjustment. A UTILITY AGREEMENT ASSEMBLY consists of the UTILITY AGREEMENT standard form ROW-U-35 and several attachments, such as engineering estimate, proposed design drawing, and Utility Joint Use Acknowledgement.
UTILITY AGREEMENT ASSEMBLY ATTACHMENT	A UTILITY AGREEMENT ATTACHMENT is a document that is listed in TxDOT's form ROW-U-35 (Standard Utility Agreement) as one of several attachments that must be attached to form ROW-U-35 for the agreement to become valid. A Utility Agreement Assembly consists of form ROW-U-35 with all required attachments.
UTILITY AGREEMENT ASSEMBLY EVENT	A UTILITY AGREEMENT ASSEMBLY EVENT is the occurrence of a change to a UTILITY AGREEMENT ASSEMBLY.
UTILITY AGREEMENT ASSEMBLY EVENT TYPE	A UTILITY AGREEMENT ASSEMBLY EVENT TYPE is a category that describes a certain kind of UTILITY AGREEMENT ASSEMBLY EVENT.
UTILITY AGREEMENT ASSEMBLY REIMBURSEMENT APPROACH	A REIMBURSEMENT APPROACH is one of three allowable processes selected by a utility company to be reimbursed for costs incurred during the adjustment of a utility facility. The utility's selection is recorded in an attachment that is part of a UTILITY AGREEMENT ASSEMBLY.
UTILITY AGREEMENT ASSEMBLY SEQUENCE	A UTILITY AGREEMENT ASSEMBLY SEQUENCE is a number that specifies the position where a UTILITY AGREEMENT ASSEMBLY ATTACHMENT appears in UACT in the list of attachments that need to be completed to produce all required documents for a UTILITY AGREEMENT ASSEMBLY. The purpose of this entity is to facilitate changes to the order in which UTILITY AGREEMENT ASSEMBLY ATTACHMENTS are presented to a system user.
UTILITY AGREEMENT ASSEMBLY UTILITY CONFLICT	A UTILITY AGREEMENT ASSEMBLY UTILITY CONFLICT is an association of a UTILITY AGREEMENT ASSEMBLY with a UTILITY CONFLICT. The purpose of this association entity is to resolve a many-to-many relationship between the two entities.
UTILITY BILL	A UTILITY BILL is a request for payment that a utility submits to TxDOT.
UTILITY BILL TYPE	A UTILITY BILL TYPE is a category that describes a certain kind of UTILITY BILL.
UTILITY JOINT USE ACKNOWLEDGEMENT	A UTILITY JOINT USE ACKNOWLEDGEMENT is an agreement between TxDOT and a utility that sets forth the rights and obligations of both parties for occupying, maintaining, accessing, and notifying changes by either party in their facilities. It establishes the relationship between a utility and TxDOT where they will continue to occupy common right of way after an adjustment. A UTILITY JOINT USE ACKNOWLEDGEMENT is also used for the utility's continued use of existing easements and facilities within state right of way.

Table 29. Utility Agreement Assembly Subject Area Entities (Continued).

Name	Definition
UTILITY JOINT USE ACKNOWLEDGEMENT EVENT	A UTILITY JOINT USE ACKNOWLEDGEMENT EVENT is the occurrence of a change to a UTILITY JOINT USE ACKNOWLEDGEMENT.
WORK SCHEDULE OVERVIEW	A WORK SCHEDULE OVERVIEW is a list of dates for the different phases of work to be performed by the utility for adjustment. A WORK SCHEDULE can be simple enough to require only a START and END date or complex enough to require dates for all phases of the work.

Utility Facility Database Subject Area

The Utility Facility Database Subject Area consists of the entities LIFE CYCLE STATUS, RECORD ORIGIN, the supertype UTILITY FEATURE, related subtypes, and OTHER FACILITY TYPE (Figure 42, Table 31.)
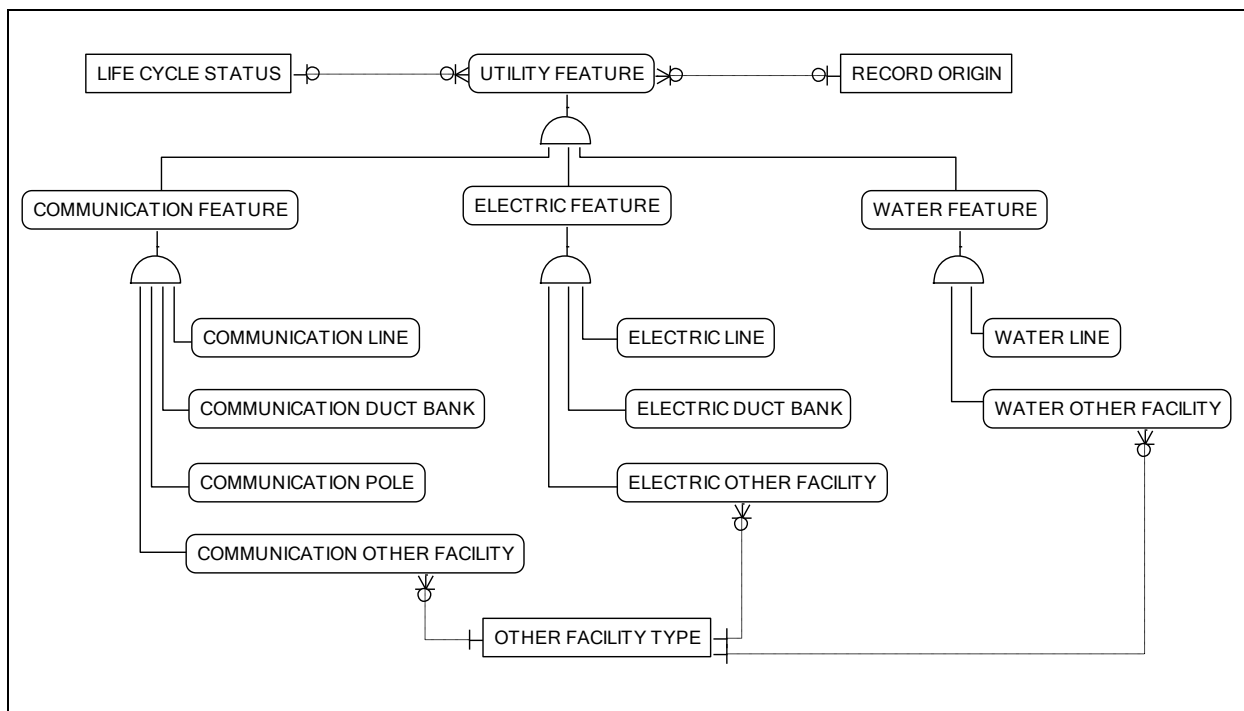
Figure 42. UACT Data Model – Utility Facility Database Subject Area.

This subject area contains a number of GAIP-compatible entities and related lookup tables that represent spatial features that can be stored in a GIS shapefile, geodatabase, or ArcSDE feature class. Projects 0-2110 and 5-2110-01 developed the structure of the UFD architecture, which is designed to manage utility facility data in a GIS environment. Figure 42 shows the logical data model, which includes several entities that only exist in the logical data model and disappear during schema generation for the physical database implementation. After the entity roll-down, only the subtypes at the lowest level (e.g., COMMUNICATION LINE or WATER LINE)

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remain as physical tables that link directly to the FEATURE table (see Figure 31). This portion of the UFD model includes only a sample of entities; the full model that was implemented as part of project 5-2110-01 includes many additional subtypes and related entities (*47*). Project documentation of project 5-2110-01, including the comprehensive research report, provides additional information about the UFD architecture.

The purpose of including this sample was to demonstrate and test the connection between UACT and UFD in a future implementation and ensure the compatibility and exchange of data between the two systems. In the implementation, UACT would read data of existing utility facilities, add these facilities to a UACT project, and then determine if these facilities would be in conflict or not. RECORD ORIGIN is an entity that was not part of the original UFD but added to the UFD during the development of UACT. Although the architecture for the UFD has been developed and successfully tested, there is currently no implemented version of the UFD that UACT would be able to connect to use to import existing utility facility data. As such, it was necessary to develop an alternative method to create utility facility data. Essentially, the researchers determined that a user of UACT without access to an existing utility facility data could use UACT to manually add utility facility data to UACT, which would then become part of the UFD. Subsequently, the researchers added the entity as a quality control mechanism to indicate the origin of a utility facility record in UACT and UFD. RECORD ORIGIN thus indicates if the record was added through UACT or if it was an existing record in the UFD that was imported into UACT.

LIFE CYCLE STATUS provides information on the current status of a utility facility (see Table 30). Each UTILITY FACILITY subtype references LIFE CYCLE STATUS to indicate the current life cycle status of the facility. This status can be changed by an authorized user, which overwrites the previous status of the facility.

Table 30. UACT Life Cycle Status Options.

ID	Name
0	Proposed
1	Under Construction
2	Operational
3	Emergency Closure
4	Abandoned
5	Demolished
6	Unknown

During the development of UACT, the researchers noted that the current version of the UFD architecture includes entities for utility facility types that TxDOT typically encounters on projects, except for some facilities that must be considered for an accrued depreciation credit. These types of "other" facilities include utility buildings, plants, power substations, lift stations, and similar large structures, which the model tracks in OTHER FACILITY TYPE. The researchers also added one "other" facility entity for every utility subtype (e.g., communication,

electric, and water) such as COMMUNICATION OTHER FACILITY to track data important for accrued depreciation calculations, such as actual service length, total life expectancy, and original cost.

Table 31. Utility Facility Database Subject Area Entities.

Name	Definition
COMMUNICATION DUCT BANK	A COMMUNICATION DUCT BANK is a linear structure that contains ducts that house underground communication lines.
COMMUNICATION FEATURE	A COMMUNICATION FEATURE is a UTILITY FEATURE that represents telecommunication utilities.
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 OTHER FACILITY	A COMMUNICATION OTHER FACILITY is a COMMUNICATION FEATURE that does not fit into any of the COMMUNICATION FEATURE subtypes provided. An example of a COMMUNICATION OTHER FACILITY would be a large facility or building used to support communication infrastructure.
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).
ELECTRIC DUCT BANK	An ELECTRIC DUCT BANK is a linear structure that contains ducts that house underground electric lines.
ELECTRIC FEATURE	An ELECTRIC FEATURE is a UTILITY FEATURE that represents electric utilities.
ELECTRIC LINE	An ELECTRIC LINE is a line that carries electricity.
ELECTRIC OTHER FACILITY	An ELECTRIC OTHER FACILITY is an ELECTRIC FEATURE that does not fit into any of the ELECTRIC FEATURE subtypes provided. An example of an ELECTRIC OTHER FACILITY would be a large facility or building used to support electric infrastructure.
LIFE CYCLE STATUS	A LIFE CYCLE STATUS is an entity that describes the current life cycle state of a utility facility. Examples include "proposed," "under construction," and "operational."
OTHER FACILITY TYPE	An OTHER FACILITY TYPE is a category that describes a certain kind of OTHER FACILITY, such as the type of a COMMUNICATION OTHER FACILITY or a WATER OTHER FACILITY.
RECORD ORIGIN	A RECORD ORIGIN is an entity that describes the origin of a record in the UACT utility inventory tables. Valid values are either "Import from utility inventory" or "Added through UACT."

Table 31. Utility Facility Database Subject Area Entities (Continued).

Name	Definition
UTILITY FEATURE	A UTILITY FEATURE is a real-world or virtual phenomenon of a utility facility associated with a model that exists in a spatial or spatiotemporal domain modeled consistent with the TxDOT GAIP standards and can be surveyable. Examples include communication feature, electric feature, and water line.
WATER FEATURE	A WATER FEATURE is a UTILITY FEATURE that represents water utilities.
WATER LINE	A WATER LINE is a pipe that carries drinkable water.
WATER OTHER FACILITY	A WATER OTHER FACILITY is a WATER FEATURE that does not fit into any of the WATER FEATURE subtypes provided. An example of a WATER OTHER FACILITY would be a large facility or building used to support water infrastructure.

Utility Installation Review Subject Area

The Utility Installation Review Subject Area consists of the main entities DOT UNIT, DOT OFFICE, DOT USER, COMPANY, COMPANY OFFICE, COMPANY USER, SYSTEM USER, OTHER UIR table, related lookup tables, and mapping tables that provide a link to other subject areas (Figure 43, Table 32.)
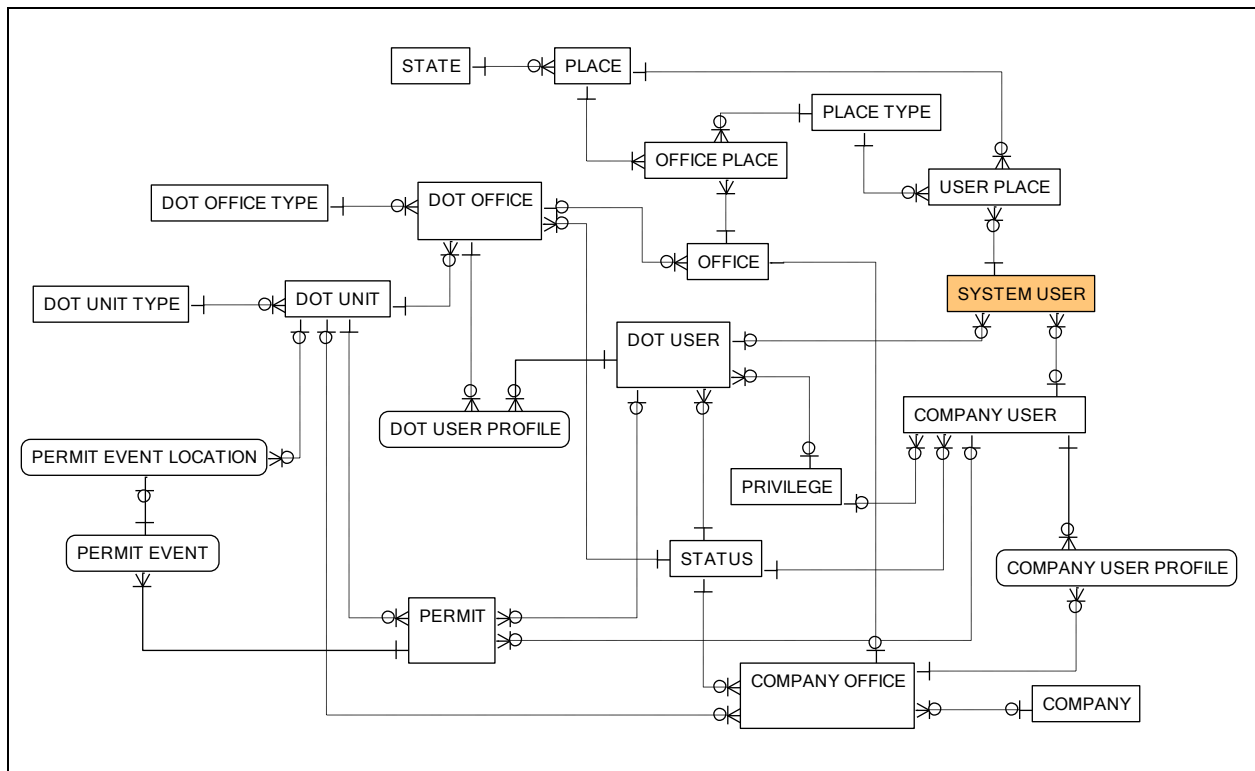

Figure 43. UACT Data Model – Utility Installation Review Subject Area.

UACT is designed to share a common user system with UIR, which includes the sharing of usernames, user profiles, company offices, and TxDOT offices between the two applications. As such, users would log in to both systems with the same username and password and view the same profile and contact information. UIR originally allowed for the storage of only utility companies in its model. In UACT, this has been expanded to include other types of companies, such as design consultants, SUE providers, and surveyors. The system determines the company type by the ROLE that is mapped to the company in the COMPANY ROLE entity (See User Subject Area and Permissions Subject Area for more information). For example, a company may perform project design, roadway construction, and surveying. A utility company would typically have only the ROLE utility ownership.

TxDOT offices are shared between the two applications. A TXDOT OFFICE record is created for each individual office, with a TXDOT UNIT marking the administrative unit of the office. A TXDOT UNIT TYPE is assigned to each TXDOT UNIT, determining if the TXDOT UNIT is at the district or division level. For example, a TXDOT OFFICE could be "Utility Permit Review Office," the TXDOT UNIT could be "San Antonio," and the TXDOT UNIT TYPE could be "District."

The UACT data model allows the direct connection with the UIR system, including the user management. All tables in the Utility Installation Review Subject Area are a part of the UIR system and were included in the UACT data model to demonstrate connections between the two systems. Implementing the UACT system may require some changes to existing UIR and/or UACT entities.

In the model, a SYSTEM USER can be a company, an agency, or an individual. The primary key for the SYSTEM USER entity is SYSTEM USER ID. This unique key identifies all users that are included in the model regardless of type. The SYSTEM USER entity also links to the DOCUMENT, MEETING, UTILITY CONFLICT, PERMISSION, PROJECT, USER, and UTILITY AGREEMENT ASSEMBLY subject areas.

The data model uses the SYSTEM USER entity to reference the user in several entities. For example, DOCUMENT VERSION tracks the user that created a new version of a document, UTILITY CONFLICT EVENT tracks the user that made a change to a utility conflict, and MEETING tracks the user that created a meeting within UACT.

Detailed user profile data are stored in DOT USER PROFILE and COMPANY USER PROFILE. For TxDOT users and company users, the model also includes entities to handle office and unit data, such as DOT UNIT, COMPANY OFFICE, OFFICE PLACE, and PLACE TYPE.

Table 32. Utility Installation Review Subject Area Entities.

Name	Definition
COMPANY	A COMPANY is any organization typically external to TxDOT that performs one or more ROLES for a PROJECT. This definition has been extended to apply to any kind of company, not just utility companies as was originally intended in the UIR application. In addition, a TxDOT office can be a COMPANY for the purpose of managing TxDOT-owned utilities.
COMPANY OFFICE	A COMPANY OFFICE is an organizational subdivision of a COMPANY. An example of a COMPANY OFFICE is a local office of a statewide operating COMPANY.
COMPANY USER	A COMPANY USER is an installation owner employee who has a user account with the UIR and/or UACT system. A COMPANY USER may have the authority to serve as an agent or representative for an installation owner in the processes of creating, modifying, and submitting a request for a utility installation permit.
COMPANY USER PROFILE	A COMPANY USER PROFILE is the detailed profile information, such as login information and contact information, of a COMPANY USER.
DOT OFFICE	A DOT OFFICE is an administrative unit within TxDOT that has a specific responsibility in the utility permit workflow in the UIR system. Note that a TXDOT OFFICE in the UIR system may not necessarily represent a physical office that exists in TxDOT. For example, the "HOU Closed Requests" represents a TXDOT OFFICE in the UIR system where the closed requests in the Houston district are sent.
DOT OFFICE TYPE	A DOT OFFICE TYPE is a category of DOT OFFICE that defines its role in a state DOT's business processes.
DOT UNIT	A DOT UNIT is an organizational sub-element of TxDOT and includes the 25 geographical areas within the State of Texas designated as districts and all TxDOT divisions.
DOT UNIT TYPE	A DOT UNIT TYPE is an organization category for a DOT UNIT. Examples for DOT UNIT TYPE are TxDOT District and TxDOT Division.
DOT USER	A DOT USER is a DOT employee who is registered with the UIR system. There are two types of DOT users in the UIR system in terms of user function. The users from TxDOT districts may be granted with the authority to serve as an agent or representative for TXDOT in the review and approval of utility installation permits. On the other hand, the security administrators in TxDOT districts and Maintenance Division, and the users from TxDOT Information Systems Division and Right of Way Division, are included in the UIR system for system monitoring and user management purposes. These users are generally not involved in the utility installation permitting process.
DOT USER PROFILE	A DOT USER PROFILE is the detailed profile information, such as login information and contact information, of a DOT USER.
OFFICE	An OFFICE is an administrative unit within TxDOT or a COMPANY that has a specific responsibility in the Project Development Process.
OFFICE PLACE	An OFFICE PLACE is a one-to-one association between an OFFICE and a PLACE. This entity is included as a linkage between the OFFICE entity and the PLACE entity.

Table 32. Utility Installation Review Subject Area Entities (Continued).

Name	Definition
PERMIT	A PERMIT is a transaction that authorizes a utility company to install non-reimbursable utilities on the state right of way. At TxDOT, the permitting process includes submitting an installation request (also known as notice of proposed installation (NOPI), the review process, approval and pre-construction, construction, and post-construction and archival. UIR generates a record for a permit in the PERMIT table when a utility company user moves from Step 1 to Step 2 while preparing an installation request.
PERMIT EVENT	A PERMIT EVENT is a transaction in the life of a permit. Every activity associated with a permit will initiate an EVENT in the database that describes that activity.
PERMIT EVENT LOCATION	A PERMIT EVENT LOCATION is the utility installation location that is described in an installation permit request when it is either originally submitted or submitted as a revised or amended request. The UIR system creates a record of the PERMIT EVENT LOCATION for the following three types of PERMIT EVENT: submitting a PERMIT request, submitting a revised PERMIT request, and submitting an amendment PERMIT request.
PLACE	A PLACE is a postal address consisting of a street address, city, state, and ZIP code.
PLACE TYPE	A PLACE TYPE is a category that describes a certain kind of PLACE. Examples for PLACE TYPE include "mailing address," "physical address," and "both."
PRIVILEGE	A PRIVILEGE is the level of access that a user has to the available functions within the UIR and/or UACT system. Depending on the user type (i.e., TxDOT or installation owner), a user may be granted with one of the following privilege levels: Guest, Consultant, User, Super User, Administrator, and System Administrator.
STATE	A STATE is a political division within the United States.
STATUS	A STATUS is the status of a UIR user account. The UIR system allows a user account to have one of the following statuses: Active, Out of Office, Pending, Rejected, Permanently Inactive, and Inactive.
SYSTEM USER	A SYSTEM USER is a person that has an account and the authority to use the UIR and/or UACT system. The system allows two types of users: DOT USERs and COMPANY USERs (e.g., installation owners). Both types of SYSTEM USERs are assigned with different levels of system access for both permitting and user management within the system.
USER PLACE	A USER PLACE is a temporary one-to-one linkage between a USER and a PLACE. A USER PLACE is created at the moment when the user account is being created and it is then deleted from the database when the user account is successfully created.

User Subject Area

The User Subject Area consists of the entities USER EVENT, USER EVENT TYPE, and the mapping tables SYSTEM USER ROLE, COMPANY ROLE, and PROJECT COMPANY (Figure 44, Table 33.)
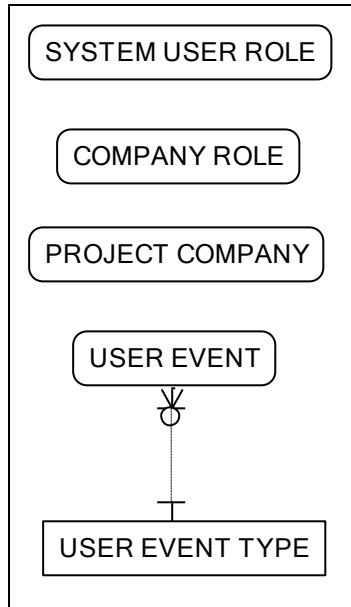
Figure 44. UACT Data Model – User Subject Area.

USER EVENT references the SYSTEM USER ID and tracks changes to UACT users including the day and time when the change occurred. A USER EVENT references a USER EVENT TYPE, which can have the value "creation," "modification," or "deletion."

SYSTEM USER ROLE is a mapping table that links a SYSTEM USER to a ROLE. The mapping table allows a many-to-many relationship between SYSTEM USER and ROLE so that a ROLE can be performed by many SYSTEM USERS and a SYSTEM USER can have many different roles. The Permissions Subject Area provides more information about the use of roles in UACT.

Similarly to SYSTEM USER ROLE, COMPANY ROLE is a mapping table that links a COMPANY to a ROLE, allowing a many-to-many relationship between the two entities. PROJECT COMPANY is the third mapping table in this subject area that links a PROJECT to a COMPANY and vice versa.

Table 33. User Subject Area Entities.

Name	Definition
COMPANY ROLE	A COMPANY ROLE is a mapping between a COMPANY and a ROLE that describes one or more ROLEs that a COMPANY performs in the TxDOT Project Development Process.
PROJECT COMPANY	A PROJECT COMPANY is a mapping between PROJECT and COMPANY, describing a COMPANY that is part of a PROJECT.
SYSTEM USER ROLE	A SYSTEM USER ROLE is a specification of the ROLE that a SYSTEM USER has. In other words, it is a mapping of ROLE and SYSTEM USER to identify the ROLE of a user in UACT.
USER EVENT	A USER EVENT is a creation or modification of a SYSTEM USER.
USER EVENT TYPE	A USER EVENT TYPE is a category that describes a certain kind of a USER EVENT transaction.

Utility Conflict Subject Area

The Utility Conflict Subject Area consists of the main entities UTILITY CONFLICT, UTILITY CONFLICT EVENT, UTILITY CONFLICT RESOLUTION STRATEGY, UTILITY CONFLICT FEATURE STATUS, NOTE, related lookup tables, and mapping tables that provide a link to other subject areas (Figure 45, Table 38.)
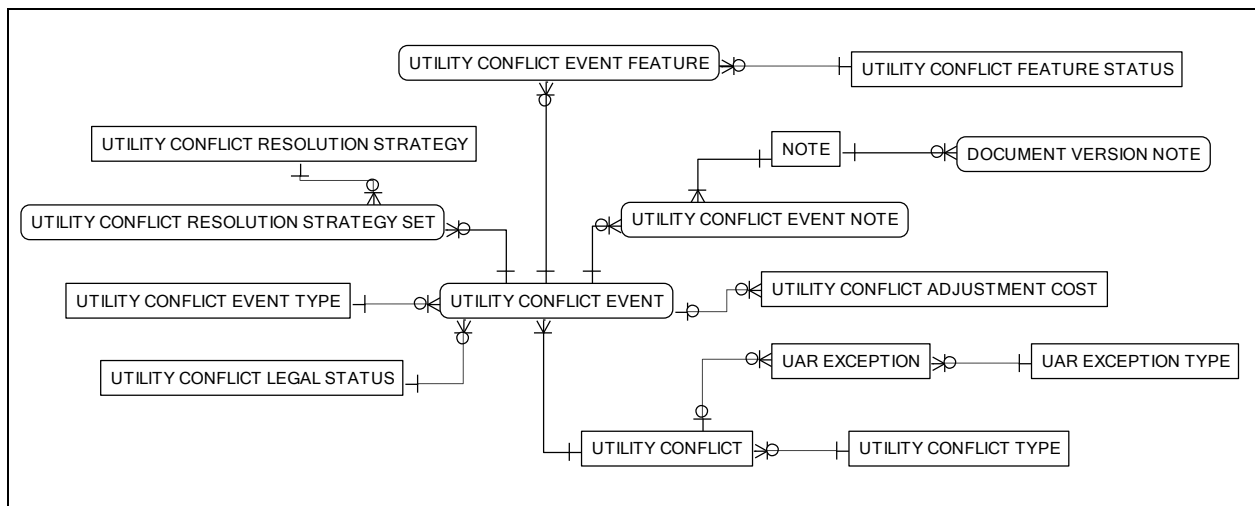
Figure 45. UACT Data Model – Utility Conflict Subject Area.

The purpose of this subject area is to track utility conflicts and associated data. Within UACT, utility conflict data is primarily distributed among three main entities, which are UTILITY CONFLICT, UTILITY CONFLICT EVENT, and UTILITY CONFLICT OUTLINE. The latter entity stores all attributes describing references to the shape and location of a conflict. For more information about UTILITY CONFLICT OUTLINE, refer to the ArcSDE Subject Area.

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Utility conflicts are created in the UTILITY CONFLICT entity that provides an ID, references UTILITY CONFLICT TYPE, links the conflict to a UACT project, provides a time and date for the record creation, and stores estimated dates for start and completion of the conflict adjustment, if available. UACT tracks four different types of utility conflicts shown in Table 34.

Table 34. UACT Utility Conflict Types.

ID	Name
0	Conflict with roadway project features.
1	Conflict with another utility feature.
2	Conflict with utility regulations or standards.
3	Conflict with safety regulations.

Every change to a utility conflict is stored in UTILITY CONFLICT EVENT along with the date and time of the change. This entity references the UTILITY CONFLICT ID, so that a new record is created for each new event to a utility conflict. Other attributes are UTILITY CONFLICT DESCRIPTION, and UTILITY CONFLICT EVENT LEGAL DATE. The latter attribute tracks the date when a user makes a change to a UTILITY CONFLICT LEGAL STATUS, which determines the current legal status of the utility conflict. Currently, UACT tracks the following types of utility conflict statuses (Table 35).

Table 35. UACT Utility Conflict Legal Status Types.

ID	Name
0	Pending plans sufficient
1	Plans sufficient submitted
2	30-day notice submitted
3	90-day notice submitted

UTILITY CONFLICT EVENT FEATURE is a mapping table that links a UTILITY CONFLICT EVENT to a FEATURE. UACT uses this table to identify the features that are part of a conflict. This structure allows a feature, e.g., an electric line, to be part of many conflicts, and also allows one conflict to include many features. However, testing of preliminary versions of UACT found that the management of utility agreements becomes significantly more difficult if utilities can be part of multiple conflicts, or if a conflict can consist of multiple utilities. Following a recommendation of the panel, the researchers limited the association of a utility facility to only one conflict through code.

The structure of UTILITY CONFLICT EVENT FEATURE allows a tracking of all feature changes to the utility conflict. UTILITY CONFLICT FEATURE STATUS provides the current status of a feature and can have the following values (Table 36).

Table 36. UACT Utility Conflict Feature Status Types.

ID	Name
0	Not yet reviewed
1	Possible conflict
2	Confirmed conflict
3	Resolved conflict

UTILITY CONFLICT EVENT also links to UTILITY CONFLICT OUTLINE directly (see ArcSDE Subject Area). This link allows the association of a UTILITY CONFLICT OUTLINE feature with a utility conflict.

UAR EXCEPTION tracks if a utility conflict is subject to an exception to the UAR, along with amount, dates, comments, and indication of approval. The category of the exception is tracked in UAR EXCEPTION TYPE.

UTILITY CONFLICT RESOLUTION STRATEGY tracks the current strategy that was selected to resolve a utility conflict. UTILITY CONFLICT RESOLUTION STRATEGY SET allows the linking of multiple utility conflict resolution strategies with a utility conflict. This entity also includes flags to indicate the recommended resolution strategy and an indicator of the strategy that was ultimately used. Table 37 shows the valid values for a UTILITY CONFLICT RESOLUTION STRATEGY.

Table 37. UACT Utility Conflict Resolution Strategy Types.

ID	Name
0	Adjustment
1	Abandon in-place
2	Exception
3	Design change

Table 38. Utility Conflict Subject Area Entities.

Name	Definition
DOCUMENT VERSION NOTE	A DOCUMENT VERSION NOTE is a mapping between a NOTE and a DOCUMENT VERSION allowing a SYSTEM USER to provide miscellaneous information about a DOCUMENT VERSION.
NOTE	A NOTE is miscellaneous information that provides extra detail or description for an event.
UAR EXCEPTION	A UAR EXCEPTION is the exemption of a utility of the rules and regulations set forth in the Texas Utility Accommodation Rules codified in Texas Administrative Code 43 Chapter 21.31 to 21.56.

Table 38. Utility Conflict Subject Area Entities (Continued).

Name	Definition
UAR EXCEPTION TYPE	A UAR EXCEPTION TYPE is a category that describes a certain kind of UAR EXCEPTION.
UTILITY CONFLICT	A UTILITY CONFLICT is an instance where a utility facility is non-compliant with the TxDOT Utility Accommodation Rules, is non-compliant with safety regulations, is located within the extent of a proposed roadway improvement design of a TxDOT PROJECT, or is located within the extent of a proposed utility facility. A UTILITY CONFLICT can be resolved by modifying the proposed roadway improvement design, adjusting/relocating the utility facility, or granting an exception/making changes to the current Utility Accommodation Rules or safety regulations.
UTILITY CONFLICT ADJUSTMENT COST	A UTILITY CONFLICT ADJUSTMENT COST is the amount that a utility owner estimates to expend on the removal of a utility conflict by adjusting the utility facility.
UTILITY CONFLICT EVENT	A UTILITY CONFLICT EVENT is the occurrence of a change to a UTILITY CONFLICT.
UTILITY CONFLICT EVENT FEATURE	A UTILITY CONFLICT EVENT FEATURE is a collection of features involved with a given UTILITY CONFLICT EVENT.
UTILITY CONFLICT EVENT NOTE	A UTILITY CONFLICT EVENT NOTE is a mapping between a NOTE and a UTILITY CONFLICT EVENT allowing a SYSTEM USER to provide miscellaneous information about a UTILITY CONFLICT.
UTILITY CONFLICT EVENT TYPE	A UTILITY CONFLICT EVENT TYPE is a category that describes a certain kind of UTILITY CONFLICT EVENT.
UTILITY CONFLICT FEATURE STATUS	A UTILITY CONFLICT FEATURE STATUS is a mapping from a UTILITY CONFLICT STATUS CODE to a step in the process of solving a utility conflict.
UTILITY CONFLICT LEGAL STATUS	A UTILITY CONFLICT LEGAL STATUS is an indication of how much progress has been made in resolving a conflict. It can be at a status of "Plans sufficient submitted," which means that the utility has been provided with plans for the project, which would allow it to adjust its facility and in turn resolve a conflict. A status of "30-day notice submitted" indicates that it has been 30 days since project plans were submitted but no action was taken. Similarly, a status of "90-day notice submitted" indicates that it has been 90 days since the submission of project plans with no action from the utility.
UTILITY CONFLICT RESOLUTION STRATEGY	A UTILITY CONFLICT RESOLUTION STRATEGY is an option to resolve a utility conflict. Examples include "Design Change," "Utility Adjustment," and "UAR exception."
UTILITY CONFLICT RESOLUTION STRATEGY SET	A UTILITY CONFLICT RESOLUTION STRATEGY SET is a set of proposed options for solving a particular conflict.
UTILITY CONFLICT TYPE	A UTILITY CONFLICT TYPE is the immediate cause of a CONFLICT.

PHYSICAL DATA MODEL DEVELOPMENT

The research team developed a physical data model for the UACT system based on the logical data model and following the TxDOT data architectures standards (*51*). In particular, the physical model:

- displays tables, columns, and foreign key constraint names;
- matches corresponding data objects in the logical data model;
- uses Information Engineering notation; and
- identifies primary, foreign, and alternative keys.

The researchers added the foreign key constraints according to the following syntax:

FK_<Child Table Physical Name>_REF_<Parent Table Physical Name>

The researchers used up to 30 characters for the foreign key constraint. In cases where the foreign key constraint would have been longer than 30 characters using the full table names, the researchers abbreviated table names as needed.

The physical data model was created for an implementation using Oracle 10g and uses four separate tablespaces:

- **UACT.** This tablespace includes the tables of the subject areas Feature, Utility Conflict, Utility Agreement Assembly, Permissions, Project, Document, Meeting, User, and System.

- **DCIS.** This tablespace includes the DCIS Subject Area table.

- **UFD.** This tablespace includes the tables of the Utility Facility Database Subject Area.

- **SDE.** This tablespace includes the tables of the ArcSDE Subject Area.

During development, the research team created two copies of the UACT tablespace to test changes to the prototype while keeping one version ready for user testing at all times. During implementation, the research team would likely keep these copies for testing and development of modifications to the prototype. The researchers also created the following Oracle tablespaces to test connections to existing systems:

- **FileNet**. This tablespace includes the tables of the FileNet Subject Area.

- **MainStreet**. This tablespace includes the tables of the MainStreet Texas Subject Area.

- **ROWIS**. This tablespace includes the tables of the ROWIS Subject Area.

- **UIR**. This tablespace includes the tables of the UIR Subject Area.

In an implementation, these tablespaces would not need to be created but would be replaced by existing systems. The tables of the subtype GAIP Feature, including Asset Features and Geopolitical Features, were implemented as ESRI ArcSDE tables in the Oracle table space.

DATA DICTIONARY

The research team developed a data dictionary of the logical data model entities and attributes, including complete entity and attribute definitions, and attribute purpose, examples, valid values, format, and datatype. The research team submitted the data dictionary as part of product P2.

CHAPTER 6. UTILITY ACCOMMODATION AND CONFLICT TRACKER PROTOTYPE

INTRODUCTION

UACT is a web-based prototype for the management and tracking of utility conflicts. Key functionalities of UACT include:

- **Utility Conflict Tracking.** DOT officials can enter utility conflict data based on existing utility facility data and create visual representations of utility conflicts using a mapping component. The prototype also provides an overview of the status of utility conflicts for each project.

- **Utility Agreement Development and Tracking.** A utility company can complete the required forms of a utility agreement online and file the document electronically for review by the appropriate district and division personnel. The system guides the user through the completion process and selects appropriate forms based on the specific circumstances of the utility conflict.

- **Document Upload and Conversion to PDF.** The prototype allows users to upload documents that are accessible to other users based on roles and privileges. The prototype converts all documents automatically to PDF to allow easy access to all privileged users.

- **DCIS Project Data Access**. The researchers designed the prototype to connect to DCIS and display project data that are collected in a DCIS data warehouse.

- **UFD Access.** The researchers designed the prototype to integrate with a GIS-based database of utility facility features.

- **User Access Model**. UACT provides a comprehensive and flexible access system based on capabilities, roles, and privileges. UACT administrators can further customize access to UACT by providing individual users access to specific projects.

The web-based nature of the application facilitates access by TxDOT users as well as a wide range of external consultants, contractors, and utility companies. TxDOT users can manage projects, utilities, conflicts, meetings, and contacts. External users can perform tasks relevant to the role they play in the highway project. This UACT version highlights the majority of features that the UACT data model supports, including GIS visualization and a user permissions system that is linked to the existing account system in UIR.

UACT SYSTEM ARCHITECTURE

UACT provides access to data related to utility coordination activities that are collected on a database server and provided to users using a web server. Figure 46 provides a general overview of the UACT system architecture.
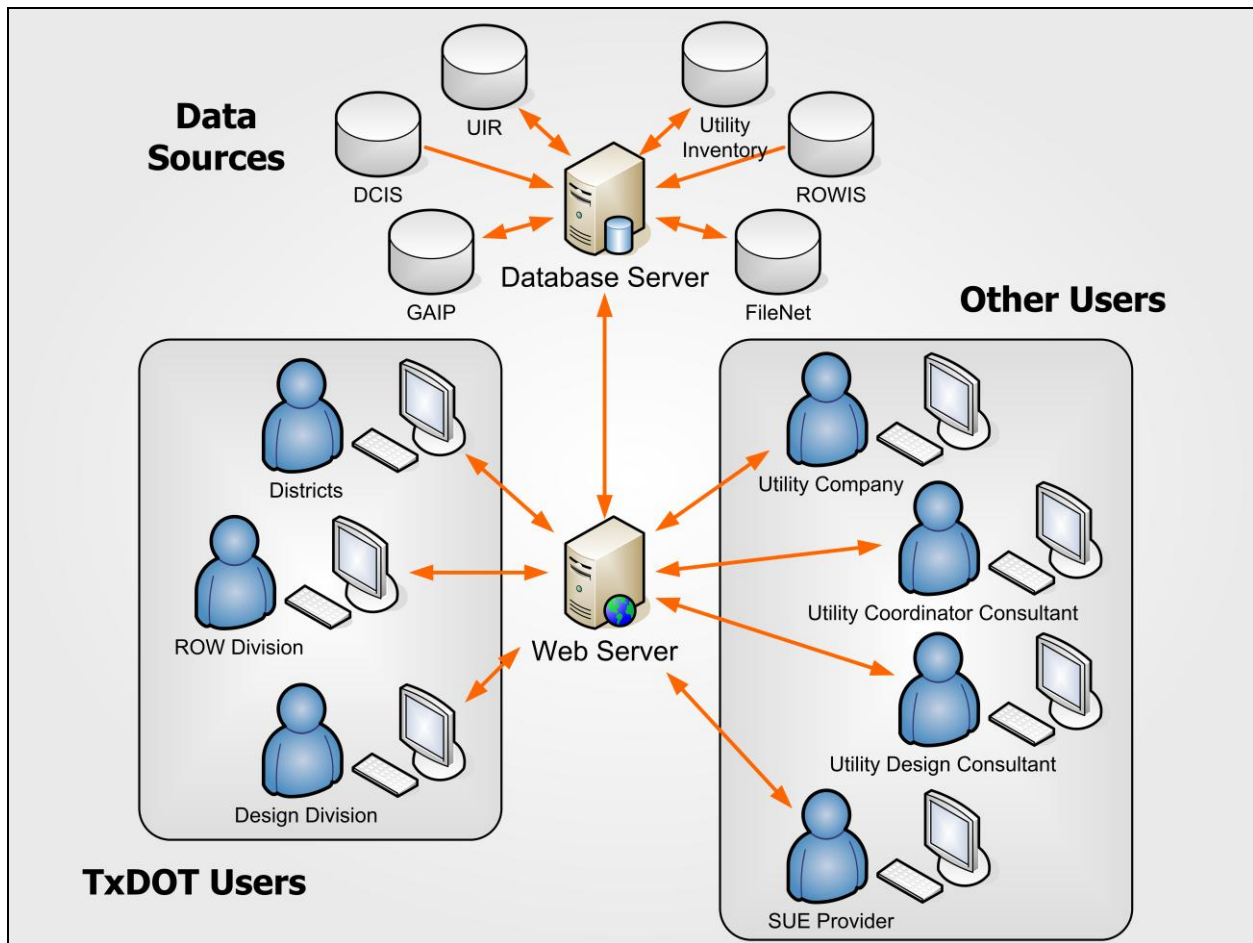
Figure 46. UACT System Architecture Diagram.

UACT is a system that consists of several components that researchers designed to manage utility conflict data using web-based access. As Figure 47 shows, UACT has two main groups of components: client-side components and server-side components. On the client side, a web browser serves as a front-end interface that allows users on client computers to interact with the UACT system to complete the utility adjustment process. Both utility company users and TxDOT users can act as clients, but their interfaces are different and have different access levels. To access UACT, users must have a computer that meets the following minimum system requirements:

- desktop or laptop computer running Windows XP with Service Pack 2 (SP2),
- Microsoft Internet Explorer® 6.0 with SP2 or higher,
- PDF reader such as Adobe® Acrobat Reader® 7.0,
- internet connection,
- e-mail account, and
- UACT active account.

Figure 47. UACT System Architecture.

On the server side, UACT includes a number of system components, including the following:

- **Web server**. Microsoft Internet Information Services® (IIS) 6.0 running on Windows Server 2003.

- **Map server**. ESRI ArcGIS Server Version 9.2.

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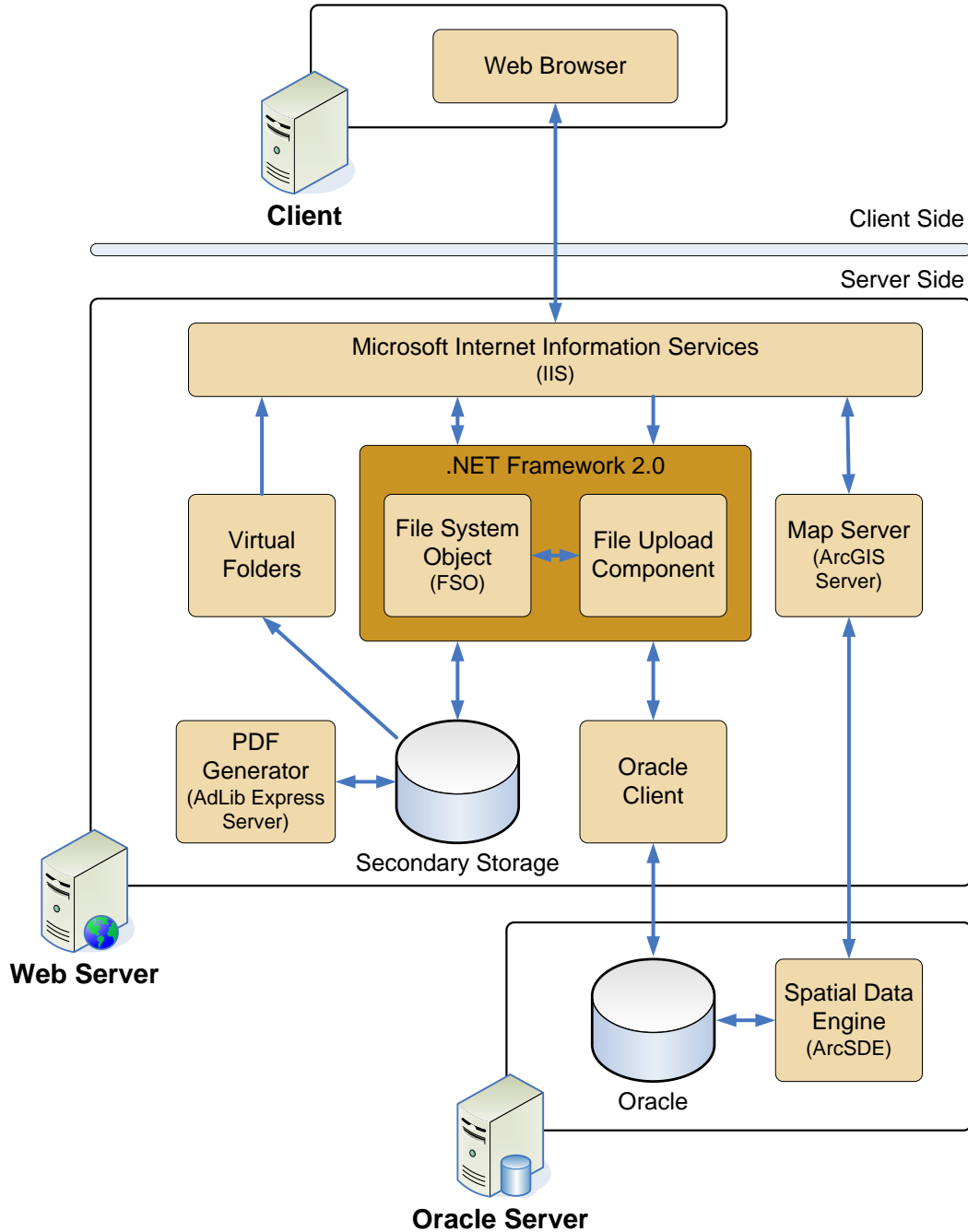- **Spatial data engine.** ArcGIS Server can be configured to access spatial data in formats such as ESRI shape file format, personal geodatabases (.mdb file format), or geodatabases using ESRI ArcSDE.

- **File upload component**. UACT currently uses a file upload component of .NET. UACT could use another upload component such as SoftArtisans® FileUp™.

- **PDF generator**. Adlib Software Adlib Express Server with Compressor Add-On. This standalone server application monitors the contents of a specific input folder at regular time intervals. In UACT, the application checks the contents of a designated input folder every five seconds. If Adlib Express Server detects a new file in that folder (typically if a utility company or TxDOT user has uploaded a file to the server), Adlib Express Server generates a PDF file and stores that file in a designated output folder. In order for Adlib Express Server to convert a file to PDF, an application that can open the file must be installed on the server.

- **Microsoft Office** (Word®, Excel, PowerPoint®, and Visio®). Adlib Express Server supports a number of native applications installed on the server, including Microsoft Office. UACT recognizes Word, Excel, PowerPoint, and Visio files, allowing Adlib Express Server to generate PDF versions of Word (.doc) files, Excel (.xls) files, PowerPoint (.ppt) files, and Visio (.vsd) files.

- **Additional PDF file generation support**. Cimmetry AutoVue 2D Desktop (now Oracle® AutoVue) enables Adlib Express Server to generate PDF versions of additional file types, in particular MicroStation® (.dgn) and AutoCAD® (.dwg).

- **Microsoft .NET™ 2.0 framework**. An integral Windows component required to run applications developed with .NET technology. The version used for the implementation of UACT is 2.0.

- **Oracle Client.** In order for the IIS web server to communicate with the Oracle database server and retrieve data, it requires a data provider that supports Oracle. UACT uses the .NET Managed Provider for Oracle from Microsoft, which is part of the .NET 2.0 framework.

As Figure 47 shows, the UACT implementation uses two server side environments: a database server (that includes Oracle and ArcSDE) and a web server (that includes all other components in addition to the UACT code). The web server also stores all files uploaded to the system as well as data files UACT generates during the utility adjustment process. A UACT implementation at TxDOT will likely involve separate mapping and data storage servers. In addition, TxDOT would connect UACT to an existing email server to allow for system-generated email notifications.

UACT uses ESRI ArcGIS Server located on the web server to serve maps of utility conflict locations to system users. ArcGIS Server connects to ArcSDE on the Oracle server, which is ESRI's Spatial Data Engine that spatially enables a portion of the data in the Oracle server. This

architecture represents an integrated environment that allows access to a comprehensive database of spatial data accessible to multiple users, as compared to the traditional approach of managing geographic data on separate local drives.

Permissions System

Experience with the implementation of the UIR system has shown that maintaining a strict workflow-control system for the specific tasks supported by UACT would result in an unfeasible level of administrative overhead. Instead, the researchers designed a permissions-based system that allows any user to make changes at any time that are within his or her level of access. The UACT permissions model provides highly detailed user access levels, mapping of companies, functions in the Project Development Process, and user groups that the system combines to a user-specific set of application capabilities.

Utility Conflict List

The core of the interface, the utility conflict list, mimics the current business processes of public and private utility coordination staff while providing a robust and more widely accessible user experience. The researchers expect that the use of the familiar paradigm of conflict list will reduce training costs and allow both internal and external offices to TxDOT to implement the system quickly. The team designed UACT as a drop-in replacement for the current district, company, and in some cases, user-specific systems such as custom Microsoft Access databases and Microsoft Excel spreadsheets. In districts where the UIR system has already been deployed, implementation costs will be further reduced due to the sharing of system resources. Training costs will be reduced by common system layout and a shared user login system between the two applications.

PROTOTYPE FUNCTIONALITY

This section provides a general overview of the functionality of the UACT beta version. For a complete description of the system functionality, refer to deliverable 0-5475-R3, the UACT user guide.

The UACT system can be accessed using a standard Internet browser. Users can access the main sections of the application by clicking on one of the links of the main navigation area provided at the top of each page of the application, as follows:

- **Home**. This is the start page that lists all active projects within UACT.

- **Project**. A section that gives an overview of the selected project's information.

- **Utility Inventory**. This section provides an overview of utility facilities associated with the currently selected project as well as the capability to add or import new utility facilities.

- **Conflict Tracking**. This section provides an overview of the currently selected project's utility conflicts.

- **Agreement Assembly**. This section provides a mechanism to complete a utility agreement assembly with the help of a sequence of steps, create new agreements, and edit existing utility agreement assemblies.

- **Reporting**. This section provides a tool to create customized reports using data stored in UACT.

- **Contacts**. This section provides a link to the project contact database that UACT shares with the UIR system.

- **Other Resources**. This section provides resources to the users of UACT that are related to utility coordination and accommodation, such as documents, policies, and guidelines.

- **Administration**. This section provides a UACT system administrator with the ability to control user access to UACT, create new users, and manage existing users and their profiles.

All UACT screens display the currently logged-in user name in the top right corner. Similarly, all screens allow the user to return to the project summary screen by clicking on the "Home" link in the top left corner. Users can log out of the application at any time on any screen by clicking on the "Logout" link on the top right corner next to the user name. The sections described above essentially represent business areas or business area sections that UACT uses to restrict access to areas of the system. For more information on access, business areas, and permissions, refer to the Permissions Subject Area discussion in Chapter 5. The following is a brief overview of the functionality of UACT in each business area.

Project Business Area

The project summary screen provides details to all stakeholders involved in a project (Figure 48). Currently, the data that is displayed on the project summary screen is stored within the UACT system. Optionally, depending on implementation, UACT could link directly to either ROWIS or DCIS in an implementation version of the system.

Figure 48. Project Listing.

Currently, a UACT project combines data elements from DCIS and ROWIS. In order to track utility conflicts and agreement assemblies, a user must associate utility facilities with the project or create new utility facilities. Users with appropriate access to this section can import utility facilities from the Utility Facility Database, which UACT automatically associates with the current project.

There are several different stakeholders with different roles in a highway project, including subcontractors and/or consulting companies employed by a utility company for a facility adjustment, that may need access to project data throughout the project development process. UACT allows the association of these stakeholders with a project using the stakeholder page.

Project documentation includes design schematics, construction plans, memorandums, bills, etc. To facilitate the sharing of project data relevant to process stakeholders, UACT provides an interface to upload documents in several business areas. Project files can be uploaded under the project business area, and users with sufficient permissions (including stakeholders and third parties as permitted) may view these documents. Documents in UACT can have several revisions that UACT manages using a version control system that is part of the document upload interface. Different versions of the same document can be uploaded when the user selects the "detailed view" of a document. The interface then changes to show a document summary and all other versions of the current document. If a user uploads a new document in the "detailed view" of an existing document, UACT automatically creates a new version of the existing document.

Utility Inventory Business Area

The Utility Inventory Business Area shows a listing of all utility facilities within the project limits that system users have entered into UACT (Figure 49). Utility facilities can also be imported from an external database of utility facilities. A drop-down list allows the user to filter the list of available utility facilities by facility type.

Figure 49. Utility Inventory Screen.

In UACT, conflicts (and by extension, utility agreement assemblies) require the existence of utility facilities to establish a real-world relationship. To increase the usefulness of UACT, it would be advisable to associate utilities facilities that are located within the project limits. Although this is not a requirement in UACT, it would reduce the clutter and facilitate the creation of useful reports. However, for any tracking operations to be performed on a project, it is a UACT requirement that at least some utility facilities are either created or imported from the external database every time a new project is created. There is no specific point in time when this operation must be performed, but it must be performed before utility conflicts and utility agreement assemblies can be created.

The Import tab in this section allows a user with adequate permissions to import utility facilities into UACT. This can be achieved by clicking on the "Import Utilities" button under the import section of Utility Inventory, after the desired utilities have been selected. After the user clicks the import button, the list of utility facilities becomes immediately available for utility conflicts and agreements.

Conflict Tracking Business Area

The Conflict Tracking Business Area shows a listing of all utility conflicts of the current project that users have entered into the system (Figure 50). The conflict data is entered by TxDOT, surveying, utility coordination personnel, or other users with appropriate permission levels through the UACT interface and stored within the database. Utility conflicts can have only one affected utility, whereas a utility facility can be associated with multiple conflicts with a proposed highway design or with one or more other utilities. For example, associating multiple conflicts with one utility facility is useful if a utility facility crosses project limits. The conflict list can be browsed using pagination links at the bottom of the list. Utility conflict data can be sorted by clicking the table header, and utility conflict details can be viewed by clicking on the "Details" link of a utility conflict record.

Figure 50. Conflict Tracking Screen.

UACT provides a method for the resolution of utility conflicts by allowing various involved parties to view and access data collected for the conflict. The data is represented in text and visual formats (using an interactive map), which provides a complete description of the conflict. Sharing this data with stakeholders can potentially save costs, ease the design process, and decrease delays in the completion of projects. Utility owners can log into UACT and view a listing of all project conflicts, view the detailed data of all conflicts they are involved in, and use the conflict data to work on the conflict resolution and/or development of a utility agreement assembly.

The details of a conflict are divided into four sections, each providing a different aspect of the conflict. Descriptive details of a utility conflict are listed under "Basic Information," including the estimated start and end adjustment dates, a description of the conflict, as well as start and end

stations along a reference project line. Under "Conflict Polygon," a visual representation of the conflict is available as an interactive map where conflicts are represented by semi-transparent polygons. Under "Conflict Documents," users with appropriate authorization may upload documents related to conflicts, such as notes, plans, estimates, etc. Documents may include plans for utility relocation or adjustment that may be used for utility agreement documentation. UACT provides a special "Notes" section for TxDOT officials as a means of recording notes or other information such as deadlines and communications with utility companies. Other TxDOT officials may have access to these notes, so they can be used as a means to communicate with information concerning the progress on a particular conflict.

For the purpose of keeping track of the utility adjustment status, UACT provides a "Legal Status" attribute. This field can be used to track the date when TxDOT submitted plans sufficient for the development of a utility adjustment ("Plans sufficient date") to the utility owner. Other options for this field include "30-day notice," "90-day notice," as well as "Plans sufficient pending."

New conflicts can be added to UACT under "Add Conflict," which provides a sequence of steps and further guidance on a context-sensitive help section. UACT breaks the process of creating a new conflict into four steps of which the last step is a confirmation screen that allows the user to confirm or modify the conflict. An important feature is the creation of a visual representation of the conflict using an interactive map. Existing conflicts can be edited using a similar sequence of steps that are also divided into four sections, with one additional step to select a conflict.

Agreement Business Area

The Agreement Assembly section of UACT enables a utility company user with sufficient permissions to create and track a utility agreement assembly electronically for submittal to TxDOT. Agreements are associated with a project and therefore require the selection of an active project before UACT can display agreements for that project (Figure 51).

The Agreements screen lists all incomplete agreements for the utility company of the current user. For all agreement assemblies, TxDOT personnel can view and edit this information (such as leaving remarks or accepting/rejecting an agreement based on their review). The list provides a quick overview of the assembly such as the U-Number assigned by TxDOT personnel, any comments left by TxDOT, the status of the agreement, the date on which the status changed, and buttons for a user to conduct actions. A user can work on an agreement that has not yet been submitted by clicking on "Continue" or "Edit." Additional details about the agreement assembly can be obtained by clicking on "Details" and a user with sufficient permissions can delete an assembly.

New agreements can be created by utility owners under the New Agreement section. This section shows a list of utility conflicts that have not been added to other agreement assemblies and allows the selection of one or more conflicts that will be added to an agreement. After selecting the desired conflicts, a click on "Create Assembly" generates a new utility agreement assembly in the database that is immediately available to the user.

Clicking "Continue" on the agreement listing page or clicking the Continue Agreement tab takes the user to a sequence of steps that helps a user with the completion of an electronic version of the agreement assembly. The user selects the assembly and then clicks on "Next." After clicking the "Next" button at the bottom of each step, the current progress up to this point is saved in the database, in case the utility agreement assembly process is interrupted. Once the user has accessed a step, a navigation button at the top becomes visible that allows the user to freely navigate between steps. Instructions for how to complete each step are provided in the UACT User Manual in addition to the context-sensitive help provided at each step on the page. Once an agreement assembly is complete, a summary of all documents created at each step is provided under the Summary tab, with additional internally generated messages for each assembly, if required. These messages indicate either missing requirements or forms that have not been completed. If all is complete, the user can generate a single PDF file of all the documents that were completed. At this point, the agreement assembly is forwarded to the TxDOT district official for review. The assembly is also locked and cannot be further edited by the utility user until the TxDOT official completes a full review of the assembly document.

Figure 51. Agreement Business Area.

Reports Business Area

The Reports Business Area allows TxDOT users with sufficient permissions to query UACT utility conflict data and generate reports on the fly for specific scenarios. The generated reports can be converted to PDF for easy printing and distributing. In the current version, users can create utility conflict certifications for PS&E documentation by selecting a conflict status on a drop-down menu and a target date on a calendar (Figure 52). Note: The current UACT prototype only contains a very small number of reports to demonstrate the functionality of the data model. A future implementation of UACT could greatly improve on the number of reports available to users.

Figure 52. Utility Certification Report.

Contacts Business Area

The Contacts Business Area displays TxDOT and utility contacts that are active in any of the UIR or UACT projects (Figure 53). Users can sort through TxDOT contacts by district, office type, or name. To demonstrate the functionality of UACT, the user name, e-mail address, and account status are shown. This information is linked to the UIR user database and therefore allows for sharing of existing and future users between both projects.

Figure 53. Contacts Screen.

Other Resources Business Area

The Other Resources Business Area is intended to provide UACT users and guests information related to utility coordination and utility conflict resolution processes and regulations (Figure 54). Currently, this section includes links to several business process models, including the process overview diagram and the detailed process diagram. A future implementation of UACT could include user documentation, guides (such as this user guide), and links to TxDOT policies and guidelines. In an implementation version of UACT, TxDOT personnel will be able to link to other resources and add or remove resources as appropriate.

Figure 54. Other Resources Business Area.

Administration Section

The Administration section provides an interface to authorized TxDOT personnel as well as the UACT system administrator to administrate the UACT system. These tasks include managing users (such as adding, editing their profile), managing access control (permissions that are assigned to users), and other miscellaneous tasks such as changing the theme of the website. Administrators of a specific role can add and remove users within their respective roles, among other administrative tasks. Note: Only users with administrative privilege or a system administrator may access the Administration interface.

The current version of UACT includes two business areas in the Administrative section: "Users" and "Access Control." These business areas demonstrate only a portion of the functionality that can be provided by the fully implemented administrative system.

Users Business Area

The Users Business Area of UACT is divided into listing existing users and detailed information in addition to adding new users. Only a system administrator or a user with "administrator" privilege can access this area, and the interface changes depending on the type of user.

Users from TxDOT as well as utility companies can be added by making the appropriate choice at the Add User form. For each user, UACT requires information about the affiliated company as well as the office in which the user resides. It is assumed that the first user creating a new office entry in the database will act as the administrator for that office and all future administrative tasks will be assigned to this user. Other information such as contact information and password are also provided here. On the next screen, the role and privilege level of the user can be selected. In addition to selecting a role and privilege, a set of permissions must be assigned to the user for full use of the account. To save time and effort, UACT provides a mechanism to the system administrator to establish default permissions that can be assigned under "Access Control." Once assigned, each newly added user receives the default set of

permissions unless permissions are modified by the administrator of the respective role or a system administrator. A confirmation screen provides a summary of all information entered. Once a user is added, the account is immediately available for use.

Access Control Business Area

The basic unit of control in UACT is a "capability." Combined with different "business areas" of the website, a permission is created, which can be assigned to a user. UACT determines functionality and interface depending on these permissions. For example, a user can have "project documents view" permission, which would allow the user to list and view details about a project document, but unless an "edit" permission is assigned, the user may not modify any of these files. This interface is strictly designed for a system administrator. The access control section is further divided into three categories as follows:

- **Permission**. Allows the system administrator to add or remove permissions as new web pages are created in UACT.

- **Default Permissions**. Allows a system administrator to associate default permissions with a role. Default permissions save time specifying permission for a new user that is added to the system.

- **Default Privilege Permissions**. Allows a system administrator to assign permissions to each privilege within a role.

New permissions can be created in the Permissions section. The matrix lists capabilities horizontally and the business area sections vertically. Adding a permission is as simple as checking the box corresponding to the correct capability and business area section. New capabilities and business areas can be added by inserting additional rows into the appropriate tables of the UACT database. The next tab allows the system administrator to associate the previously added permissions with specific roles. For each role, a different set of permissions can be created. The process is similar to adding permissions where a role must be selected first, followed by checking the appropriate checkboxes. The third tab associates the role permissions with a specific privilege for each role. This can be completed by selecting the desired role and privilege from the drop-down list and checking the desired boxes under the permission matrix. For all three steps, clicking "Save" makes the changes immediately available throughout the system. For more information on capabilities and permissions, refer to the Permissions Subject Area discussion in Chapter 5 of the UACT user guide.

TESTING AND USER FEEDBACK

The researchers used two servers for development and testing/demonstration purposes. The research team used the demonstration site to give presentations of the prototype to project stakeholders and let users try out features of UACT. The research team used the development site of the prototype to incorporate suggested changes to the system and develop new features. Once new features or changes became stable enough for further testing, the researchers updated

the demonstration site. For an implementation of this prototype, the researchers recommend to maintain this approach as it aids in the development process by allowing developers to work on different portions of the website without interference from users. It also ensures minimum quality standards as any new feature must pass a quality control process before it becomes available on the demonstration site.

Feedback from Stakeholders on UACT Prototype

The researchers met with representatives of the following stakeholder groups to gather feedback on the prototype:

- TxDOT District Officials: Amarillo, Austin, Corpus Christi, Dallas, Houston, Odessa, and San Antonio.

- TxDOT Right of Way (ROW) Division.

- Other stakeholders, including utility companies and utility consultants.

The researchers also contacted representatives from the Bryan and Tyler districts and conducted several conference calls. The researchers visited most of the district multiple times and collected feedback at various stages of the prototype development. Feedback from stakeholders on the first year (alpha) version of the prototype is summarized in the first-year report. This section of the report covers only meetings with stakeholders that provided feedback on the beta version of the prototype described in this chapter.

Utility stakeholders had very positive comments about the prototype and were looking forward to the implementation of the system. Many stakeholder comments suggested improvements that the researchers were able to include in the prototype development. There were also several suggestions that did not immediately affect the UACT data architecture and should be considered in the implementation phase of this prototype. The following provides a summary of the comments and suggestions the research team received during the presentation of the UACT prototype to the various stakeholders that should be considered during an implementation phase.

Project Business Area

- **Project Import.** The Houston District has a system in place to download DCIS data and filter/restructure the data for their needs. A future implementation of UACT may be able to take advantage of that data connector. In addition, UACT should provide further options/search fields to add DCIS project data as projects to UACT, e.g., funding/dollar amounts, and other categories. It may be useful to provide a mechanism that filters out projects without conflicts before searching DCIS data for import into UACT, e.g., by filtering projects that do not have a right of way CSJ. There should also be an option to disassociate a project from UACT.

- **Project Manager.** Use and significance of the project manager field was unclear to some stakeholders. Users may associate this field with the person who is in charge of the project and not the utility manager. An option would be to include additional fields that show the person (or persons) who are in charge of the utility adjustments. In this case, it might be advantageous to distinguish between reimbursable and non-reimbursable adjustments because in many districts, different people within the Right of Way Section handle reimbursable versus non-reimbursable adjustments.

- **Project Stakeholders.** It would be very useful to have a scheduling feature for coordination meetings with stakeholders. From the list of project stakeholders, the user could select meeting participants and send them an email with a link to additional information in UACT.

Utility Inventory Business Area

- **Import Utility Facilities.** For both options "Import" and "Add," the system could include a mechanism to select a utility facility using a mapping component. This could be a more efficient mechanism to select utility facilities than using a table, although a tabular view would also be needed to provide attribute data. The utility inventory should also be populated using an existing database (from previous projects) or using a SUE deliverable for the current project (e.g., in MicroStation format.)

Conflict Tracking Business Area

- **Conflict Notes.** Stakeholders liked the idea of being able to attach notes to conflicts and suggested to tie these notes to email. Stakeholders considered it critical to keep a repository of notes for documentation purposes, particularly because there might a long time between communications with utility companies (e.g., six months.) Conflict notes would be very useful for TxDOT internal purposes and could be used to measure progress. If the notes tool would be accessible outside of TxDOT, it would need to be monitored with the ability to edit notes or hide notes as required. District officials commented that all stakeholders, including utility companies, should have read-only access to the notes. If users external to TxDOT would have access, conflict notes could be expanded to include a field "reply by date." Stakeholders also recommended evaluating a move of the conflict notes from the conflict level to the project level.

  The San Antonio District Right of Way Section uses GroupWise (i.e., the task tool) extensively to log every single phone call, email, meeting, etc. that happens with each individual utility. A nice feature about this tool is the ability to include reminders. When the Right of Way Section receives requests for a project status, the Right of Way Section prints a view from the task tool and forwards the printout. The Right of Way Section identified some limitations with this current process, namely that the task tool apparently limits the number of entries and the number of columns. The conflict notes could be an option to replace the limitations in the current process.

- **Conflict Type.** Stakeholders questioned whether it was necessary to have the fourth conflict type "Conflict with Safety Regulations," since the UAR already contains safety provisions. At a practical level, a safety violation might be the result of a conflict with, say, a highway feature. It appears that "Conflict with Safety Regulations" could result in confusion since users would not necessarily know how to separate "safety" issues from other issues.

- **Conflict Location.** District officials pointed out that the number of conflicts per project may be substantial. It may be advisable to provide an additional location indicator such as north, south, east, and west from a central project location for offsets of conflicts, instead of defining positive and negative offsets.

- **Association of Conflicts with Utility Companies.** District officials commented that one conflict should only be associated with one utility owner. That way, utility conflicts could be easily associated with utility agreements. If the system would allow one conflict to consist of multiple utility facilities with different utility owners, the association with utility agreements would become very complex and cumbersome to track. UACT's data model currently provides complete flexibility with the association of conflicts with utility companies through a many-to-many relationship. This relationship is only limited through the system code to a one-to-one relationship.

Agreement Business Area

- **Association of Conflicts with Agreements.** District officials commented it would be confusing and inadvisable to allow one conflict to be handled partially in more than one utility agreement assembly. If one conflict would need to be handled by two agreements, it would be advisable to split the conflict into two or more conflicts.

- **Submittal of Utility Agreement Assemblies.** The San Antonio Right of Way Section currently marks up the first submittal of the utility agreement assembly that utilities submit in PDF, along with a bulleted list in Microsoft Word that lists the required edits. It would be a good idea to include a feature that will allow a creation of this bulleted list.

- **Help with Utility Agreement Assemblies.** District officials suggested it would be very helpful to have a portion of the screen dedicated to providing help in each step including links to TxDOT manual excerpts and other resources as necessary. Another option would be to have pop-up help boxes when the user hovers over certain areas of the interface. The prototype has a dedicated area for the help system and provides a structure and format for the help content.

- **Attachment B (Method of Cost Accounting.)** Under the actual cost option, it may be useful to include options for category-based (labor, materials, etc.) and unit cost accounting.

- **Attachment C (Schedule of Work.)** The duration specified in Attachment C should be counted in days (not weeks) and there should be an option as to whether the days are based on workdays or calendar days. The system could include automatic checks and balances for the dates provided, e.g., provide a warning if the adjustment date is 30 days before letting or later, or if too little time is allowed between development of the agreement and the start of utility work. The system could also provide a warning if the utility adjustment start date is less than 30 days calculated from the date the agreement is being compiled, and display warning message such as "Do no physical adjustments without a signed and executed copy of this utility agreement."

- **Attachment D (Statement Covering Contract Work.)** The person logged in and preparing the utility agreement assembly is not necessarily the same as the one who has authority to sign the agreement. For Attachment D it may be best to have a text field to enable utility companies to enter any name they want. Some districts use a form where utility companies designate specific people with signature authority. An option would be to implement an electronic version of the form where utility companies register and designate certain users to have signature authority.

- **Attachment G (Betterment Calculation.)** This attachment should include a warning concerning financial calculations that utilities should not round numbers and should provide two decimal places for all cost items.

- **Attachment H (Proof of Property Interest.)** The system should determine if a project is located on an interstate highway, since proof of property interest is not required on interstate projects, which would allow the user to skip Attachment H. If proof of property interest is required, the user should be lead through a process to determine the type of required document, which should include fee simple interest, license agreements (for railroad agreement – courthouse document, deed, parcel plan, property description, title information), easements (legal document for easements), change of ownership (ownership documents being passed down to the current facility in place), prescriptive rights (undocumented, user can fill out affidavits), and disinterested third parties who have knowledge about a specific property right.

- **Joint Use Acknowledgements.** Although utilities only have to have this form completed prior to billing, it makes sense to sign this document at assembly preparation time to avoid any delays later.

- **Additional Clarification Sheets.** District officials suggested that utility companies should be able to add clarification sheets to specific forms or attachments to clarify circumstances of the adjustment as needed. District officials suggested that utility companies should upload clarifications along with each attachment instead of uploading clarifications in a general area or as an appendix.

- **Archiving of Utility Agreement Documents.** District officials commented that as a general suggestion it would be a tremendous improvement over current business process if UACT could provide the functionality to archive scanned versions of the signed utility

agreement documents. As an example, there could be a feature to upload signed and scanned documents for archival after closeout of the agreement.

- **Tracking of Additional Documentation.** If the utility facility is identified but not in conflict, the district requires a Utility Joint Use Acknowledgement, Plan-and-Profile of the installation, and a Statement of No Conflict. Further, if the utility is in conflict but moves within the right of way lines, the district requires a Utility Joint Use Acknowledgement, Plans-and-Profile of the installation, but no cost estimate because the utility pays for the adjustment. However, the district often does not receive either documentation. UACT could help the district track these documents and ensure that the district receives them.

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

The focus of the research project was utility data exchange in the project development process and the development of a prototype utility conflict data management system. This research analyzed the specific information flows and data needs to determine a business process model that was transformed into data models for the development of the prototype. The research performed an analysis of utility conflict data/information flows between utility accommodation stakeholders in the TxDOT project development process, developed data models to accommodate work and data flows between such stakeholders, and developed a prototype system for the management of utility conflict data. In summary, the main contributions of this research project are as follows:

- An expanded model of the TxDOT utility coordination process integrated with the project development process.
- Identification and/or confirmation of major utility coordination issues.
- Identification of requirements for a utility data management system.
- Data model and data dictionary of a utility data management system.
- An architecture to track utility conflicts and manage utility conflict data.
- A flexible and scalable proof-of-concept prototype called Utility Accommodation and Conflict Tracker (UACT).

CONCLUSIONS

The following is a list that summarizes the main findings of the research team that led to the development of data models and a prototype system for the management of utility conflict data:

- The utility coordination process creates a huge amount of data that involves a tremendous amount of coordination between a multitude of stakeholders.

- Detailed information of the utility coordination process is often undocumented, and resides with a large group of stakeholders that must be interviewed to obtain the information.

- The Business Process Model Notation was a more effective notation to obtain feedback from stakeholders about business processes, as compared to the IDEF notation.

- The review of TxDOT manuals revealed that, for the most part, it is difficult to relate tasks and activities across manuals. TxDOT manuals do not share a common system to arrange or label tasks and activities, and occasionally, there are significant differences between descriptions of the same activity in different manuals.

- A shortage of information on sequence and dependencies of tasks is a limitation of the PDP Manual's general usefulness and for its use to develop a business process model.

- A significant amount of utility information is either lost in the current process, too difficult to access, or not effectively shared.

- Notifications to Right of Way Sections about upcoming projects are critical to avoid process delays within TxDOT, but notifications are not always provided.

- Districts perceive the use of SUE as an overall effective mechanism to locate utilities that are only limited by funds available for SUE. However, even SUE occasionally misses utilities made of clay-tile or other materials that are not easily detectable using SUE techniques.

- Local involvement in utility coordination activities can be a challenge for TxDOT, especially when an LPA initially takes the lead in the utility coordination but then turns the lead over to TxDOT due to an underestimation of the process complexity.

- Minor project features such as sidewalks and bike trails can become major issues if they are only afterthoughts and not addressed early in the process.

- Districts have adopted local procedures and implemented local systems to deal with utility coordination issues. Local district procedures can contribute to the complexity of the utility coordination process.

- Databases and systems currently in use at TxDOT do not effectively support the utility coordination process, which creates a need for the modification of existing systems or creation of a new system such as UACT to provide essential support.

ANTICIPATED BENEFITS OF UACT

UACT provides a number of benefits to the project development process. The research team expects that an implementation of the prototype will translate into significant cost and resource savings for TxDOT. UACT represents a prototype that was created to test the main functionality of the data model produced by this research. Using UACT, the research team was able to implement and test most of the following benefits, whereas others are supported by the data model and should become part of a full UACT implementation. The following are some of the expected benefits of an implementation of the UACT prototype:

- **Web-based access to project and utility coordination data through Internet or mobile devices.** Because of the web-based system architecture, users with Internet access could retrieve project data and utility coordination data such as utility conflict status or utility agreement assembly status at any time. For example, a utility could retrieve information about upcoming utility coordination meetings, important project dates, project plans and specifications, or could check on the status of a recently submitted utility agreement assembly. A utility might also check the list of project stakeholders and retrieve a stakeholder's contact information. With the required authority, a utility might also add a recently discovered utility conflict to the utility

conflict tracking list using a mobile Internet device. In addition to these activities, a TxDOT user could set up utility coordination meetings and send notifications to all stakeholders. A TxDOT user could also review electronic versions of utility agreement assemblies and notify the utility or other TxDOT users about potential problems. In addition, a TxDOT user could create on-the-fly management reports such as a utility conflict status report using automated queries of the UACT database.

- **Improved access to project and right of way data through integration with existing systems.** The UACT data architecture provides for a data connection to DCIS and ROWIS. Because of the legacy database structure of DCIS, data from DCIS are stored in a data warehouse located in a separate table space. ROWIS is based on a relational database, which would allow a closer integration of the two systems. However, in contrast to UACT, both ROWIS and DCIS do not provide web-based access.

- **Elimination of redundant data entry and quality control of DCIS project data in UACT and ROWIS.** Because of the legacy database structure of DCIS, there is currently no direct system link between DCIS and ROWIS. As a result, project data, including critical data elements such as construction CSJ and right of way CSJ, are entered manually into ROWIS. Although there are some review policies in place, occasionally, data inconsistencies appear between ROWIS and DCIS. Inconsistencies can be the result of dual data entry, although most of the inconsistencies appear to be caused by updates in DCIS that are not communicated to the ROWIS system administrator. An implementation of UACT could take advantage of the DCIS data warehouse and allow ROWIS to reference the project data instead of re-entering the data. In addition, UACT could include quality control measures that would alert users to changes in the DCIS data.

- **Integration with utility facility database and UIR.** UACT integrates seamlessly with the data architecture for a GIS-based utility facility database. The implementation of such an inventory of utility facilities could therefore occur concurrent with the implementation of UACT. Further, UACT's data model shares the user administration with the UIR system, which would allow the addition of UACT as a module under UIR or access to both UIR and UACT under a third umbrella application. The umbrella application could be ROWIS or a completely separate application that unifies web-based, GAIP-compatible applications at the ROW Division.

- **Reduced time and cost to produce and process utility agreement assemblies.** Utility agreement assemblies provide the required documentation that allows TxDOT to reimburse certain utility adjustments. These assemblies are time consuming for utility companies to prepare, and are frequently in the way of a timely utility adjustment. TxDOT districts spend considerable resources negotiating and coordinating the completion of these documents. UACT enables the completion of documentation required for the reimbursement of utility facilities, i.e., utility agreement assemblies using an online interface. As of this writing, the research team is not aware of any other state agency that has a working system that would be equally advanced.

- **Further standardization of utility agreement assemblies and reduced need for TxDOT assistance.** For the most part, utility agreements use standard forms that are in statewide use. However, utilities do not always fill out the forms consistently or know which forms are required in a particular case. A good example is the determination of reimbursement eligibility on non-interstate highways, which due to its complexity requires TxDOT assistance in almost all cases. As a result, TxDOT district and division personnel assist frequently with the completion of forms or prepare attachments for utility companies. UACT could determine the required forms based on project data and a user questionnaire, and in combination with a context-sensitive help system could automate the completion of forms in most cases. This would greatly reduce if not eliminate the assistance required by district personnel. UACT would also standardize all user-uploaded documents to an 11 by 17 PDF, which would assist districts with the review of utility agreement assemblies.

- **Standardization of utility certifications for PS&E documentation.** Districts provided several copies of utility certifications that list known utility conflicts that have an estimated adjustment date after the letting date. Districts provide these certification lists and add them to PS&E documentation as special provisions to alert the bidding contractor to potential issues and avoid damages and liability caused by utility delays. The researchers found that there is currently no unified format for these utility certifications: Samples that the research team collected from several districts had unique structure and content. UACT could provide a single format suitable for use at all districts that would unify the format of utility certifications statewide.

- **Visualization of utility conflict locations.** An integral part of UACT is a GIS module using ESRI ArcGIS and ArcSDE software that allows the creation of utility conflict outlines using a standard web browser with Internet connection. Users do not need to purchase special software or download plug-ins to create or modify utility conflict outlines. The module presents an outline in the form of a semi-transparent rectangle that a user can overlay over a utility facility. Utility conflict outlines can be displayed on maps and associated attribute data can be queried.

- **Reporting tools to monitor project status and performance.** All transactions in UACT are stored in a database that facilitates the creation of a variety of status reports. UACT provides a report section that is designed for custom reports based on user input. In its current version, UACT includes one report, the utility certification report, that can be added as a special provision to PS&E documentation. To create the report, UACT selects all utility conflict records with both an estimated adjustment date after the letting date and either a possible or confirmed conflict status. An implementation of UACT could take full advantage of the database potential by expanding the current reporting interface to allow users to create custom queries and management reports.

- **Tracking features to provide accountability for actions compliant with Texas law.** UACT allows the tracking of important notifications and document transmissions for utility adjustments that can be used to demonstrate compliance with state law (*61*). For example, the tracking feature creates a record when TxDOT notifies utilities about a

conflict and when TxDOT transmits to the utility documents sufficient to proceed with the adjustment. This data can be used to create reports that could be used in cases where TxDOT would need to demonstrate compliance with Texas law or when TxDOT's actions would be in question in a court of law.

- **More effective utility coordination and improved relations with utilities.** Based on feedback from stakeholders, the research team expects that many of the benefits outlined above will translate into a reduced need for TxDOT district personnel to spend time and resources on utility coordination activities. This expectation is supported by the following:

  - UACT significantly improves the transparency of the utility coordination process,
  - UACT simplifies many activities of the utility coordination process such as the creation of utility agreement assemblies,
  - UACT reduces the amount of time to create and process utility coordination documents,
  - UACT empowers utilities to do their part in the process while reducing the amount of resources that TxDOT needs to spend assisting utilities, and
  - UACT significantly improves access to project, right of way, and utility data.

  The researchers also expect that these improvements, which demonstrate TxDOT's dedication to national leadership and innovative solutions for utility issues, will result in improved relations with utility companies.

- **Potential for significant cost savings and reduced utility delay during construction.** During several interviews, TxDOT district officials repeatedly emphasized the need for a utility conflict management system. At this point, the impact of utility delays on project costs could not be established but is subject to ongoing TxDOT research. However, anecdotal evidence based on assessments of TxDOT district officials allows an optimistic outlook on the expected return on investment of a UACT implementation, to a degree that the investment would have the potential to pay for itself after a few projects.

RECOMMENDATIONS

The following section summarizes recommendations of the research team for further investigation or implementation of research products. For convenience, there are two groups of recommendations: Recommendations related to the implementation of UACT and general recommendations intended to improve overall utility coordination practices at TxDOT.

Recommendations Related to the Implementation of UACT

To realize anticipated benefits of UACT, the research team recommends an implementation of the UACT prototype at two or three testing districts to prepare for a statewide implementation of UACT. Specifically, the research team offers the following recommendations related to the implementation of UACT:

- **Implement UACT using a multi-phase process.** The researchers recommend implementing UACT in three phases: Phase one would consist of a field test that would enable users of the TxDOT ROW Division and one or two TxDOT districts to test the functionality of the current UACT prototype. This phase would be characterized by heavy interaction between the project team and several stakeholders at the test implementation districts, including TxDOT district officials, utility owners, utility consultants, and TxDOT officials at the TxDOT ROW Division and TSD. Testing of the prototype would be accomplished using real project data of one or two projects in each testing district. Phase one should include preparation and conducting of tests at two TxDOT districts using testing servers external to TxDOT, and preparation of the transition of UACT to TxDOT servers.

  Phase two would start about six months before the completion of phase one, would prepare a statewide UACT implementation plan, and transition the UACT system from testing servers to TxDOT servers. This phase would start at the conclusion of the testing phase and open up testing to three or four additional districts and result in a production version of the UACT system.

  Phase three would start at the conclusion of phase two and consist of a statewide UACT implementation including system maintenance activities after the system transition training of system users including workshops, and expansion of the system to additional TxDOT districts.

- **Use UACT to upgrade TxDOT ROW Division Utility Agreement Database.** The TxDOT ROW Division uses an ad-hoc database system to monitor and track billings and payments for utility agreements. The researchers analyzed this database, created a normalized data model of the database, and made several improvements to the data model based on feedback from stakeholders. The researchers integrated the improved version of the data model into UACT. As a result, the UACT data model is capable to provide the functionality of the current Utility Agreement Database while providing significant productivity gains through integration with other utility coordination processes. An implementation of UACT would require the programming of additional user interfaces to take advantage of the full potential of the current UACT data model. The plan for implementation of UACT should account for the programming of these interfaces and a transition period after which the current Utility Agreement Database would become obsolete.

- **Replace current utility coordination support systems used at TxDOT districts with UACT.** In absence of a statewide system to support utility coordination activities, many districts have developed ad-hoc utility tracking systems. In general, these systems are detached from other core databases such as ROWIS and DCIS, i.e., they cannot share existing data, which requires duplicate data entry (redundancy) and may lead to data inconsistencies. Since districts rarely, if at all, share resources for development, maintenance, and upgrades of these systems, district resources are extremely limited, which becomes apparent in the ad-hoc database structures that lack formal and robust data models and may not be compliant with TSD data requirements. By comparison, the

research team designed UACT from the ground up following TSD recommendations and requirements, integrating recommendations from districts for system features they were unable to include in the systems due to lack of resources. The implementation of UACT would result in a significant improvement of management activities for utility coordination and provide a unified approach for utility coordination stakeholders.

- **Integrate UACT with UIR system.** The data model for UACT includes a section for user management that to a large degree uses the data structure developed in the UIR system (*47*). During the development of UACT, the research team essentially used the UIR's data structure for user management to ensure that a future implementation of UACT could be integrated with UIR. The researchers' vision was to develop UACT as an application that could be integrated with UIR either as part of UIR or as a module of a larger umbrella application. However, the system requirements for UACT resulted in some changes to the user tables that the researchers imported from the UIR data model. An implementation of UACT that is fully integrated with UIR would require some, although minor, changes to the production version of UIR, including some additional fields, changes to existing field names, changes to datatypes, and possibly changes to foreign key constraints.

- **Incorporate construction specification and unit cost framework for utility installations into UACT.** Project 0-4998 developed a prototype framework for utility adjustment specifications and unit costs to provide consistency with TxDOT's highway construction unit cost structure and standard construction specifications (*62*). The prototype framework supports current federal and state laws and regulations concerning utility reimbursement requirements, and supports the development of utility adjustment cost estimates at various stages in the utility adjustment process. An implementation of UACT should review how the products of project 0-4998 could be incorporated into the UACT system.

- **Integrate Utility Facility Database into UACT.** Project 0-2110 developed a prototype inventory model for utility installations that was refined in project 5-2110-01 and tested using a UFD (*46*). The UACT data model incorporated a portion of the 5-2110-01 data model, specifically tables from the Communication, Electric, and Water Subject Areas, to ensure compatibility of the UACT data model with an implementation of the UFD. An implementation of UACT should include the implementation of the UFD, which could occur at any of the following three suggested levels:

  o Level one represents the researchers minimum recommended degree of UFD implementation and integration between UFD and UACT with the least amount of effort required by the implementing agency. This level would require that the current UACT data model would be modified to include all 58 utility facility tables of the 5-2110-01 data model. These tables would remain non-spatial, i.e., they would not provide a spatial representation of the feature that could be queried and displayed in a GIS environment. In addition, the UACT code would need to be modified so that a user could create conflict outlines first, before creating utility facilities that would be used primarily to track utility conflicts.

The utility facility records would therefore primarily support the business process of managing utility conflicts and utility accommodation activities. The utility facility attribution could accordingly be limited to a minimum with a high level of utility facility aggregation.

o   Level two would require a slightly higher amount of effort to implement UFD and integrate the database with UACT, as compared to level one. Level two would provide the ability to store utility facilities as feature classes that could be used to query and display the facility data in a GIS, and support the entire utility facility attribution and spatial aggregation of the data model developed by 5-2110-01. The implementation should also provide the ability for users to upload and convert utility facility data. As part of this effort, there would be a need to develop data upload standards and specifications. Further, it would be necessary to develop and code interfaces for utility facility data manipulation. The implementation should also consider providing the ability to extract data from uploaded utility facilities, e.g., using a GIS mapping interface, and include a task that would focus on the testing of the data implementation and interfaces.

o   Level three would be the most comprehensive implementation of the UFD and integration with UACT, and is the level that the research team recommends. This level would include a modification of the existing 5-2110-01 data model as the need arises during the implementation and creation of a physical data model for the Oracle DBMS. The data model should be implemented for testing purposes on servers external to TxDOT and provide ability for users to upload and convert utility data. Similar to level two, level three would develop data upload standards and program interfaces for data manipulation, followed by a period of testing of database and interfaces. After successful testing, the database should be transitioned to TxDOT servers.

- **Update ROWIS to improve utility coordination efficiency**. The main purpose of ROWIS is to provide a tool to manage data of the right of way acquisition process. Over time, ROWIS has taken on additional responsibilities that its initial design did not include. For example, the ROW Division uses ROWIS to track utility agreements, since no other system exists to track this information. However, ROW Division officials can only track utility agreements by creating a right of way parcel to represent the agreement. As a result, important agreement information cannot be tracked for lack of attribution, or must be tracked in a separate database such as the Utility Agreement Database. This database is not integrated or linked to ROWIS, which causes redundant data entry efforts and may cause data inconsistencies. In addition, there is currently no link to DCIS, which forces further redundant data entry and potential inconsistencies of project data in ROWIS. There are currently no quality control mechanisms in ROWIS that could verify the validity of project data in ROWIS automatically. As a result, there are occasional data inconsistencies between ROWIS and DCIS that could be avoided if automated quality control mechanisms would be in place. In addition, ROWIS is not compatible with GAIP; therefore, it cannot distribute data through MST.

An implementation of UACT would address some of the shortcomings of the current utility data management: The Utility Agreement Database could be retired, and redundant data entry between the Utility Agreement Database and ROWIS could be avoided. UACT and ROWIS would share several data items. At this point it is unclear if these data items should be entered in UACT (then ROWIS would link to the data) or in ROWIS (then UACT would link to the data). Although either way would be feasible, it may be advantageous to consider entering the shared data elements (and possibly other such as project data) through UACT. The benefits of that implementation strategy would be that UACT should be able to link to DCIS data and provide quality control mechanisms when updates to the data occur. If TxDOT would pursue this implementation strategy, some changes to ROWIS would be required to provide adequate integration with UACT.

Although ROWIS and UACT could be implemented separately, UACT (and possibly UIR) could become part of ROWIS as extension or add-on modules. This implementation alternative would obviously require the most changes to ROWIS. The question of the most suitable implementation alternative would need to be addressed during the implementation of UACT.

- **Continue involvement of utility companies and other stakeholders during the UACT implementation process.** The research team met multiple times with utility companies and other stakeholders during development of the prototype, which resulted in the implementation of several recommendations into the prototype. The continued involvement of utility companies and other stakeholders during the implementation process will be critical to a successful implementation of UACT. Most likely, this effort would include workshops for a limited number of stakeholders at the beginning of the implementation project to gather feedback, followed by training workshops open to all stakeholders at the conclusion of the implementation.

- **Consider utilities participating in prepayment funding agreements in UACT implementation.** This project provided a business process model for recent changes to the UAR related to participation of utilities in utility relocation prepayment funding agreements, as authorized by SB 1209 (*55*). The development of the UACT prototype did not develop interfaces that specifically address this alternative reimbursement method since TxDOT did not anticipate a great demand for the program in the near future. The implementation of UACT should investigate if that assessment remains correct in the future or otherwise include additional interfaces to include the reimbursement of utilities under SB 1209.

- **Consider the use of electronic signatures.** The UACT prototype provides the ability to create a complete electronic version of a utility agreement assembly but requires that a utility submit the final version of a utility agreement assembly in paper format. This requirement is in place because of the need for signatures of both parties that enter into a contract that may involve substantial financial resources. A future implementation of the prototype may remove the requirement for a paper version if both contract parties are satisfied by electronic signatures. In that case, the process would be completely

electronic, which would result in additional time savings related to processing the agreement assembly. Use of electronic signatures would be consistent with the *Rules Concerning the Practice of Engineering and Professional Engineering Licensure* of the Texas Board of Professional Engineers that now allows professional engineers to use an electronic seal and electronic signature when sealing their work (*63*). The agency in charge of the implementation of the prototype should evaluate under which conditions the use of electronic signatures would be feasible.

General Recommendations to Improve/Optimize Utility Coordination Practices at TxDOT

If TxDOT chooses to postpone an implementation of UACT, the researchers offer the following recommendations that could be implemented independently from an implementation of UACT:

- **Develop new or update existing curricula for utility companies and new TxDOT employees using utility coordination business process model.** The TxDOT utility coordination process is a complex collection of interdependent activities subject to constant change that even few people at TxDOT fully understand. Utility companies and other process stakeholders often struggle with the federal and statutory provisions of the process, which can lead to substantial delays in the process. There is need to provide guidance to process stakeholders, which would improve the process for all process stakeholders. The Texas Engineering Extension developed materials that provide an overview of utility coordination activities, important statutes, utility accommodation rules, and related documentation (*64*). The most current version of this document available to the researchers was from April 2001. As a result, many laws and procedures discussed in the document are outdated. The researchers recommend that TxDOT update this document or use it as a starting point to develop new curricula that would include the business process model and task listing developed by this research.

  The business process model provides a view of activities related to utility-focused right of way coordination in the project development process. The business process model uses the BPMN notation that stakeholders found easy to follow and understand. TxDOT could use the business process model to advance stakeholder understanding of the TxDOT utility coordination process, including utility company officials and new TxDOT employees. In combination with the overview diagram, TxDOT could develop an online viewer of the business process model as a reference tool. At the lowest level, TxDOT could provide a direct link from an activity box to a detailed activity description. As part of the effort, there would be a need to develop several detailed activity descriptions for new activities that the researchers identified in the research effort that do not have a corresponding descriptions in a current TxDOT manual.

- **Develop and publish a guideline that describes the utility coordination process for use by utility companies and other stakeholders and update the utility manual.** The research team found that frequently, utility companies and other stakeholders have difficulty understanding the requirements of the TxDOT utility coordination process. Although several TxDOT manuals provide significant information on the process, including descriptions of the utility cooperative management process in the Utility Manual and related task descriptions in the Project Development Process Manual, this

information is not provided in an easily accessible format and is nested within other information that may not be directly related to utility coordination activities. There is a need to develop a guideline that would summarize and highlight the utility coordination process from the perspective of stakeholders outside of TxDOT in a concise and easy-to-understand format. The guideline should be in a very short format (only a few pages plus diagrams) that provides an overview to stakeholders that are unfamiliar with the process and could provide references to additional information in the utility manual. The guideline could also include a link to the Utility Accommodation Rules. In addition, TxDOT should update the utility manual to include the updated business process model produced by this research.

- **Harmonize task descriptions in specialized TxDOT manuals and references in the TxDOT PDP Manual.** In its current structure, the TxDOT PDP Manual provides an overview of the project development process at a high level in a structured format that assigns codes to the major tasks of the process. In order to keep the volume of the TxDOT PDP Manual manageable, it does not present the level of detail that other specialized manuals (e.g., Utility Manual, Environmental Manual, and PS&E Preparation Manual) provide but instead references manuals where appropriate. Likewise, there are references from specialized manuals to the PDP Manual. Although references exist, they tend to be non-specific. For example, every task in Chapter 3 of the PDP Manual contains a reference to the Environmental Manual, but no chapter or section reference. There is no common system among manuals to arrange tasks and activities that the manuals describe, and there is further no common labeling system for tasks. As a result, it is difficult to relate tasks and activities across manuals. The researchers also found that the lack of coordination between the PDP Manual and specialized manuals can produce significant differences in task descriptions. This situation could be improved significantly if TxDOT would adopt a common task labeling system for all manuals. For example, the authors of the specialized manuals could reference PDP task codes, which in turn would help the authors of the PDP Manual to provide useful references. In this way, the PDP Manual could serve as an umbrella manual and useful starting point for insight into the project development process.

- **Evaluate feasibility to accelerate aerial utility adjustments on leased poles.** The current practice of adjusting aerial utility installations on leased poles follows a hierarchy that may cause unneeded delays. TxDOT should consider technical and/or regulatory strategies to assess if it is feasible to request or require utility companies that own the poles to allow utilities that lease the poles to move their lines as soon as they are capable. A technical strategy could be to provide slots on the poles that could be assigned to utilities for installation of their facilities. A regulatory strategy could be to strengthen the UAR to include text that would encourage owners of utility poles to accelerate the adjustment process.

In closing, it may be worth mentioning that TxDOT district officials had very positive comments about the prototype and were very supportive of an implementation of the system. The general perception was that the UACT system would have a great potential for significant cost savings, reduced need for utility coordination, and improved relationship with utilities. The system has

also generated interest from several out-of-state agencies that have recognized TxDOT's national leadership in utility management initiatives and the potential value of integrated utility data management.

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APPENDIX A. UTILITY SURVEY

UTILITY INTERVIEW

Provide company name, employee name, and date.

General Questions

1. Briefly describe your job.
2. Briefly describe your role in the utility coordination management process and/or project development process.
3. At what point in a TxDOT project do you get involved?
   - What determines when you get involved?
   - Do you think there is value for utilities to get involved at the schematic/preliminary design phase?
4. When do you typically sign the utility agreement or Utility Joint Use Acknowledgement?
   - What do you need to complete these agreements?

Utilities and Utility Conflicts

5. What interaction do you have with TxDOT?
6. Do you produce as-built plans for TxDOT?
   - For what projects?
   - Are there format requirements?
   - How are they submitted?
7. What format do you use for utility location data?
8. Are you involved in detecting utility conflicts?
   - How are they detected?
   - How do you resolve utility conflicts, and what steps are taken?
   - Do you use SUE (subsurface utility engineering) to locate utilities? If yes,
     i. At what quality level (A, B, C, or D)
     ii. What determines what quality level you use?
9. Do you use a database or other software system to track utility conflicts?
10. What kind of obstacles and issues do you face when dealing with TxDOT?
11. If TxDOT would develop an online system to exchange data with utilities and track utility conflicts, what would be critical elements of that system to you?

APPENDIX B. LIST OF ACTIVITIES IN THE DETAILED BUSINESS PROCESS MODEL

LIST OF ACTIVITIES BY ACTIVITY GROUP

1.1 Project Programming and Funding

Activity Code	Activity Name	PDP Code	UM Code	Document
1.1.1	Place project in TIP	1640		
1.1.2	Annual UTP			UTP project listing
1.1.3	Develop STIP	1650		STIP project listing
1.1.4	Perform site visit	1010		
1.1.5	Obtain input from local entities and others	1320		
1.1.5.1	Contact local entities			Local entity notes
1.1.5.2	Develop utility-friendly project list			Utility-friendly project list
1.1.5.3	Invite utilities and ROW staff			
1.1.5.4	Annual (Utility) meeting		PA 1	Utility-friendly project list
1.1.5.4.1	Discuss STIP with utilities			
1.1.5.4.2	Provide STIP project listing chronologically by letting date			
1.1.6	Prepare cost estimate	1200		
1.1.6.1	Prepare construction cost estimate			Construction Cost Estimate
1.1.6.2	Prepare right of way and eligible utility reimbursement cost estimate			ROW Cost Estimate ROW-RM-1
1.1.6.3	Enter project data into DCIS using 900 series (temporary) CSJ number			
1.1.7	Prepare and execute AFAs	1610		Advance Funding Agreement
1.1.8	Identify potential design/construction funding	1600		

1.2 Obtain PLAN Authorization

Activity Code	Activity Name	PDP Code	UM Code	Document
1.2.1	Obtain approval of PLAN authority	1230		(Construction) CSJ Number
1.2.1.1	Replace 900 series with valid CSJ number from TP&P			
1.2.2	Obtain project specific minute order, if required	1235		Minute Order

1.3 Assign ROW-CSJ

Activity Code	Activity Name	PDP Code	UM Code	Document
1.3.1	Assign ROW-CSJ			ROW-CSJ Number

1.4 Obtain DEVELOP Authorization

Activity Code	Activity Name	PDP Code	UM Code	Document
1.4.1	Obtain DEVELOP authority	1620		
1.4.1.1	Send ranked project listing to TP&P			Ranked project listing
1.4.1.2	Select projects for DEVELOP authorization			
1.4.1.3	Forward project listing to Transportation Commission			
1.4.1.4	Approve projects through Minute Orders			Minute Order

1.5 Obtain CONSTRUCT Authorization

Activity Code	Activity Name	PDP Code	UM Code	Document
1.5.1	Obtain CONSTRUCT authority	1630		
1.5.1.1	Send ranked project listing to TP&P			Ranked project listing
1.5.1.2	Select projects for CONSTRUCT authorization			
1.5.1.3	Forward project listing to Transportation Commission			
1.5.1.4	Approve projects through Minute Orders			Minute Order

2.1 Data Collection and Preliminary Utility Coordination

Activity Code	Activity Name	PDP Code	UM Code	Document
2.1.1	Initial Project Notification		PA 2	
2.1.1.1	Provide preliminary project description, scope, letting schedule			
2.1.1.2	Set date for preliminary design conference			
2.1.1.3	Request block maps/markups from utilities			
2.1.1.4	Identify responsible party at utility			

2.1 Data Collection and Preliminary Utility Coordination (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
2.1.2	Conduct Design Concept Conference (Preliminary Design Conference)	2000	PA 3	Advanced Planning Risk Analysis, Partial Design Summary Report, Meeting notes
2.1.2.1	Discuss preliminary design and schedule			
2.1.2.2	Circulate Design Summary Report (DSR)			
2.1.2.3	Discuss UAR, eligibility, expected magnitude of impact			
2.1.2.4	Obtain concurrence or disagreement on DSR			
2.1.2.5	Discuss action plan for SUE			
2.1.2.6	Complete parts of Design Summary Report (DSR)			
2.1.2.7	Set date for Design Conference			
2.1.3	Conduct early coordination with stakeholders	2110		
2.1.3.1	Coordinate with district environmental coordinator			
2.1.3.2	Coordinate with roadway design engineer			
2.1.3.3	Identify possible construction methods			
2.1.3.4	Identify environmental/design constraints			
2.1.3.5	Explore design modifications and effect on natural resources			
2.1.3.6	Identify resource and regulatory agencies and stakeholders			
2.1.4	Obtain related data, plans, studies, and reports	2160		Environmental studies, Bicycle plans, As-built construction plans, Right of way maps, Bridge inventory data, Traffic signal studies, Geotechnical reports, Traffic accident data, Archived project history files, Pavement Management System data, Hydraulic reports, Automated Road Inventory diagrams, Traffic data, LPA plans
2.1.4.1	Research names of property owners			
2.1.4.2	Identify and contact individuals having relevant information			
2.1.4.3	Maintain inventory of information received			

2.1 Data Collection and Preliminary Utility Coordination (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
2.1.5	Obtain aerial photography/planimetrics/DTMs/digital orthophotography	2220		

2.2 Preliminary Design (Schematic Design)

Activity Code	Activity Name	PDP Code	UM Code	Document
2.2.1	Determine right of way and access needs	2630		
2.2.1.1	Develop plan to address identified encroachments			
2.2.2	Obtain information on existing utilities	2180		
2.2.2.1	Review recent area-wide aerial photography			
2.2.2.2	Review as-built documentation			
2.2.2.3	Provide project dimensions to utilities			
2.2.2.4	Observe utility location markers in the field and note owner's name			
2.2.2.5	Request utility location information from utilities			Project dimensions
2.2.2.6	Develop preliminary utility inventory			Preliminary utility inventory
2.2.3	Alternative selection	2300-2340		Preliminary schematic alternatives
2.2.4	Develop geometrics	2350-2380		Preferred alternative
2.2.5	Develop preferred geometric alignment	2500		Preferred geometric alignment
2.2.6	Perform hydrologic study	2610		Hydrologic study
2.2.7	Obtain approval of geometric schematic before public hearing	2880		
2.2.8	Conduct public meeting	2260		Public meeting notes
2.2.10	Review geometric schematic with stakeholders	2860		
2.2.11	Revise geometric schematic based on input from public hearing	2890		
2.2.12	Obtain approval for final geometric schematic	2920		Geometric schematic

2.3 Environmental Documentation

Activity Code	Activity Name	PDP Code	UM Code	Document
2.3.1	Prepare "Purpose and Need" statement	3240		
2.3.2	Determine public involvement needs	3010		
2.3.3	Determine type of environmental document to prepare	3210		
2.3.4	Process draft environmental document	3420		
2.3.5	Conduct public hearing	3500		Public hearing notes

2.4 Environmental Clearance

Activity Code	Activity Name	PDP Code	UM Code	Document
2.4.1	Process draft environmental document	3420		
2.4.2	Obtain environmental clearance	3600		

3.1 PS&E Development (Detailed Design)

Activity Code	Activity Name	PDP Code	UM Code	Document
3.1.1	Conduct Design Conference	5020	PA 5	Geometric schematic, Design Summary Report
3.1.2	Send latest project construction plans to all utility owners			Preliminary construction plans
3.1.3	Begin Detailed Design	5040-5160		
3.1.4	Invite utility companies to introduction meeting			
3.1.5	Introduction meeting for utilities			
3.1.6	Update potential utility conflict list			Updated potential utility conflict list
3.1.7	Update design plans			
3.1.8	Notify ROW and utility company			
3.1.9	Send updated design plans to utility company			
3.1.10	30% Design meeting		PA 6	
3.1.11	Send 30% Design plans if applicable			
3.1.12	Determine general location of storm sewer trunk lines			
3.1.13	Review data collection needs	5120		

3.1 PS&E Development (Detailed Design) (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
3.1.14	Refine hydrology study	5140		
3.1.15	Complete drainage design			
3.1.16	60% Design meeting		PA 6	
3.1.17	Request CONSTRUCT authorization			
3.1.18	90% Design meeting		PA 6	
3.1.19	Update DCIS construction and right of way estimates			

3.2 PS&E Assembly/Design Review

Activity Code	Activity Name	PDP Code	UM Code	Document
3.2.1	Prepare PS&E package	5830		General notes, Cost estimate, Certifications, Plan sheets, Project agreement, PS&E Submission Data Form 1002, Special provisions, Standard and special specifications
3.2.2	Conduct district PS&E review	5840		
3.2.3	District conducts final agreement/permit review	5855		
3.2.4	Collect outside additional funding based on advance funding agreements	5860		Final Project Cost Estimate, Advance Funding Agreements, Financial Clearance Notification
3.2.5	District performs final review of PS&E	5900		
3.2.6	Submit PS&E to Design Division	5910		

4.1 Preliminary Utility Coordination

Activity Code	Activity Name	PDP Code	UM Code	Document
4.1.1	Provide input on utility-friendly project list			Utility-friendly project list input
4.1.2	Attend annual (utility) meeting			
4.1.3	Provide support for right of way estimate			Right of way estimate support documentation
4.1.4	Attend Preliminary Design meeting			

4.2 Preliminary Right Of Way Research

Activity Code	Activity Name	PDP Code	UM Code	Document
4.2.1	Enter project info into ROWIS using Construction CSJ			
4.2.2	Request ROW-CSJ from ROW Division			ROW-RM-CSJ Request
4.2.3	Review district request			
4.2.4	Request ROW-CSJ from TP&P Division			
4.2.5	Receive ROW-CSJ from TP&P Division			ROW-CSJ Number
4.2.6	Perform preliminary right of way research	4000		
4.2.6.1	Research abutting property ownership			
4.2.6.2	Obtain old right of way maps			
4.2.6.3	Establish existing right of way limits			
4.2.6.4	Establish restrictions to state ownership (easements)			

4.3 SUE Level C and D (Visual and Records)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.3.1	Perform SUE Level D			
4.3.2	Hire SUE consultant			SUE contract, SUE work order
4.3.3	Perform SUE Level C and D			SUE deliverables
4.3.4	Update utility layout			Updated utility layout

4.4 Right Of Way Mapping Before Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.4.1	Start right of way mapping			
4.4.2	List utilities on right of way map cover sheet			
4.4.3	Update right of way map with additional utilities, if applicable			
4.4.4	Prepare right of way map	4300		
4.4.4.1	Abstract map			Geometric schematic
4.4.4.2	Preliminary map			

Activity Code	Activity Name	PDP Code	UM Code	Document
4.4.4.3	Final map			Map checklist ROW-MapCheck, Right of way map

4.4 Right Of Way Mapping Before Letting (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.4.5	Update right of way map			Map checklist ROW-MapCheck, Right of way map
4.4.6	Forward new right of way map to ROW Division			Right of way map

4.5 Obtain Right Of Way Release

Activity Code	Activity Name	PDP Code	UM Code	Document
4.5.1	Send right of way estimate update			
4.5.2	Update/refine right of way cost estimate in DCIS			
4.5.3	Approve right of way map			Right of way map
4.5.4	Enter right of way and parcel data into ROWIS			
4.5.5	Update/refine right of way cost estimate in DCIS			
4.5.6	Release right of way project	4415	SA 4	Right of way map

4.6 SUE Level C (and Some B)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.6.1	Identify existing utilities on geometric schematic	2640		
4.6.1.1	Coordinate with district utility coordinator			
4.6.1.2	Hire SUE consultant			SUE contract, SUE work order
4.6.1.3	Send preliminary schematic to utilities and request markups			
4.6.1.4	Perform SUE (Level B, C or D)			SUE deliverables
4.6.1.5	Develop utility layout			Utility layout
4.6.1.6	Collect utility information from utility owners			
4.6.1.7	Develop list of potentially impacted utilities			Potential utility conflict list
4.6.2	Identify potential utility conflicts	2650		
4.6.2.1	Review preliminary schematic with district utility coordinator			Potential utility conflict list

4.6.2.2	Locate utility conflicts in plan and profile			
4.6.2.3	Develop utility conflict list			Utility conflict list

4.6 SUE Level C (and Some B) (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.6.2.4	Contact utility owners to discuss plans and address utility conflicts			

4.7 Secure Federal, State and Local Funding Agreements

Activity Code	Activity Name	PDP Code	UM Code	Document
4.7.1	Verify Minute Order			
4.7.2	Review contractual agreements			
4.7.3	Obtain contractual agreements with LPAs	4400		
4.7.3.1	Review local participation requirement			
4.7.3.2	Review previously executed AFAs			
4.7.3.3	Decide when and by whom right of way is acquired			
4.7.3.4	Review utility conflict list			Utility conflict list
4.7.3.5	Review approved right of way map if applicable			
4.7.3.6	Execute ROW-RM-129		SA 3b and SA 6	Agreement to Contribute Funds ROW-RM-129
4.7.3.7	Give local entity approved right of way map if applicable			
4.7.3.8	Execute ROW-RM-37		SA 3b	Contractual Agreement for ROW Procurement ROW-RM-37
4.7.4	Federal Project Authorization and Agreement (FPAA)		SA 3a	
4.7.5	Alternate Procedure approval from FHWA		SA 5	

4.8 Locate Utilities (SUE Level B and Some A)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.8.1	Locate existing utilities	4200		

4.8.1.1	Hire SUE consultant			SUE contract, SUE work order
4.8.1.2	Perform SUE			SUE deliverables
4.8.1.3	Update utility layout			Updated utility layout

4.9 Right Of Way Acquisition Before Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.9.1	Appraise parcels	4430		Contract for Appraisal Services ROW-A-2
4.9.2	Identify impediments to parcel acquisition	4420		
4.9.3	Acquire right of way parcels			
4.9.4	Review right of way map update			
4.9.5	Request CONSTRUCT authorization			

4.10 Utility's Consultant Contract Approval

Activity Code	Activity Name	PDP Code	UM Code	Document
4.10.1	ROW approval of consultant contract if reimbursable			

4.11 Agreements with Utilities

Activity Code	Activity Name	PDP Code	UM Code	Document
4.11.1	Prepare and execute joint-use/multiple-use agreements (acknowledgements)	4425		
4.11.1.1	Review utility's letter of no conflict			Letter of no conflict
4.11.1.2	Execute Utility Joint Use Acknowledgement A			Utility Joint Use Acknowledgement ROW-U-JUAA
4.11.1.3	Execute Utility Joint Use Acknowledgement B			Utility Joint Use Acknowledgement ROW-U-JUAB
4.11.2	Prepare and execute utility adjustment agreements	4620		
4.11.2.1	LPA prepares Utility Adjustment Assembly for approval			

4.11.2.2	Prepare and submit draft agreement assembly to utility owners			
4.11.2.3	Request for Determination of Eligibility		SA 7	
4.11.2.4	District approves utility consultant contract		SA 8	
4.11.2.5	Determine eligibility (district approval)			

4.11 Agreements with Utilities (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.11.2.6	LPA authorizes work			
4.11.2.7	Prepare Utility Adjustment Assembly for approval			Utility Adjustment Plans, Utility adjustment checklist, ROW-U-Adjcheck, Standard Utility Agreement ROW-U-35, Joint Use Acknowledgement ROW-U-JUAA or ROW-U-JUAB, Statement Covering Utility Construction Contract Work ROW-U-48, Compensable Interest Certificate ROW-U-84
4.11.2.8	Send agreement assembly to division for approval			
4.11.2.9	Agreement assembly approval at district (Tier 1)			
4.11.2.10	Agreement assembly approval at district (Tier 1 or 2)			
4.11.2.11	Execute utility agreement			
4.11.3	Coordinate utility adjustment plans	4610		
4.11.3.1	Review SUE deliverables and utility conflict list			
4.11.3.2	Invite one or more utility companies			
4.11.3.3	Meeting with one or more utility companies			
4.11.3.4	Develop utility adjustment plans			Utility adjustment plans
4.11.4	LPA submits request for inclusion in highway contract to district			
4.11.5	Submit two sets of plans and explanation of need			
4.11.6	Gather division approval for plans and methods of installation			Advance Funding Agreement Attachment "I"
4.11.7	Submit letter of recommendation			
4.11.8	Process advance funding agreement			Utility Advance Funding Agreement

4.12 Locate Utilities (SUE Level A)

Activity Code	Activity Name	PDP Code	UM Code	Document
4.12.1	Perform SUE Level A			
4.12.2	Update utility layout			Updated utility layout
4.12.3	Submit SUE deliverables and utility layout			SUE deliverables

4.13 Adjustment Monitoring and Reimbursement Before Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.13.1	Clear right of way for utility adjustment			
4.13.2	Utility owners adjust facilities	4630	SA 11	Reimbursable Authorization Letter ROW-U-13
4.13.2.1	Notify utility owners that agreements are executed			
4.13.2.2	Maintain utility adjustment construction records			
4.13.3	Meetings with utilities with outstanding adjustments			
4.13.4	Reimburse utility owners for eligible adjustment costs	4650	SA 13	

4.14 Utility and Right Of Way Certifications

Activity Code	Activity Name	PDP Code	UM Code	Document
4.14.1	Prepare right of way and encroachment certifications	4500		
4.14.1.1	Research status of right of way acquisition and removal of identified encroachments			
4.14.1.2	Prepare right of way encroachment certifications			
4.14.2	Prepare utility clearance certifications	4640		
4.14.2.1	Include form Utiladj 1 in PS&E			
4.14.2.2	Include form Utiladj 2 in PS&E			Certification for Utility Adjustment (Not Clear) Utiladj2
4.14.2.3	Include triple zero special provision			Certification for Utility Adjustment (None or Clear) Utiladj1
4.14.2.4	Attach form Utilstat			Utility Status Data Sheet Utilstat

4.15 Right Of Way Mapping After Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.15.1	Update right of way map			Map checklist ROW-MapCheck, Right of way map
4.15.2	Forward new right of way map to ROW Division			Right of way map

4.16 Right Of Way Acquisition After Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.16.1	Appraise parcels	4430		
4.16.2	Identify impediments to parcel acquisition	4420		
4.16.3	Acquire right of way parcels			
4.16.4	Review right of way map update			Right of way map

4.17 Adjustment Monitoring and Reimbursement After Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
4.17.1	Dispose of improvements	4490		Final disposition of ROW Improvements ROW-RM-9
4.17.2	Clear right of way for utility adjustment			
4.17.3	Preconstruction utility meeting			
4.17.4	Utility owners adjust facilities	4630	SA 11	Utility adjustment checklist ROW-U-Adjcheck, Reimbursable Authorization Letter ROW-U-13
4.17.4.1	Notify utility owners that agreements are executed			
4.17.4.2	Maintain utility adjustment construction records			
4.17.5	Utility coordination meetings during construction		PA 10	
4.17.6	Reimburse utility owners for eligible adjustment costs	4650	SA 13	
4.17.7	Receive utility's as-built documentation			As-built documentation

5.1 Final Processing and Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
5.1.1	Perform financial clearance analysis	6000		
5.1.2	Prepare and review draft (bid) proposal	6010		
5.1.3	Obtain funding and approval of PS&E	6030		State Letter of Authorization (State LOA), FPAA
5.1.4	Release final (bid) proposal	6100		
5.1.5	Release final (bid) proposal	6100		Final bid proposal
5.1.6	Conduct bid opening	6150		
5.1.7	Award contract	6210		

6.1 Initial Utility Involvement

Activity Code	Activity Name	PDP Code	UM Code	Document
6.1.1	Attend annual meeting			Utility-friendly project list
6.1.2	Provide feedback for eligible utility reimbursement cost estimate			

6.2 Preliminary Design Meeting

Activity Code	Activity Name	PDP Code	UM Code	Document
6.2.1	Receive project notification			
6.2.2	Schedule attendance at Design Concept Conference			

6.3 Initial Coordination and Markup

Activity Code	Activity Name	PDP Code	UM Code	Document
6.3.1	Receive project dimensions and provide preliminary facility locations			As-built plans
6.3.2	Review preliminary schematic and markup utility locations			Preliminary schematic
6.3.3	Review utility conflict list and make changes if applicable			Utility conflict list
6.3.4	Attend introduction meeting for utilities			

6.4 Conflict Determination

Activity Code	Activity Name	PDP Code	UM Code	Document
6.4.1	Review preliminary plans			Preliminary construction plans
6.4.2	Hire consultant			
6.4.3	Send existing drawings to consultant			Existing utility installation drawings
6.4.4	Consultant reviews utilities, redlines TxDOT drawings			
6.4.5	Review facilities, redline TxDOT drawings			
6.4.6	Use SUE to add utilities without record to scale to drawing			
6.4.7	Identify conflicts, redline drawings, and submit to TxDOT			SUE deliverables
6.4.8	Attend 30% Design meeting			
6.4.9	Receive notification that adjustment is necessary			
6.4.10	Receive updated design plans			
6.4.11	Verify that conflict has been resolved			

6.5 Utility Design

Activity Code	Activity Name	PDP Code	UM Code	Document
6.5.1	Receive 30% Design plans from TxDOT, if applicable			
6.5.2	Prepare letter of no conflict and submit to TxDOT			Prepare letter of no conflict and submit to TxDOT
6.5.3	Prepare and submit Joint Use Acknowledgement B			Joint Use Acknowledgement ROW-U-JUAB
6.5.4	Prepare and submit Joint Use Acknowledgement A			Joint Use Acknowledgement ROW-U-JUAA
6.5.5	Develop design to adjust facility			
6.5.6	Utility exposes facility and ties it to control point			
6.5.7	Attend 60% Design meeting			
6.5.8	Utility sends findings to TxDOT			
6.5.9	Prepare utility agreement			
6.5.10	Receive utility offsets and 60% Design plans			

6.5 Utility Design (Continued)

Activity Code	Activity Name	PDP Code	UM Code	Document
6.5.11	Receive notification that adjustment is necessary			
6.5.12	Receive updated design plans			
6.5.13	Meeting with ROW officials			
6.5.14	Verify that conflict has been resolved			
6.5.15	Update design and plan set if applicable			
6.5.16	Complete cost estimate and schedule of work			Compensable Interest Certificate ROW-U-85 or Affidavit of Property Ownership (Utility Owner) ROW-U-U1A, Utility adjustment plans, Adjustment cost estimate, Statement Covering Utility Construction Contract Work ROW-U-48, Standard Utility Agreement ROW-U-35
6.5.17	Attend 90% Design meeting			
6.5.18	Submit utility agreement			

6.6 Utility Adjustment Before Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
6.6.1	Receive notification to proceed			Notification to proceed
6.6.2	Perform adjustment			
6.6.3	Submit as-built documentation			As-built documentation
6.6.4	Request payment within allowable timeframe			Payment Request ROW-A-15
6.6.5	Receive reimbursement from TxDOT			

6.7 Utility Adjustment After Letting

Activity Code	Activity Name	PDP Code	UM Code	Document
6.7.1	Meeting with TxDOT to discuss design plans			
6.7.2	Update design and plan set if applicable			
6.7.3	Receive notification to proceed			Notification to proceed
6.7.4	Perform adjustment			
6.7.5	Submit as-built documentation			As-built documentation
6.7.6	Request payment within allowable timeframe			Payment Request ROW-A-15
6.7.7	Receive payment from TxDOT			

APPENDIX C. LOGICAL DATA MODELS OF
UTILITY DATA MANAGEMENT SYSTEM PROTOTYPE
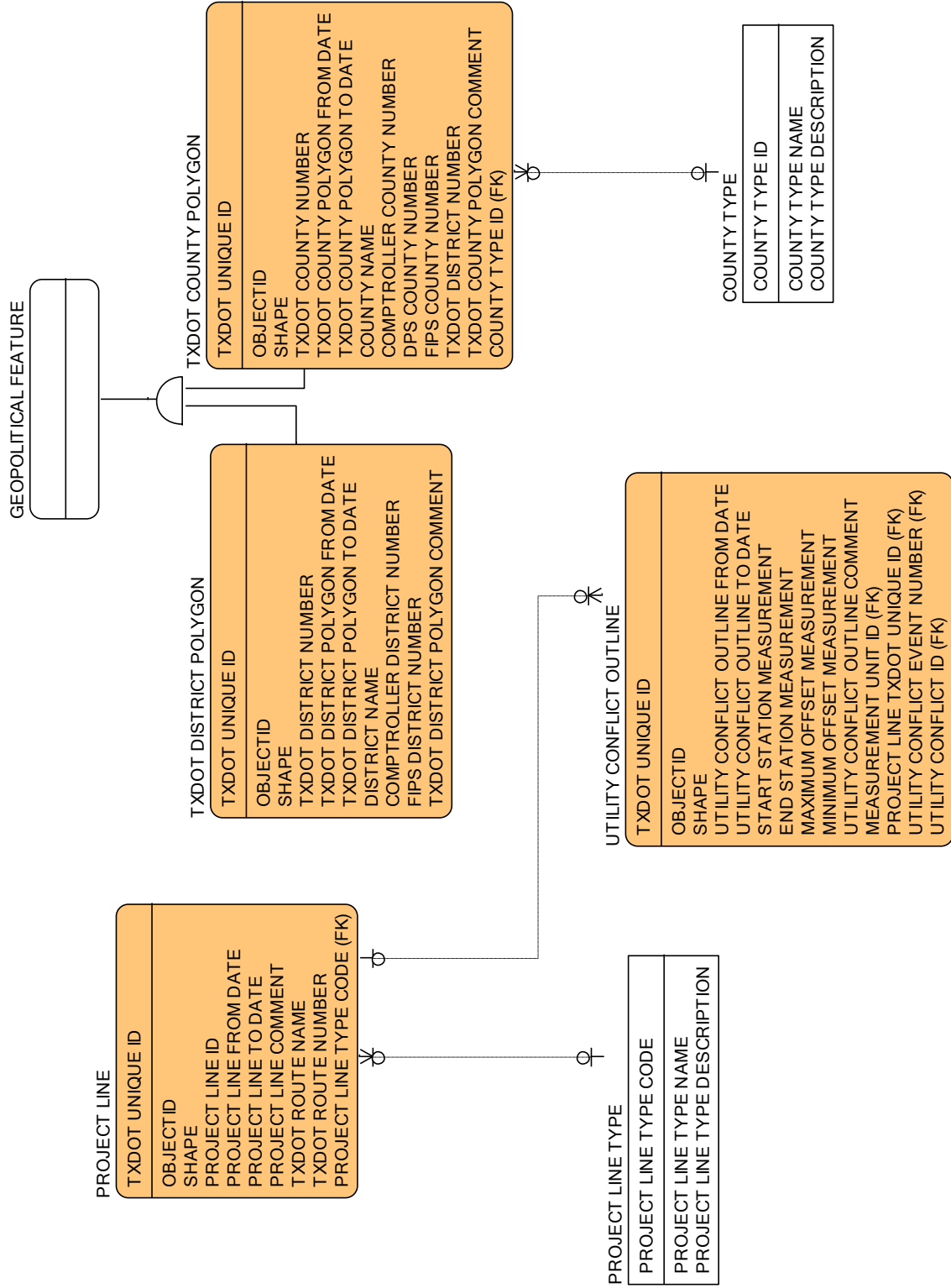
Figure 55. UACT Logical Data Model, ArcSDE Subject Area.

DCIS DATA WAREHOUSE

CONTROL SECTION JOB NUMBER
ACTUAL LETTING DATE
ADDITIONAL ROW AMOUNT
ANCESTOR CSJ 1
ANCESTOR CSJ 2
ANCESTOR CSJ 3
ANCESTOR CSJ 4
ANCESTOR CSJ 5
BEGINNING REFERENCE MARKER DISPLACEMENT NUMBER
BEGINNING REFERENCE MARKER NUMBER
CONTRACT CSJ
COUNTY NUMBER
DATE LAST REVISION
DISTRICT LETTING DATE
ELIGIBLE FEDERAL FUNDING FLAG
ENDING REFERENCE MARKER DISPLACEMENT NUMBER
ENDING REFERENCE MARKER NUMBER
ENGINEER NUMBER
ESTIMATED CONSTRUCTION COST AMOUNT
ESTIMATED CONSTRUCTION COST AMOUNT DATE
ESTIMATED ROW COST
ESTIMATED ROW COST DATE
HIGHWAY NUMBER
LAYMAN DESCRIPTION1
LAYMAN DESCRIPTION2
LETTING SCHEDULE 1
LIMITS FROM
LIMITS TO
LOCAL CONTRIBUTIONS AMOUNT
PROJECT NUMBER
ROADWAY FUNCTIONAL CLASS CODE
ROW CSJ
TIME LAST REVISION
TIP FISCAL YEAR
TOTAL OBLIGATED AMOUNT

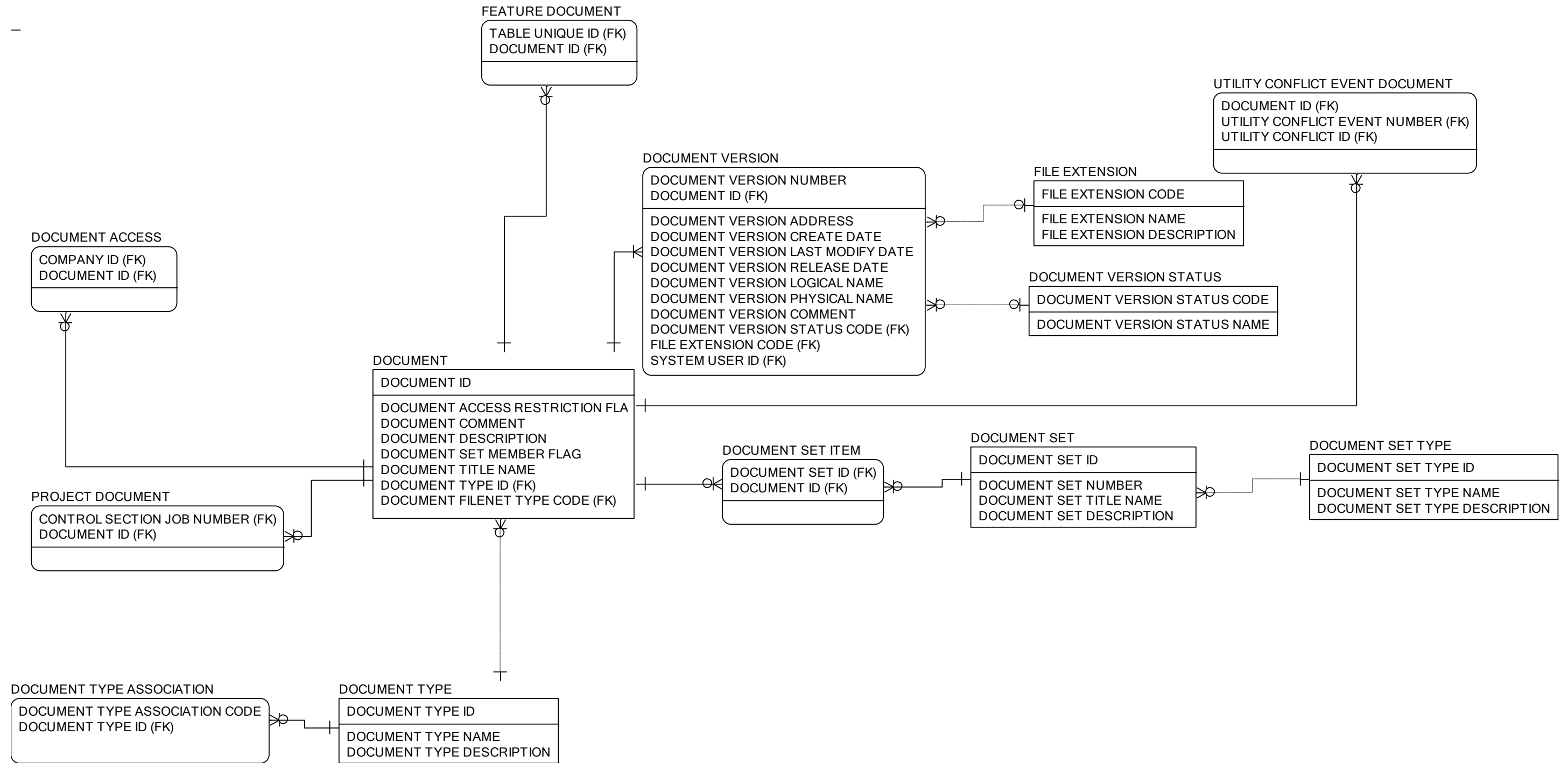**Figure 56. UACT Logical Data Model, DCIS Subject Area.**

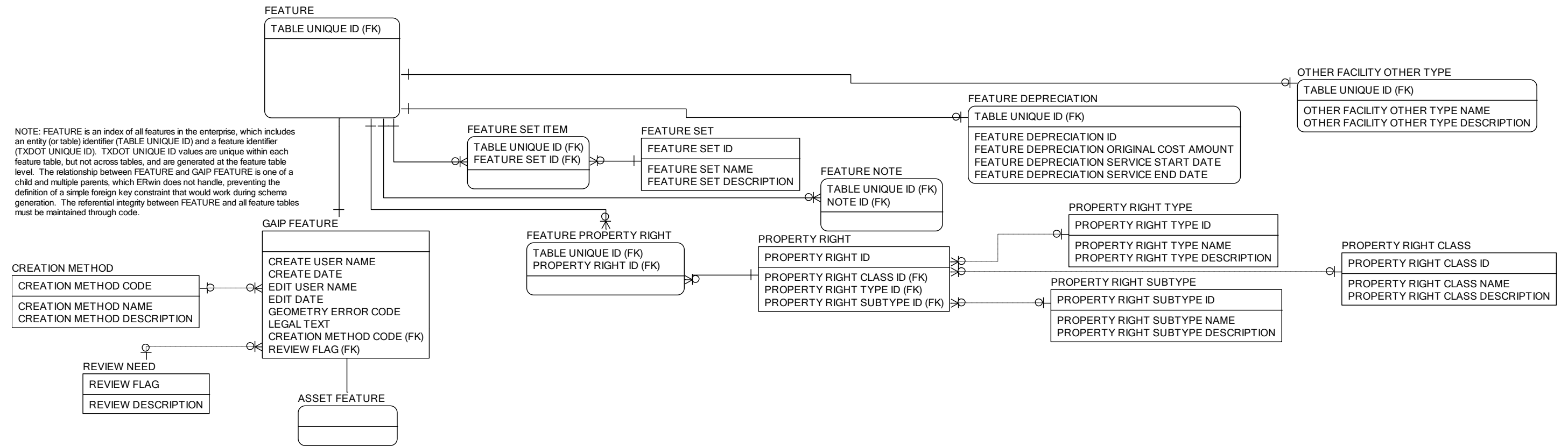**Figure 57. UACT Logical Data Model, Document Subject Area.**

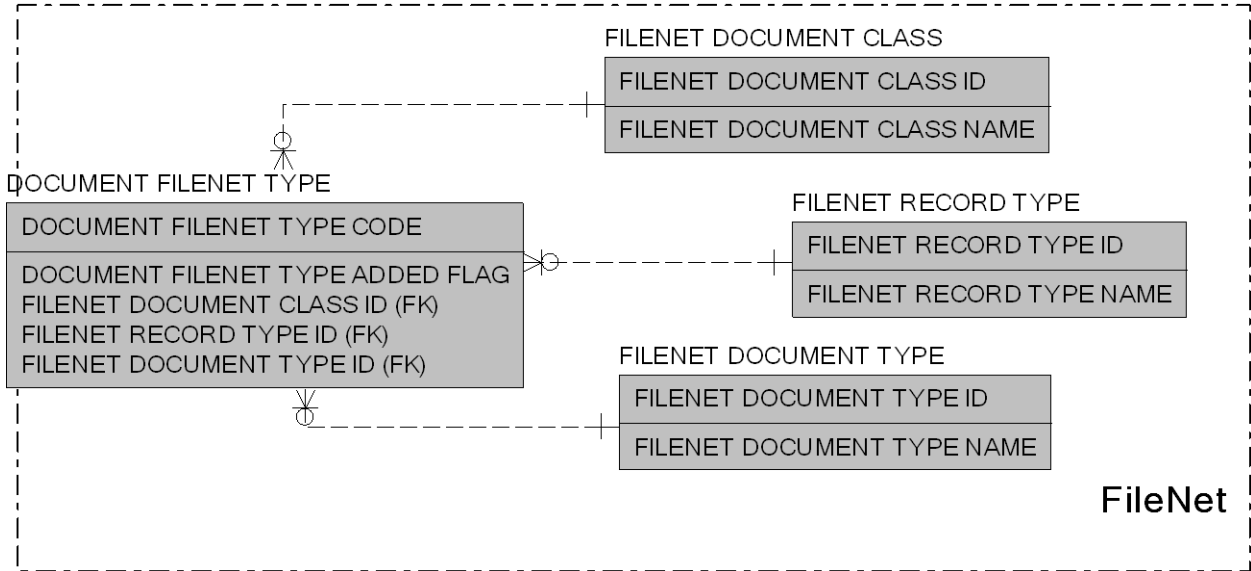**Figure 58. UACT Logical Data Model, Feature Subject Area.**

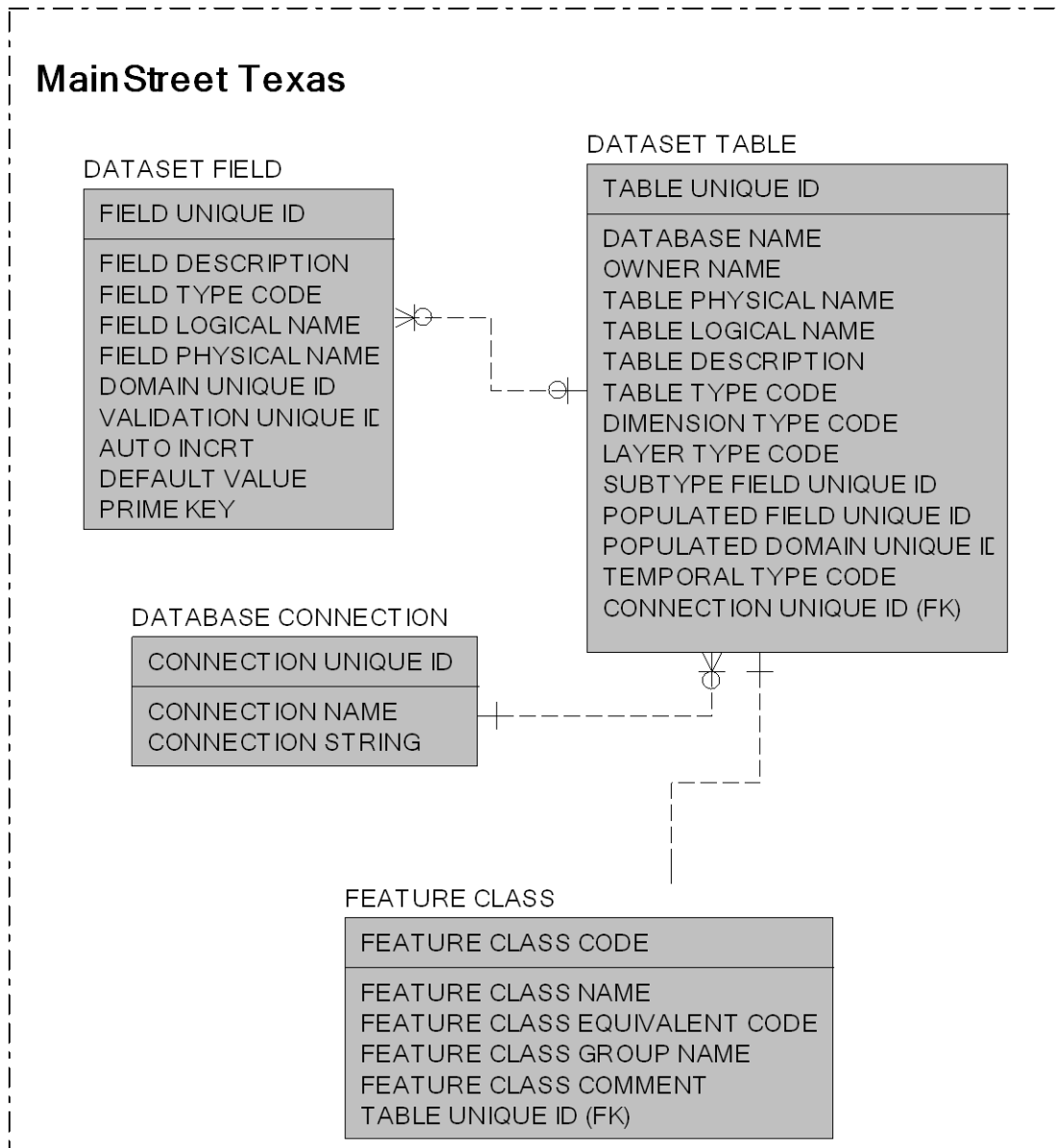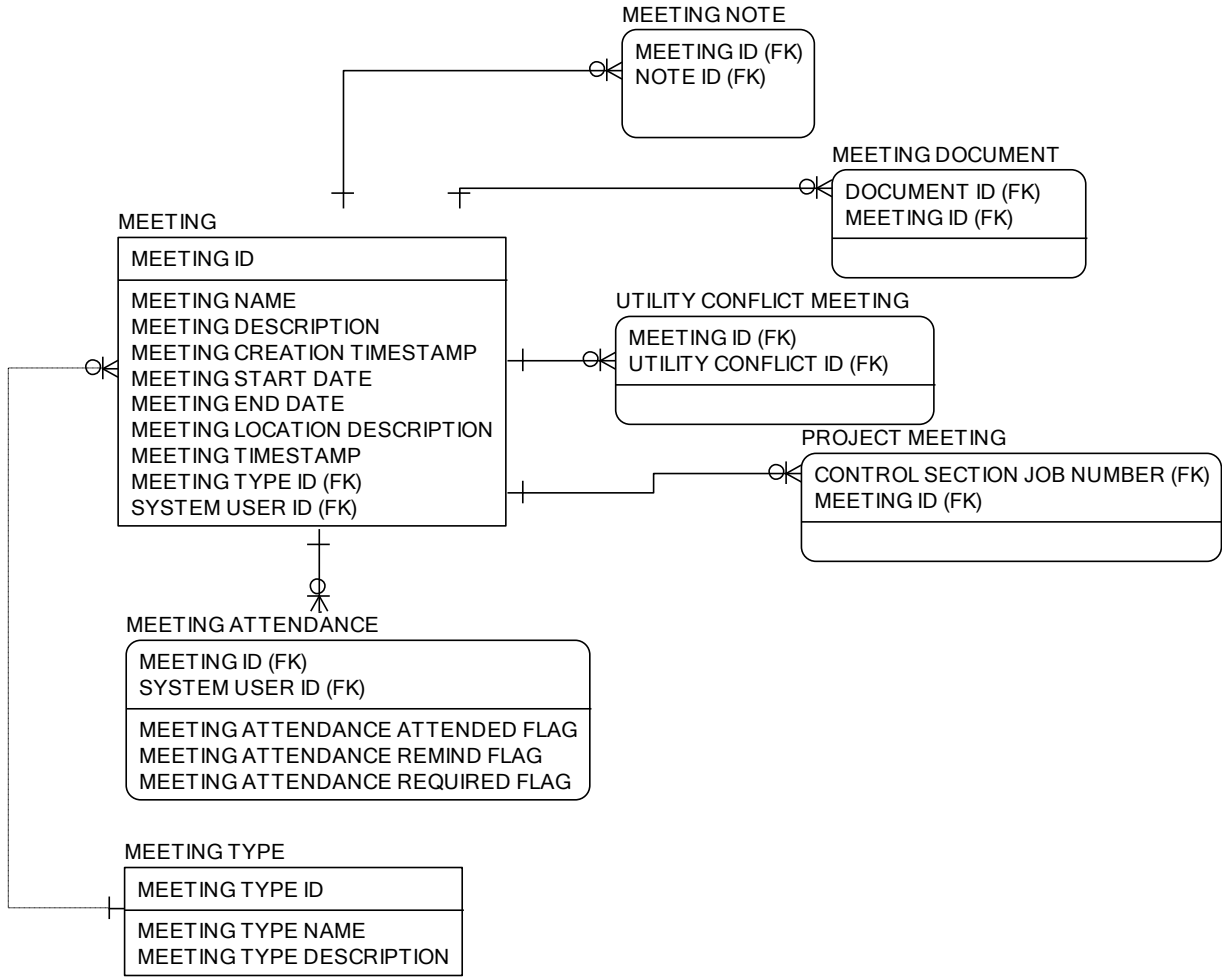**Figure 59. UACT Logical Data Model, FileNet Subject Area.**

MainStreet Texas

DATASET FIELD

FIELD UNIQUE ID
FIELD DESCRIPTION FIELD TYPE CODE FIELD LOGICAL NAME FIELD PHYSICAL NAME DOMAIN UNIQUE ID VALIDATION UNIQUE ID AUTO INCRT DEFAULT VALUE PRIME KEY

DATASET TABLE

TABLE UNIQUE ID
DATABASE NAME OWNER NAME TABLE PHYSICAL NAME TABLE LOGICAL NAME TABLE DESCRIPTION TABLE TYPE CODE DIMENSION TYPE CODE LAYER TYPE CODE SUBTYPE FIELD UNIQUE ID POPULATED FIELD UNIQUE ID POPULATED DOMAIN UNIQUE ID TEMPORAL TYPE CODE CONNECTION UNIQUE ID (FK)

DATABASE CONNECTION

CONNECTION UNIQUE ID
CONNECTION NAME CONNECTION STRING

FEATURE CLASS

FEATURE CLASS CODE
FEATURE CLASS NAME FEATURE CLASS EQUIVALENT CODE FEATURE CLASS GROUP NAME FEATURE CLASS COMMENT TABLE UNIQUE ID (FK)

Figure 60. UACT Logical Data Model, MainStreet Texas Subject Area.

Figure 61. UACT Logical Data Model, Meeting Subject Area.
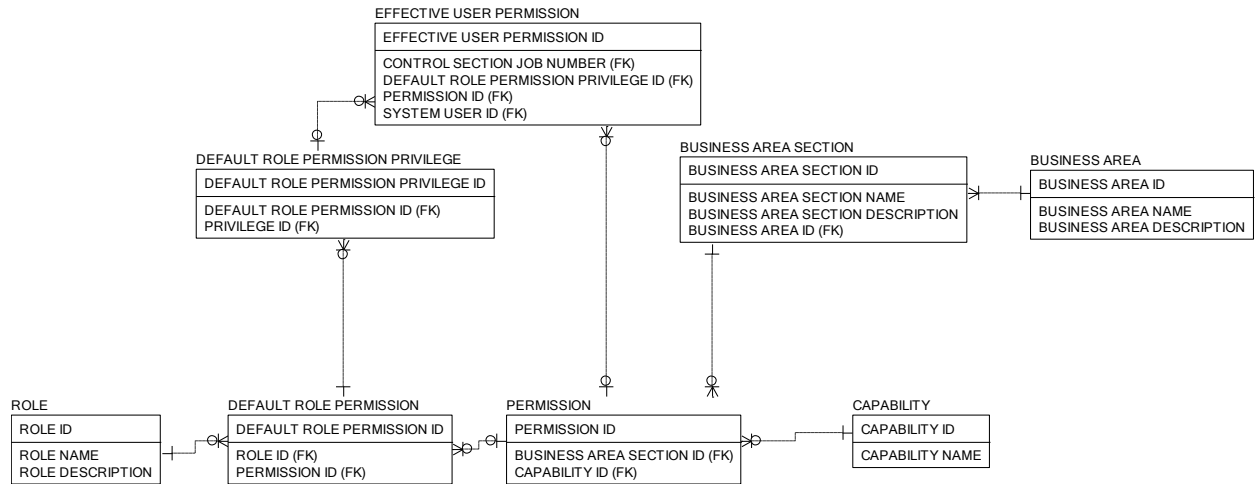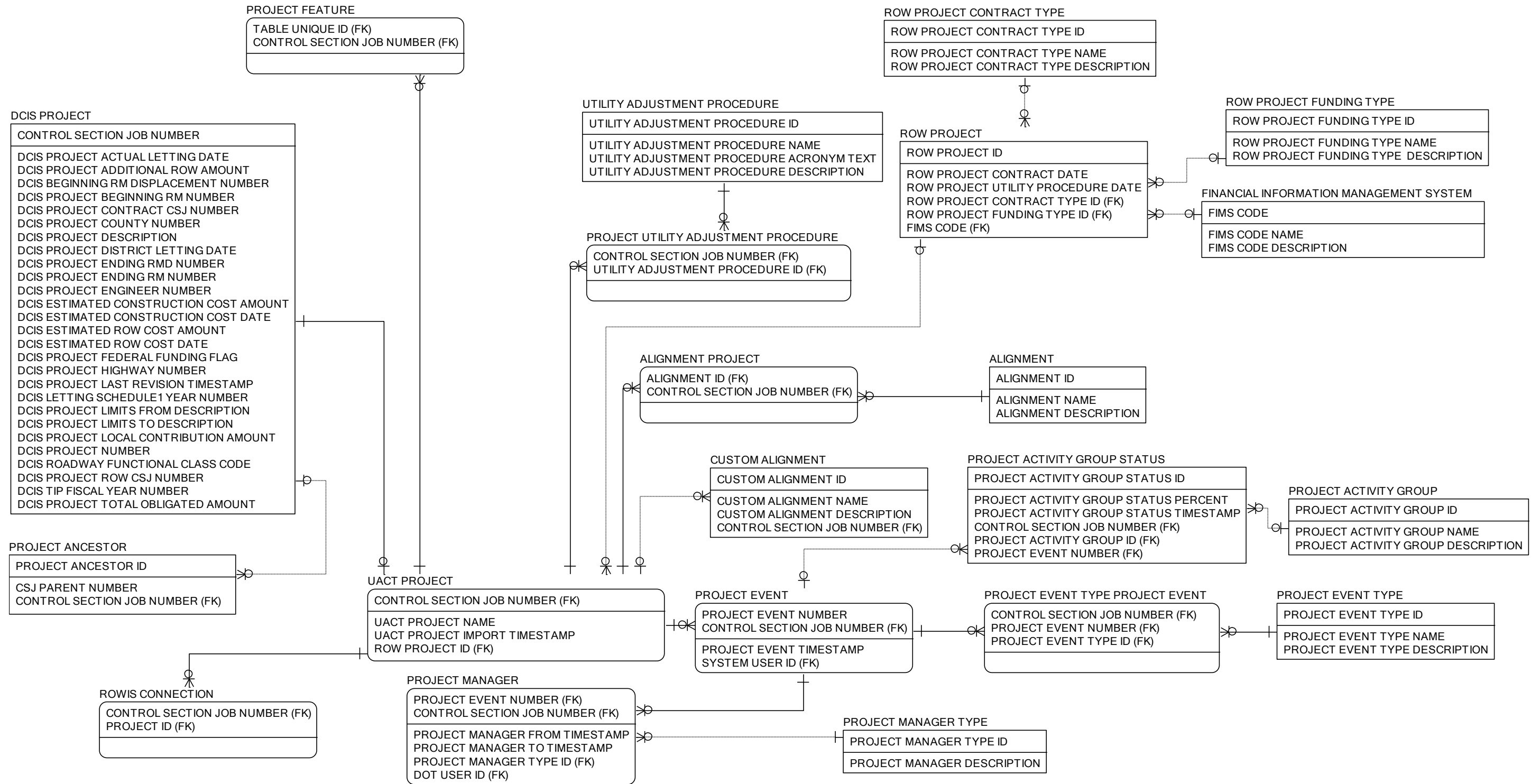
Figure 62. UACT Logical Data Model, Permissions Subject Area.
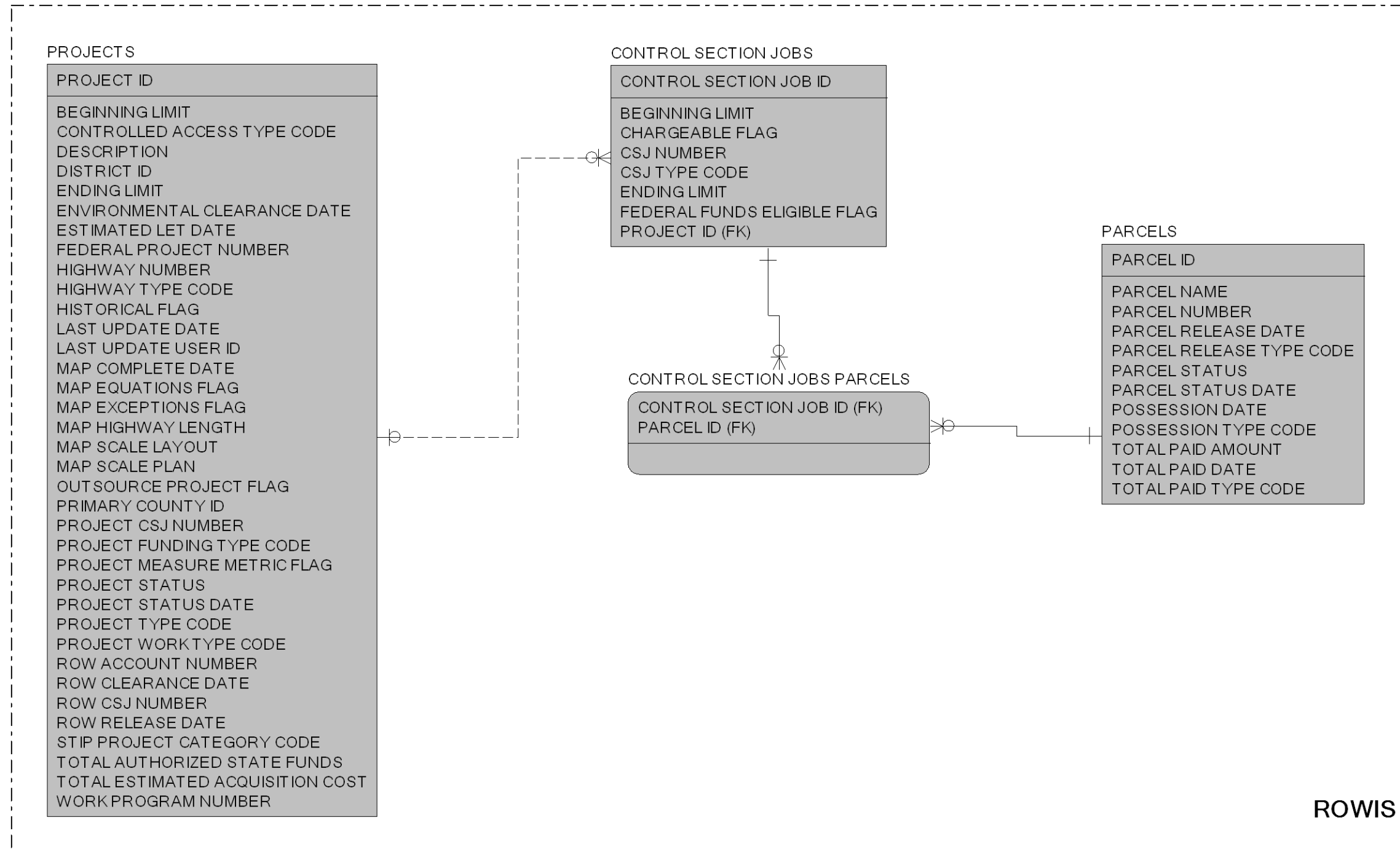
Figure 63. UACT Logical Data Model, Project Subject Area.

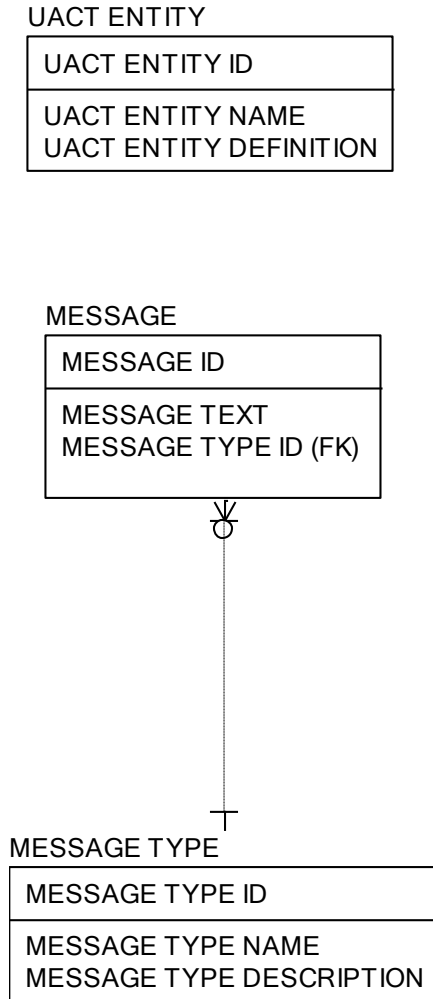**Figure 64. UACT Logical Data Model, ROWIS Subject Area.**

UACT ENTITY

UACT ENTITY ID
UACT ENTITY NAME UACT ENTITY DEFINITION

MESSAGE

MESSAGE ID
MESSAGE TEXT MESSAGE TYPE ID (FK)

MESSAGE TYPE

MESSAGE TYPE ID
MESSAGE TYPE NAME MESSAGE TYPE DESCRIPTION

Figure 65. UACT Logical Data Model, System Subject Area.

– SYSTEM USER ROLE

ROLE ID (FK)
SYSTEM USER ID (FK)

COMPANY ROLE

ROLE ID (FK)
COMPANY ID (FK)

CONTROL SECTION JOB NUMBER (FK

PROJECT COMPANY

CONTROL SECTION JOB NUMBER (FK)
COMPANY ID (FK)

USER EVENT

USER EVENT NUMBER
SYSTEM USER ID (FK)

USER EVENT TIMESTAMP
USER EVENT TYPE ID (FK)

USER EVENT TYPE

USER EVENT TYPE ID

USER EVENT TYPE NAME
USER EVENT TYPE DESCRIPTION
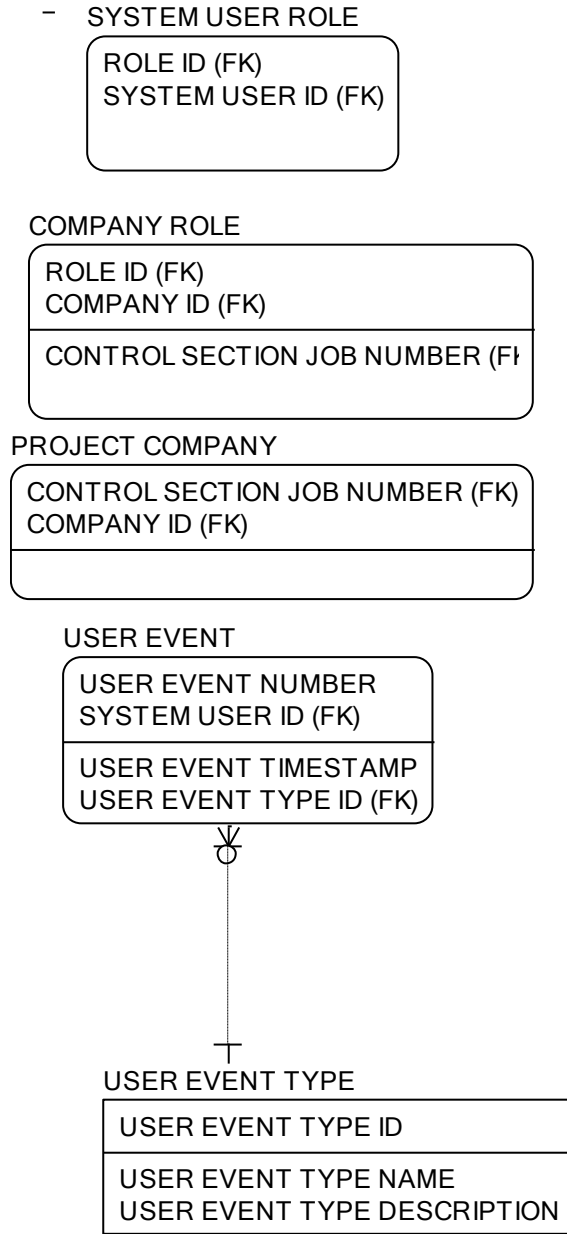
Figure 66. UACT Logical Data Model, User Subject Area.
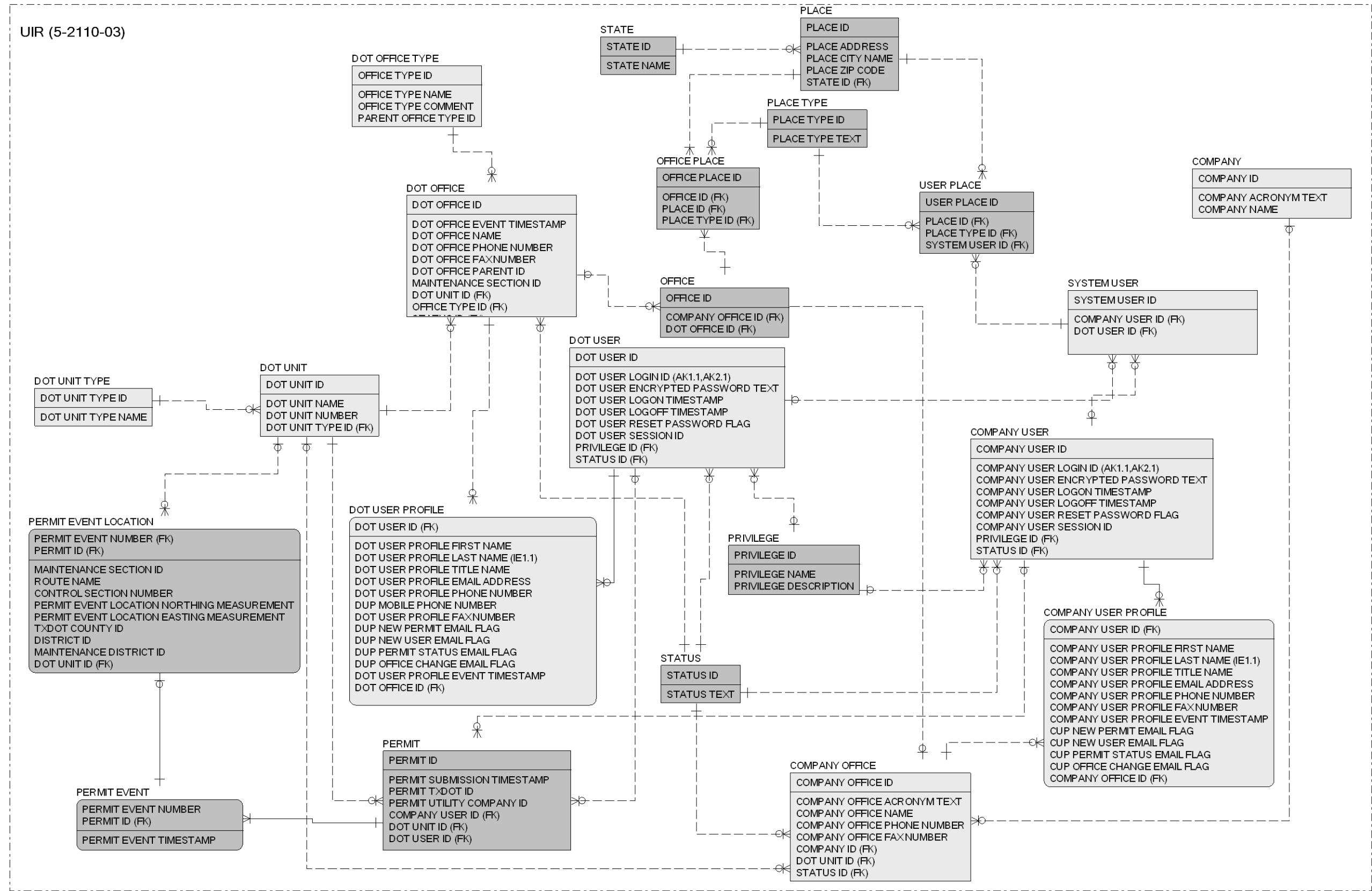
Figure 67. UACT Logical Data Model, UIR Subject Area.
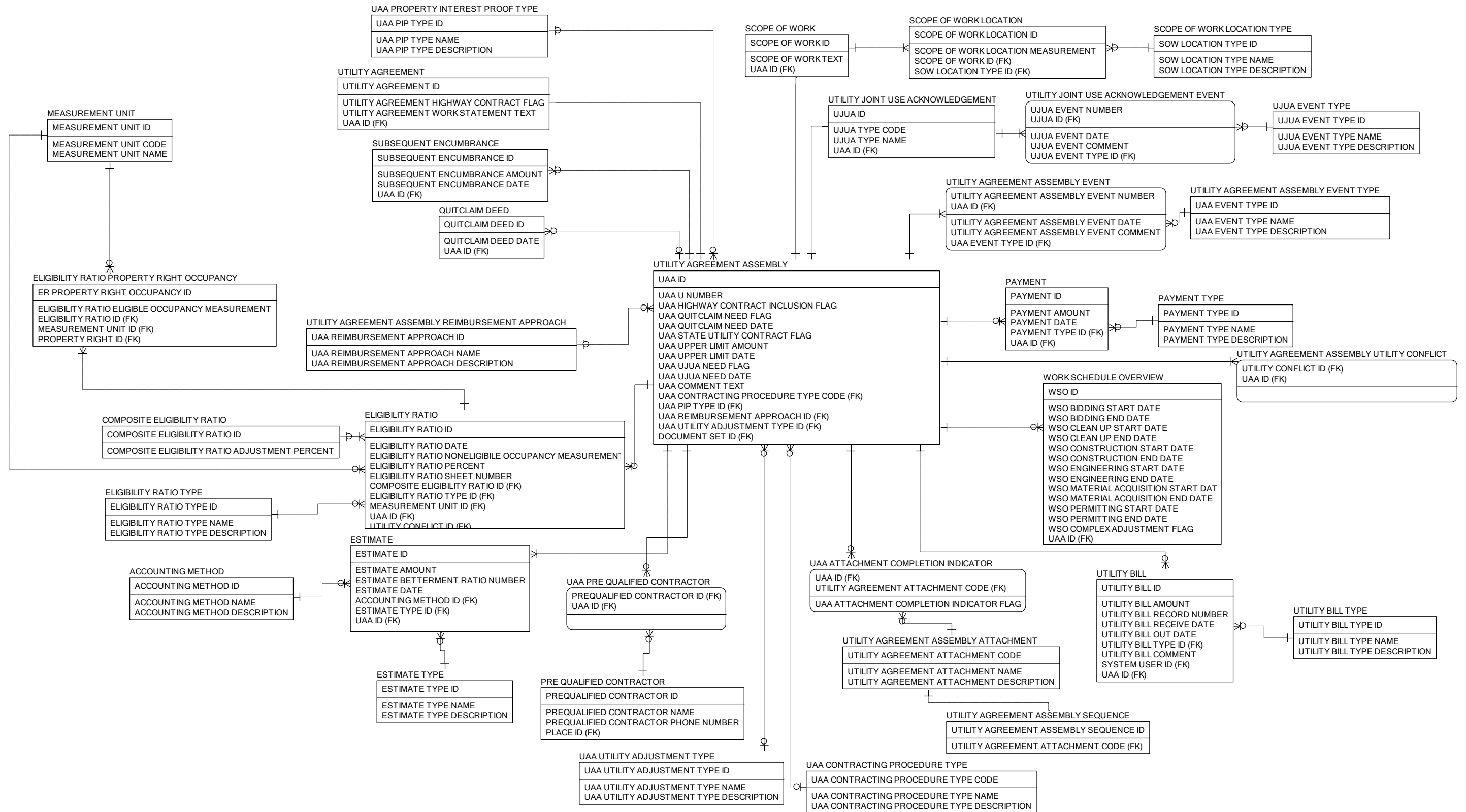
Figure 68. UACT Logical Data Model, Utility Agreement Assembly Subject Area.

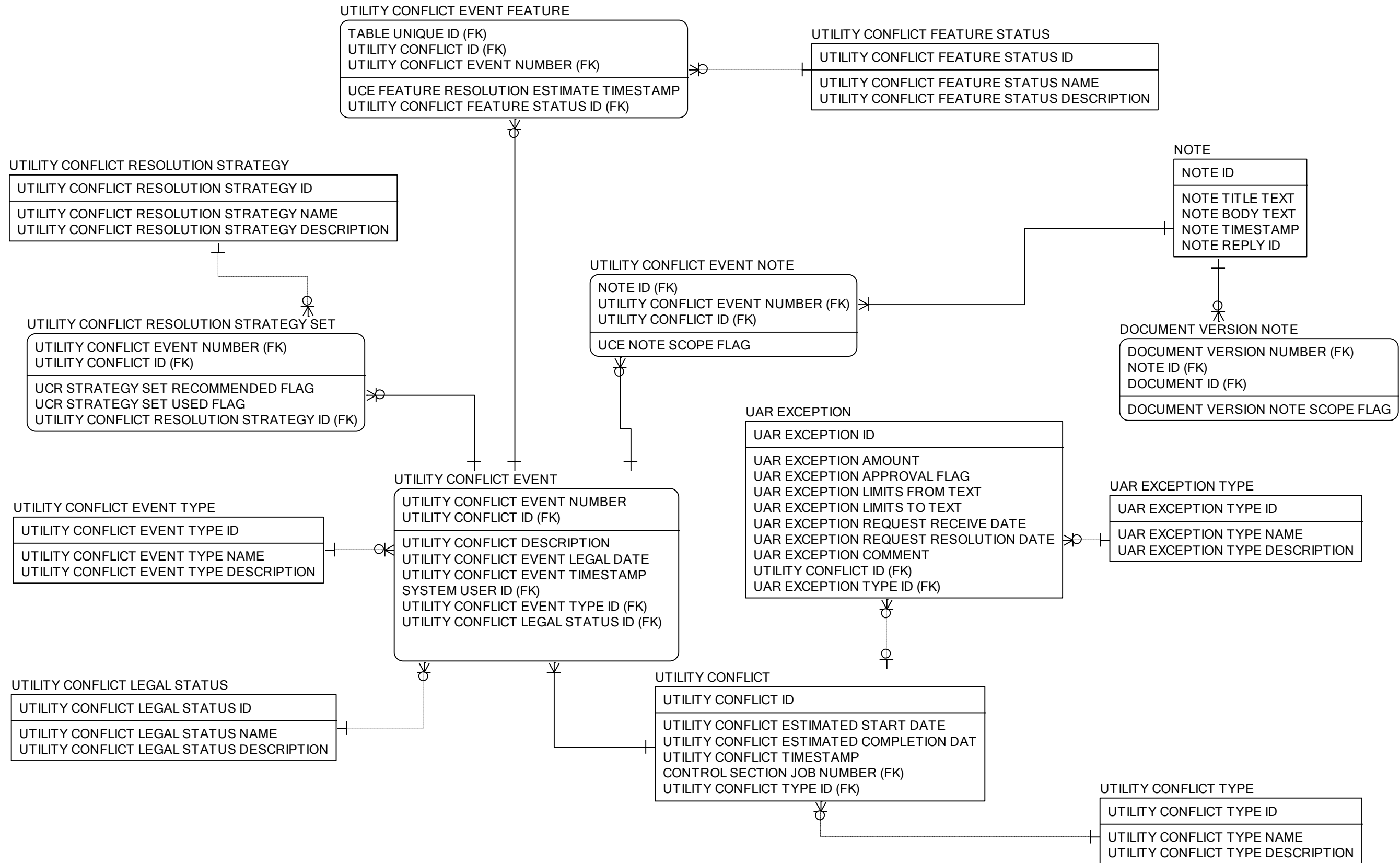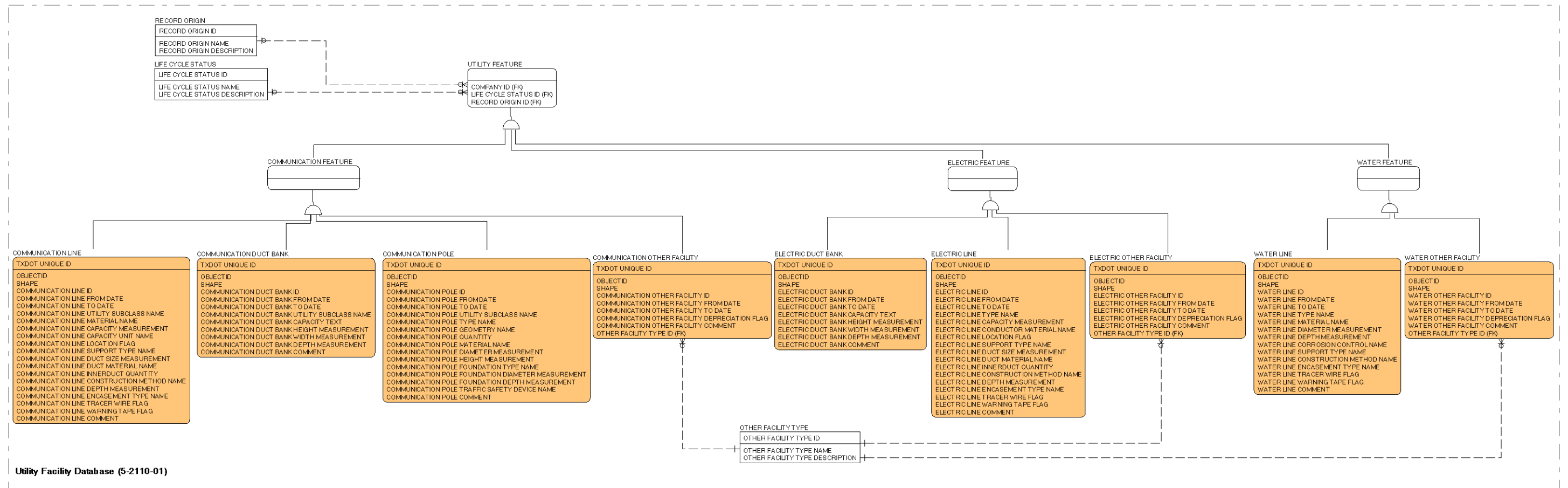**Figure 69. UACT Logical Data Model, Utility Conflict Subject Area.**

Figure 70. UACT Logical Data Model, Utility Facility Database Subject Area.