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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.

This report summarizes the work completed during the first year, which resulted in the development of utility relocation data models and an alpha version of the utility conflict management system. 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 TOOL

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

AASHTO	American Association of State Highway and Transportation Officials
BNP	Business Need Priority
CAD	Computer Aided Design
CDA	Comprehensive Development Agreement
CFR	Code of Federal Regulations
COTS	Commercial-Off-the-Shelf
CSJ	Control Section Job
DBMS	Database Management System
DCIS	Design and Construction Information System
DCO	Design Construction Office
DFD	Data Flow Diagram
DOE	Date of Eligibility
DOT	Department of Transportation
EDMS	Electronic Data Management System
EWA	Emergency Work Authorization
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
GIS	Geographic Information System
HPTMS	Highway Project Task Management System

ICAM	Integrated Computer-Aid Manufacturing
IDEF	ICAM Definition Language
IDEF0	Integration Definition for Function Modeling
IDEF3	Integration Definition for Process Description Capture Method
Interstate System	National System of Interstate and Defense Highways
ISD	Information Systems Division at TxDOT
IT	Information Technology
LPA	Local Public Agency
LRS	Linear Referencing System
LUP	Local Utility Procedure
MST	Main Street Texas
NGS	Network Ground Set
NOPI	Notice of Proposed Installation
OLAP	Online Analytical Processing
OLTP	Online Transaction Processing
PDP	Project Development Process
PS&E	Plans, Specifications, and Estimate
RDBMS	Relational Database Management System
ROW	Right of Way
ROWIS	Right of Way Information System
SAS	Statistical Analysis Software
StratMap	Texas Strategic Mapping Program
SUP	State Utility Procedure of the UCMP

TACS	Tables and Characteristics System
TGIC	Texas Geographic Information Council
TNRIS	Texas Natural Resources Information System
TTA	Texas Turnpike Authority
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation
TP&P	Transportation Planning and Programming Division at TxDOT
UACT	Utility Accommodation and Conflict Tracker
UAR	Utility Accommodation Rules (formerly Utility Accommodation Policy)
UIR	Utility Installation Review
UCMP	Utility Cooperative Management Process
UTP	Unified Transportation Program

CHAPTER 1. INTRODUCTION

RESEARCH NEED

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, and (c) by a mechanism other than a highway facility design change or utility adjustment such as an engineering solution. 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, 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 during the first year of the research project 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.
- 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 concluding remarks.

CHAPTER 2. REVIEW OF UTILITY INFORMATION FLOWS IN THE PROJECT DEVELOPMENT PROCESS

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. 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 ROW representative, ROW division representative, construction contractor, External Audit, Budget and Finance Division representative, and the 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 ROW 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 ROW, 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 ROW 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 ROW, 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 PS&E Preparation Manual as starting points to analyze utility relocation business processes at TxDOT. The researchers recognized 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.

TXDOT INFORMATION SYSTEMS

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 HPTMS 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 FileNet, ProjectWise, and the San Antonio District's File Management System (FMS). A short description of each system follows.

Design & Construction Information System (DCIS)

TxDOT uses DCIS to prepare projects for project specification and estimation (PS&E) development and contract letting *(13)*. 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. The control section job (CSJ) number is the key descriptor for the record of each project in DCIS. 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.

Figure 1 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 1. DCIS Blank Project Identification Screen *(13)*.

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).

Highway Project Task Management System (HPTMS)

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 to interact with DCIS called the Highway Project Task Management System (HPTMS). The system is able to download data from DCIS and transfer it to a relational database system 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 2 shows a screenshot of the system.

Figure 2. Corpus Christi District Highway Project Task Management System "Welcome" Screen and "Reports and Charts" Screen.

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 3 and Figure 4). The DCO database is used to track change orders, subcontractors, final estimate processing times, claims/disputes, contract acceleration strategies, and others *(14)*. 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.

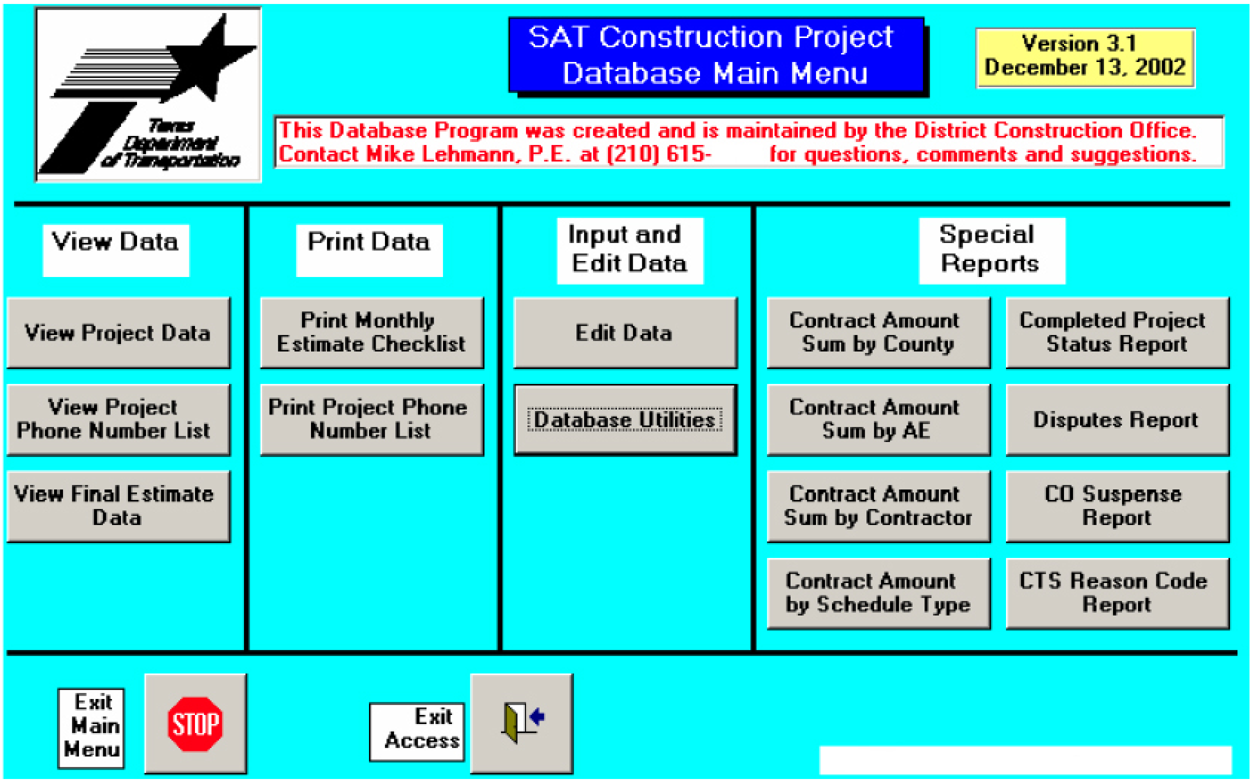


Figure 3. San Antonio District Design Construction Office Database "Welcome" Screen (*14*).

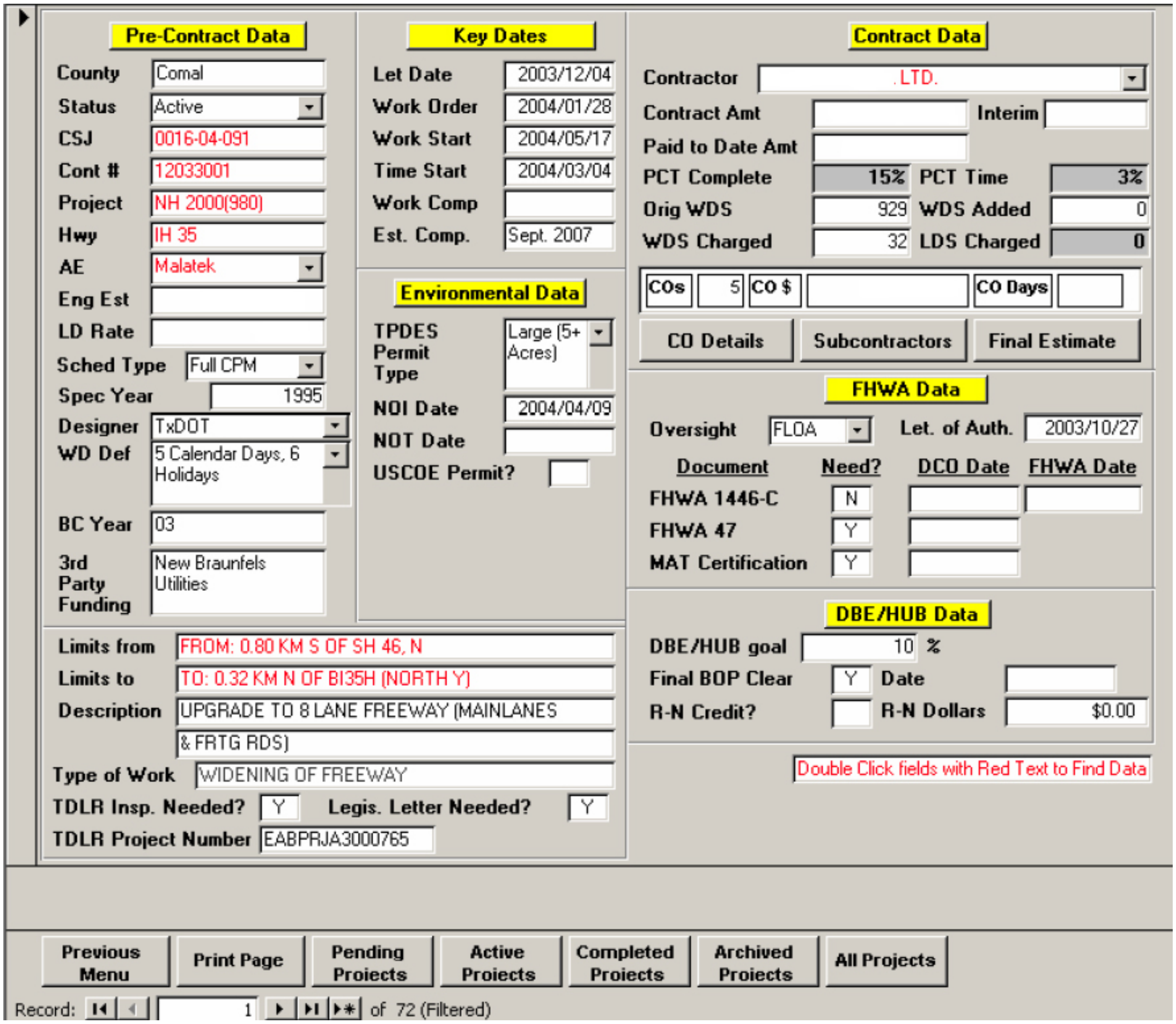


Figure 4. San Antonio District Design Construction Office Database "Project Data Entry" Screen *(14)*.

Right of Way Information System (ROWIS)

The ROW Division implemented ROWIS in 1997 to track and report financial data of property acquisitions throughout the ROW acquisition process *(15)*. The system enables users to track ROW parcel development and fee appraiser work orders during events such as negotiations, settlements, or eminent domain proceedings, and can create various reports. The system can also track reimbursable and non-reimbursable utility agreements, but is limited in the variables it can handle. Unfortunately, ROWIS lacks the ability to display ROW parcels and utility conflicts on a map, or link to schematics that show that information. Figure 5 is a screenshot of the ROWIS application.

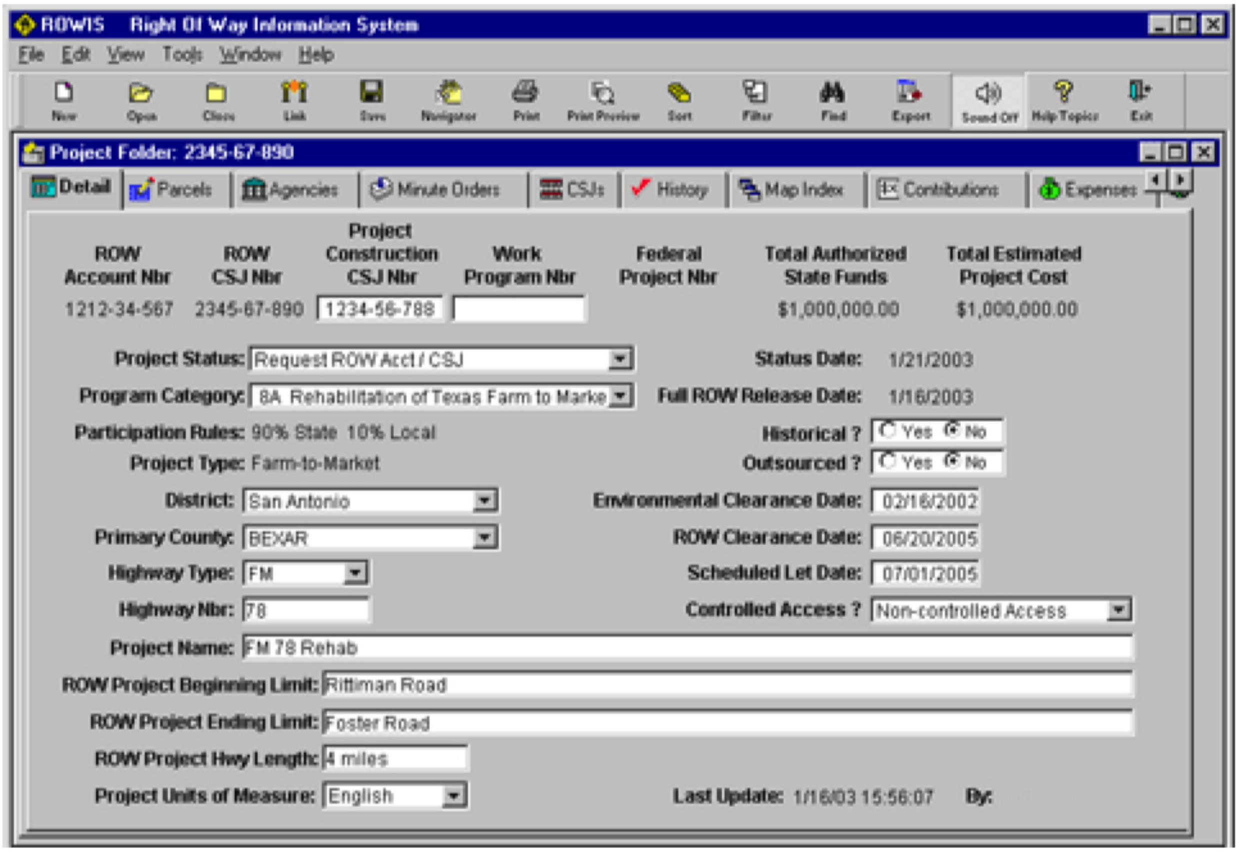


Figure 5. ROWIS Screenshot.

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 *(16)*. FileNet resides on top of a database management system (DBMS) such as Oracle, IBM DB2, or Microsoft SQL Server. The TxDOT FileNet implementation stores files in the file structure of the server computer (although file embedding in the database is also possible) and pointers to those files in the database. The Information Services Division considers FileNet to be TxDOT's standard business document record keeping system for document management *(17)* and is currently implementing the statewide use of FileNet.

TxDOT's goal is to implement FileNet separately for each business unit within the organization. Although most TxDOT districts and divisions currently follow ad hoc procedures to manage electronic documentation, TxDOT is currently implementing FileNet at the Austin District and in several divisions (such as Motor Carrier, Motor Vehicle, Finance, and Occupational Safety). The Houston District has used FileNet in various capacities since 1996 and is currently using it to archive PS&E documents and as-builts. TxDOT's experience with the implementation of FileNet has led to the development of a TxDOT specific archiving standard outlined in the Content Services Library Standards document *(18)*. This standard aims to facilitate the use and implementation of FileNet and describes document classes, security, folder settings, standard properties, and document properties. In addition, this standard has appendices that provide property definitions, recommended property values, recommended record types, and document types for standard document classes.

FileNet's interface (Figure 6) is similar to Windows Explorer, but includes several other functions such as viewing current file users, assigning file attributes or tags, querying, searching, and file versioning.

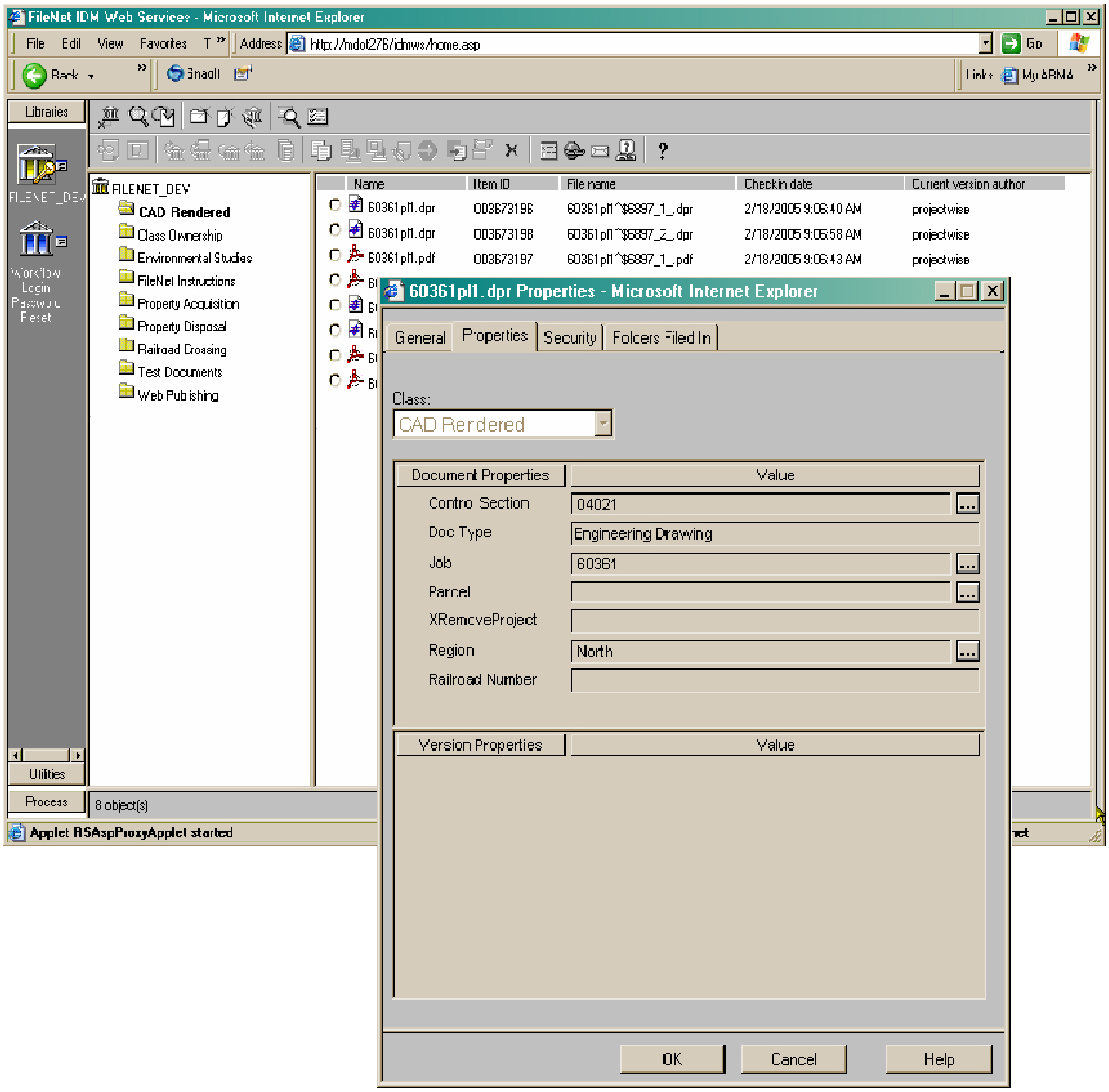


Figure 6. FileNet Sample Screens (*19*).

Currently, TxDOT uses FileNet version 7 in either client-server or web-based implementations. The web-based version of TxDOT's FileNet is called TxDocsOnline, which uses a FileNet engine and does not require the installation of FileNet software on client computers. The TxDocsOnline implementation of FileNet is built around the concept of a library standard that is based on functions, not projects, as described in the Content Services Library Standards document (*18*). Document classes are defined as folders and below document classes are record types. Each record type has a predefined list of documents for that record type. Every document class has a record type, every record type has a document type, and every document type has a status and a date. Each file in the library is assigned a location and file attributes that permit file indexing and querying. TxDOT's goal is to have a separate library for each business unit customized to its specific business process and document types. The FileNet implementation is not planned to be able to cross the entire organization and/or districts. TxDocsOnline documentation includes content services library standards and a user guide (*18*, *20*).

As in the case of other enterprise-level solutions such as PeopleSoft and SAP, a FileNet installation is a highly involved activity that requires the commitment of considerable financial resources and continuous participation of licensed FileNet technicians. FileNet is not a commercial-off-the-shelf (COTS) software and is not designed, in software and hardware specifications and cost, for individual users or small groups.

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 7). 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.

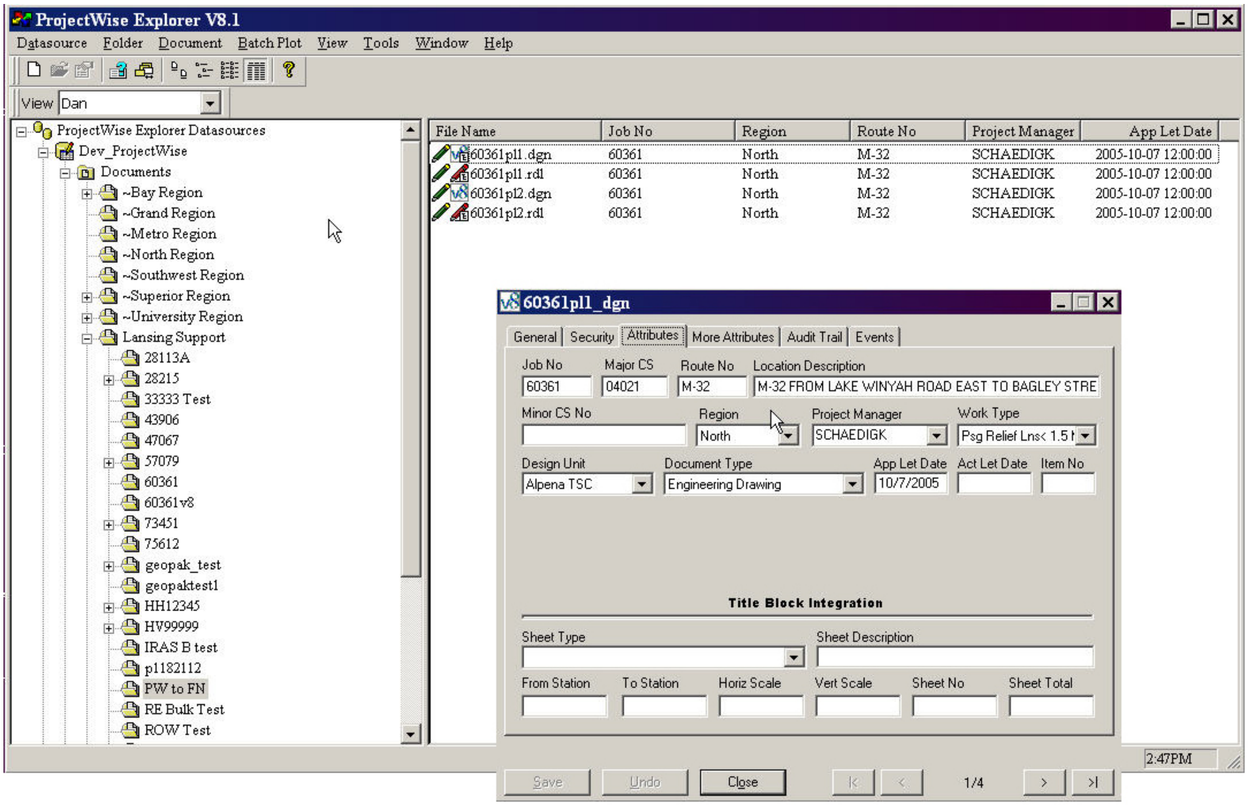


Figure 7. ProjectWise Sample Screenshots (*21*).

TxDOT is currently exploring the use of ProjectWise for management of engineering documents such as Microstation CAD drawing files through pilot implementation. A pilot ProjectWise implementation is the SH 130 design-build project in Central Texas, which is managing over 32,000 files occupying some 22 GB of hard drive space (*21*).

TxDOT is evaluating the use of ProjectWise for engineering drawing file management, and all efforts related to data architectures, models, specifications, file structures, and naming convention are either in their infancy or have not yet begun.

San Antonio District FMS

The San Antonio District File Management System (FMS) is a systematic arrangement of folders, files, and procedures to create uniformity in project development and documentation. 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 1). To minimize erroneous modifications, only the file manager can access the primary files.

Table 1. FMS Primary File Types *(22)*.

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, & 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 & summaries

TXDOT USE OF GEOGRAPHIC INFORMATION SYSTEMS

There are several geographic information system (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 the Texas Natural Resources Information System (TNRIS) hosts.

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 Texas reference marker (TRM) *(23)*.

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 GIS Architecture and Infrastructure Project (GAIP) *(24)*. GAIP includes the establishment of a roadbed LRS, a roadbed specific base map, required computer platforms, 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.

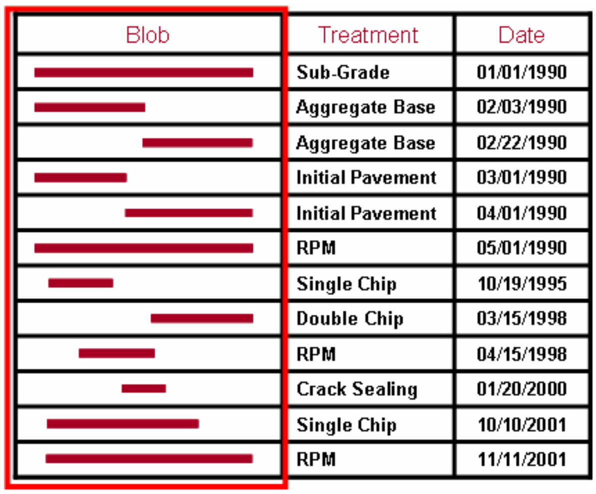
The GAIP architecture replaces the traditional method of linear referencing or dynamic segmentation with a method called dynamic location (Figure 8). With dynamic segmentation, feature attribute tables defined by from/to values are necessarily associated with a route cartography. An attribute query results 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. When there is a feature change (either spatially or non-spatially), the system "retires" the old feature and, as needed, generates a new feature with new attribute values. Retiring a feature does not mean the system deletes the feature from the database. Instead, the system populates a time stamp indicating the completion of the life cycle for that feature.

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).

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 (NGS) along with the logical and physical data models for the NGS *(23, 26)*. TxDOT classifies NGS components according to jurisdiction, engineering function, and cartographic support. By definition, the NGS 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. The current standard of accuracy is that each NGS segment should be within ±10 percent of the actual roadbed centerline. The GIS Technical Architecture document covers all aspects of the TxDOT GIS infrastructure (i.e., GAIP) such as technical architecture, software, hardware, database, and spatial data components *(27)*. It also describes the data path, configurations, policies, standards, and procedures for supporting and maintaining the business system.

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



"GAIP" Spatial Object Approach

Figure 8. Traditional and GAIP Approaches to Linear Referencing (*25*).

Main Street Texas (MST)

There are several ongoing efforts at TxDOT to make GIS data available to internal and external users using web-based mapping technology. The effort most relevant to this research is an application called Main Street Texas (MST) (*28*, *29*, *30*). MST is a web-distributed, spatiotemporal, integrated information system that uses custom software and a suite of database gateways to gain access to multiple database platforms and locations in addition to existing TxDOT GIS Oracle data (*27*, *24*). The MST web-based portal uses location to query, correlate, and organize disparate data (e.g., spatial, relational, sequential) and enables relational and spatial intersect queries for the production of tabular and mapping reports (Figure 9). MST also supports Online Transaction Processing (OLTP) and Online Analytical Processing (OLAP) to ensure data currency and allow users to perform runtime ad hoc queries (*27*). 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, ROW maps, and primary survey controls (*31*).

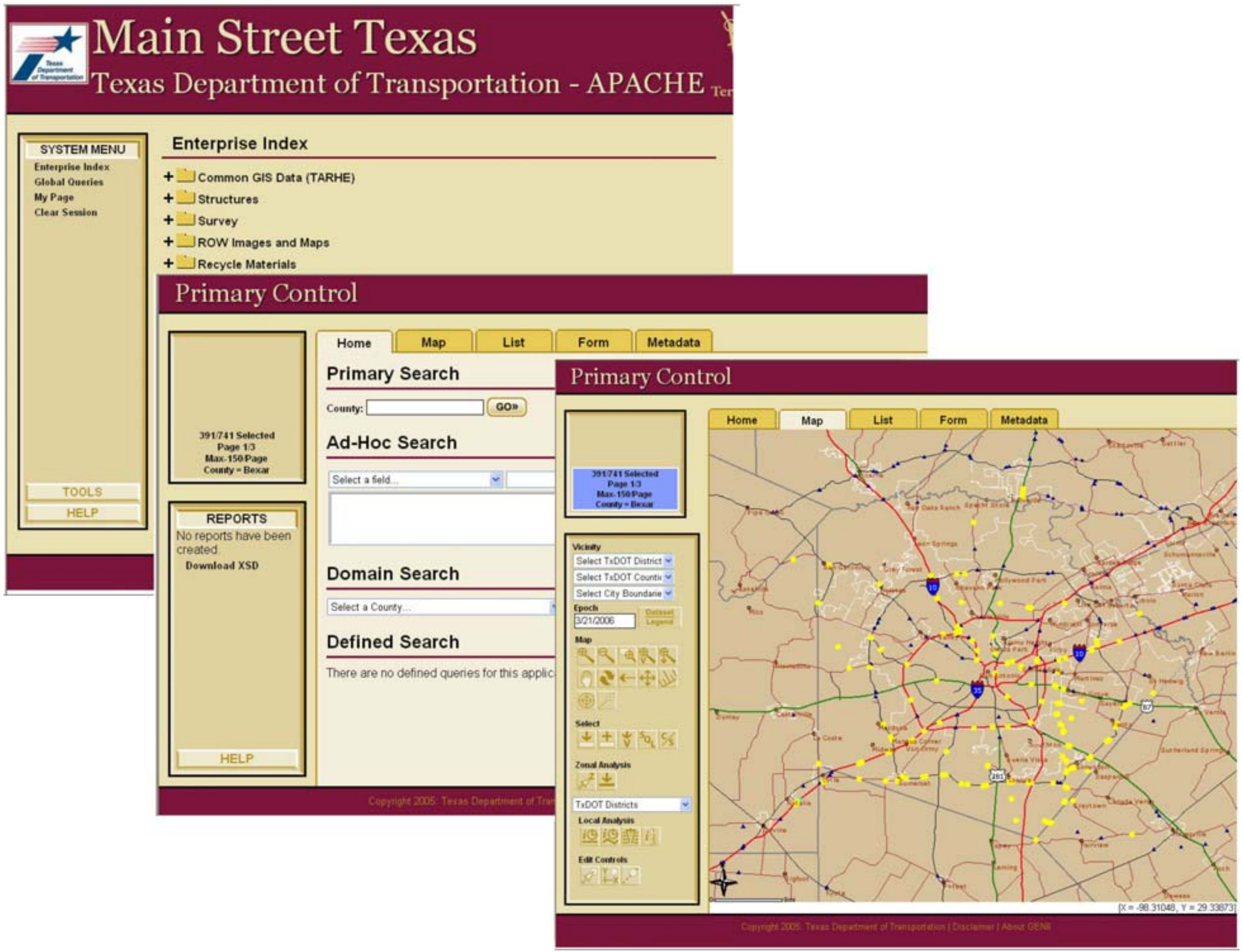


Figure 9. Main Street Texas Sample Screenshots (*32*).

San Antonio ROW Map Locator Application

Recently, the San Antonio District developed a web-based application to view ROW maps in order to facilitate access to that information, particularly by surveyors (*33*). The web interface includes an interactive map that enables users to navigate and zoom to any part of the district (Figure 10).

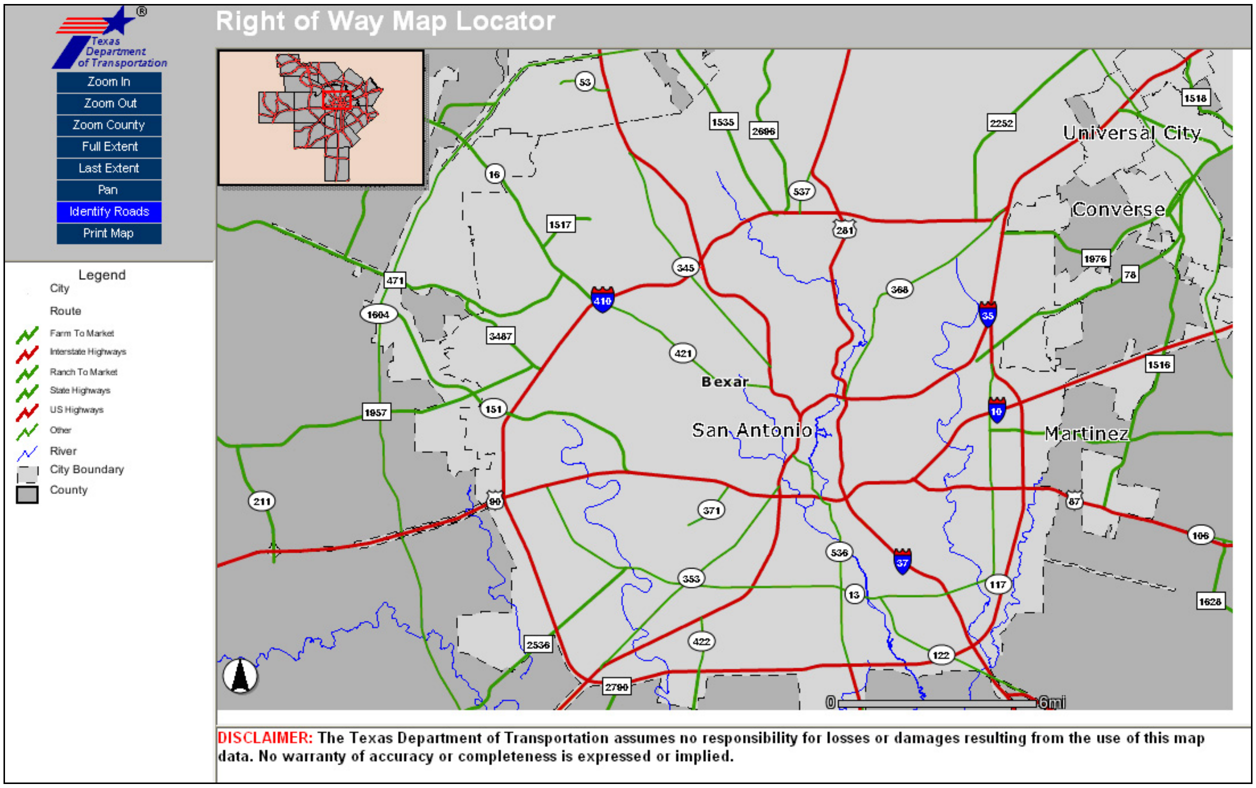


Figure 10. San Antonio ROW Map Web Interface Screenshot (*33*).

Clicking on a control section enables users to download or view PDF or TIF ROW map images (Figure 11). The application provides ROW map viewing, printing, and downloading, as well as multi-scale roadway centerline views in a point-and-click environment that automates the process to provide ROW map information to the public. TxDOT is currently expanding the ROW map application to other districts. The ROW map application is available both on the San Antonio District Internet page and on the MST portal.

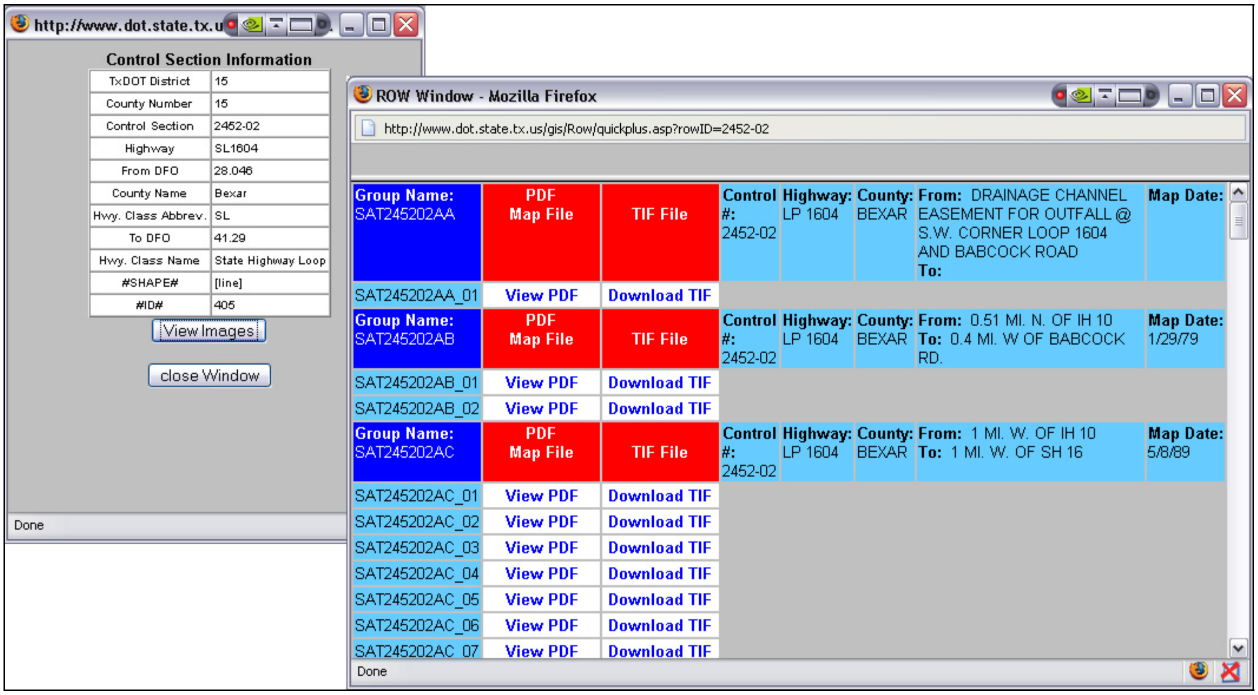


Figure 11. San Antonio ROW Map Road Query (*33*).

CHAPTER 3. DEVELOPMENT OF TXDOT UTILITY RELOCATION BUSINESS PROCESS MODEL

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, ROW 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 a task identification. In addition to the task code, the manual provides a title, description, pertinent project types, responsible party, sub-tasks, helpful suggestions, critical sequencing, and reference material. The manual also includes a chart that provides an overview of the PDP (Figure 12).

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, 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.

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 as "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 specific “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.

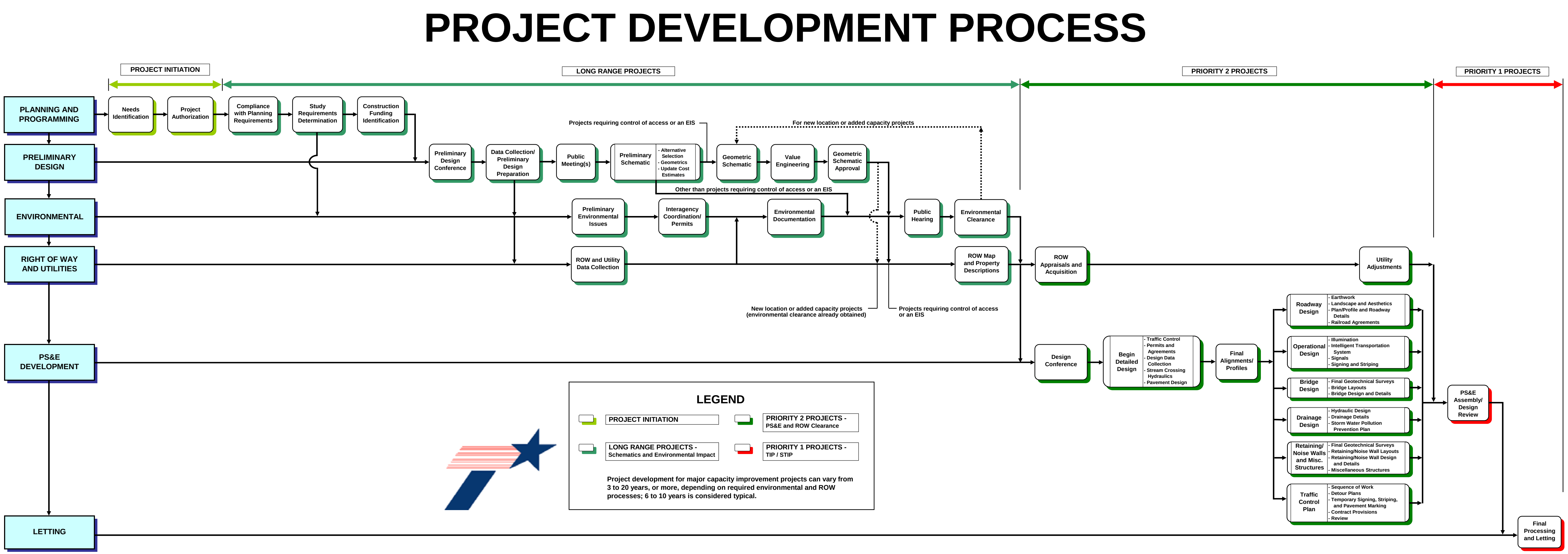


Figure 12. PDP Manual Diagram (adapted from *34*).

Another, significant issue when using the above manuals are frequent differences in the process descriptions. A comparison of descriptions and recommended attendees using the above example "Design Conference" illustrates this issue (Table 2).

Table 2. 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, ROW, 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 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 that these tasks should be completed in sequence, 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 of the same chapter, “Drainage Design.” 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 category “Helpful Suggestions.” In other cases, information provided in the “Critical Sequencing” category appeared to rather be a sub-task 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.

UTILITY COORDINATION AT TXDOT DISTRICTS

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. Specifically, 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 about issues, 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, 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 it 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 ROW of a planned project unless the utility signs a letter of intent that they will move out of the ROW 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

District officials two major utility coordination issues, one being utilities that cannot adjust in time for letting, and two being 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 at the Austin District. 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 ROW 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 ROW parcels over multiple Construction CSJs. This problem may occur if TxDOT splits up large projects in phases with different Construction CSJs while maintaining one ROW CSJ. Officials mentioned that it is now a statewide mandate to adjust the ROW 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 ROW section does not know what happens to new utility installations after as-builts are provided, nor does ROW 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 for each project segment of the SH 130 project consisting of three parts: (1) Identification, (2) Assembly and Agreement, and (3) Construction and Payment. 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 ROW 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, owner; executed, developer; Texas Turnpike Authority (TTA) approval; joint-use agreement, owner; joint-use agreement, 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 tract 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
- 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 ROW section typically learns about new projects during annual meetings with each of the design sections and area offices that update what is on the UTP and the TIP, and what the letting schedule is. Increasingly, the advanced planning group notifies ROW 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, 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 ROW 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 district, area office, division, and the utility. The area offices have been using utility permits for non-reimbursable installations in the past and are now transitioning toward joint-use acknowledgements.

The typical process of adjusting utilities includes the following steps:

1) Find out what utilities are installed within project limits.
2) Determine ownership and contacts for utilities involved in the project.
3) Determine which lines are in conflict and will have to move.
4) Determine available space for utilities to move.
5) Examine adjustment constructability and develop timeframe and set of plans.
6) Determine who has to go where, who has to move first, and who has to go how deep.

In addition, reimbursable adjustments need a ROW release. Non-reimbursables typically do not involve the purchase of new ROW, therefore they do not need a ROW release. The district office enters all reimbursable contracts into ROWIS. For non-reimbursables, 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 it is a pay item, 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 ROW 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 ROW 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 ROW line. If the ROW 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 which 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, ROW purchases, ROW 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.
- Mechanism to show the conflict location.

Utility Coordination at the Houston District Office

Utility Coordination Process

Utility and ROW 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 ROW 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, ROW certifications certify that all ROW parcels have been acquired for a defined project section except for those listed on the certification. The ROW 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 occurs 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:

1) Preliminary Design
2) 30 percent Design
3) 60 percent Design

4) 90 percent Design
5) 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 is 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 is 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 considerable 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 it from the consultant. The district collects a wealth of utility data, but this data is 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 (*12*). 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 (*35*). 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 (*36*). 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 MS 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 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 ROW 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 the Utility Installation Review (UIR) system. 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:

1) ROW Release and UCSJ Request (Design, ROW, and ROW Division)
2) Alternate Procedure (Design, ROW, and utility)

3) Determine Conflicts/Develop Utility Plans (Design, ROW, and utility)
4) Agreement Assembly (ROW and utility)
5) Agreement Assembly Review (ROW and utility)
6) Agreement Assembly Review and Approval (ROW Division)
7) Utility Adjustment (utility)
8) Billing Assembly (ROW, ROW Division, and utility)
9) Billing Assembly Review (ROW, ROW Division , and utility)
10) Payment Process (ROW, 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 ROW needs to complete are:

- Develop the ROW map, which is often outsourced to consultants.
- Coordinate environmental clearance.
- Establish a ROW account in the ROWIS database.
- Coordinate project limits with design staff.
- Prepare Advanced 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 ROW 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 ROW map at the start of a project. To develop the map, consultants need information on project limits and parcels, the existing ROW 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 *(35)*. 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 *(36)*.

A further issue at the district that has surfaced in the past is a problem with construction and ROW CSJs. In the past, ROW 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 ROW and construction CSJ numbers, mandated by the ROW Division. The district now uses one ROW CSJ for each construction CSJ number (Figure 13). According to the district, the change to one ROW CSJ for each construction CSJ has been well received by auditors, utilities, and TxDOT staff.

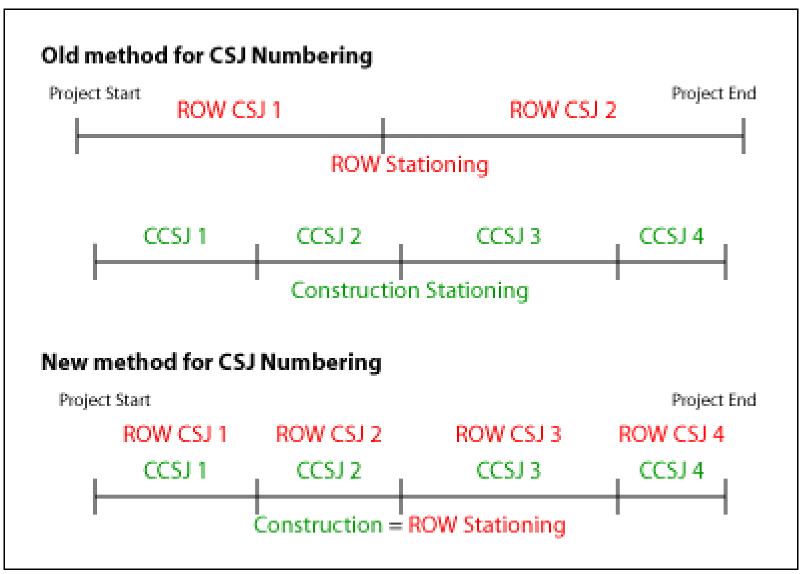


Figure 13. Use of Construction and ROW CSJ Numbers.

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;
- ROW limits;
- utility company;
- U-Number;
- Construction-CSJ; and
- ROW-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 ROW section would like notifications about new projects as early as possible. Occasionally, the ROW 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 ROW section would like to receive notifications every time a new project is entered into DCIS, which would ensure that they are aware of projects that may involve utility adjustments.

The ROW section would prefer if the district would use only one permit for non-reimbursable utility installations. That could be the JUA and would require a change in the UIR system. ROW could get involved in the process but would rather the Maintenance section forward the agreement directly to the division, maybe using the existing UIR system. An issue here could be the need for signatures. If ROW would need to get involved, they would need one set of plans, either paper copies or electronically 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.

BUSINESS PROCESS MODEL DEVELOPMENT

Concisely, the PDP Manual explains what activities a project may entail, but includes only limited information on how these activities relate to each other or how separate groups within TxDOT should interact. Although it is commonly known that Planning and Programming is followed by Preliminary Design, PS&E Development, and finally Letting, it is less clear where Environmental and Right of Way and Utilities fit into the process. It is also less clear how and at what times these different TxDOT entities should interact. With these limitations in mind, the researchers used the information to first develop a business process model for the relocation of utilities at TxDOT.

The researchers started by translating the PDP Manual into a very extensive business process model that included all approximately 200 PDP tasks. Due to a lack of information on dependencies this model resulted in a long chain of activities with little concurrent activities and few links between different TxDOT groups. Most task sequence information given in the PDP manual consisted of statements such as tasks are provided in “approximately chronological order.” Clearly, the first model 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.

In the next step, 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) with the current UCMP flowchart. With the help of the research advisory panel, the researchers were able to validate the chart activities and relationships, identify dependencies, and outline activity pre-requisites. The researchers were then able to gradually integrate those tasks from the PDP Manual that had an apparent relation to the TxDOT utility relocation process. The result of this effort was an integrated PDP/UCMP utility relocation business process model.

IDEF0 and IDEF3 Business Process Models

The researchers developed the first business process model using Computer Associates AllFusion Process Modeler, which is a companion to the Computer Associates AllFusion ERWin Data Modeler, the standard data modeling tool for logical data models at TxDOT. AllFusion Process Modeler uses the 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” (*37*).

IDEF0 consists of a Top Level Context Diagram that is decomposed into sub-functions on child diagrams. Each child diagram that entails another decomposition or child diagram is also a parent diagram for its child diagram. Diagrams consist of boxes that represent functions and arrows that have different roles depending on the position where the arrow attaches to a box (Figure 14, Figure 15, and Figure 16).

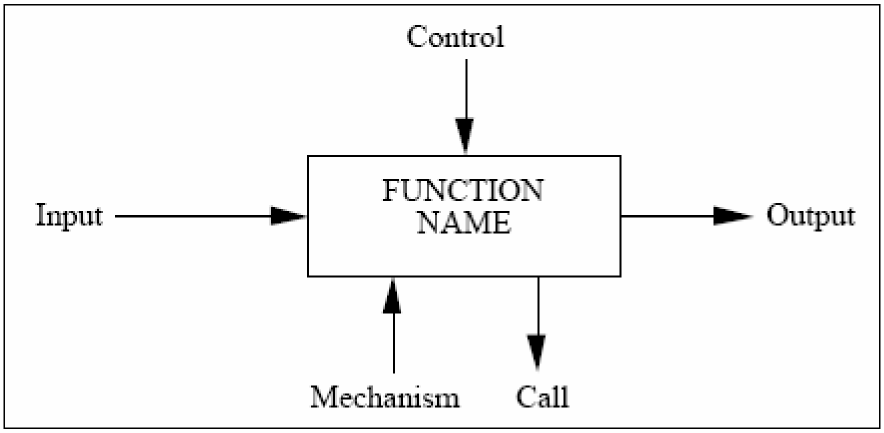


Figure 14. Function Box and Data/Objects Arrows.

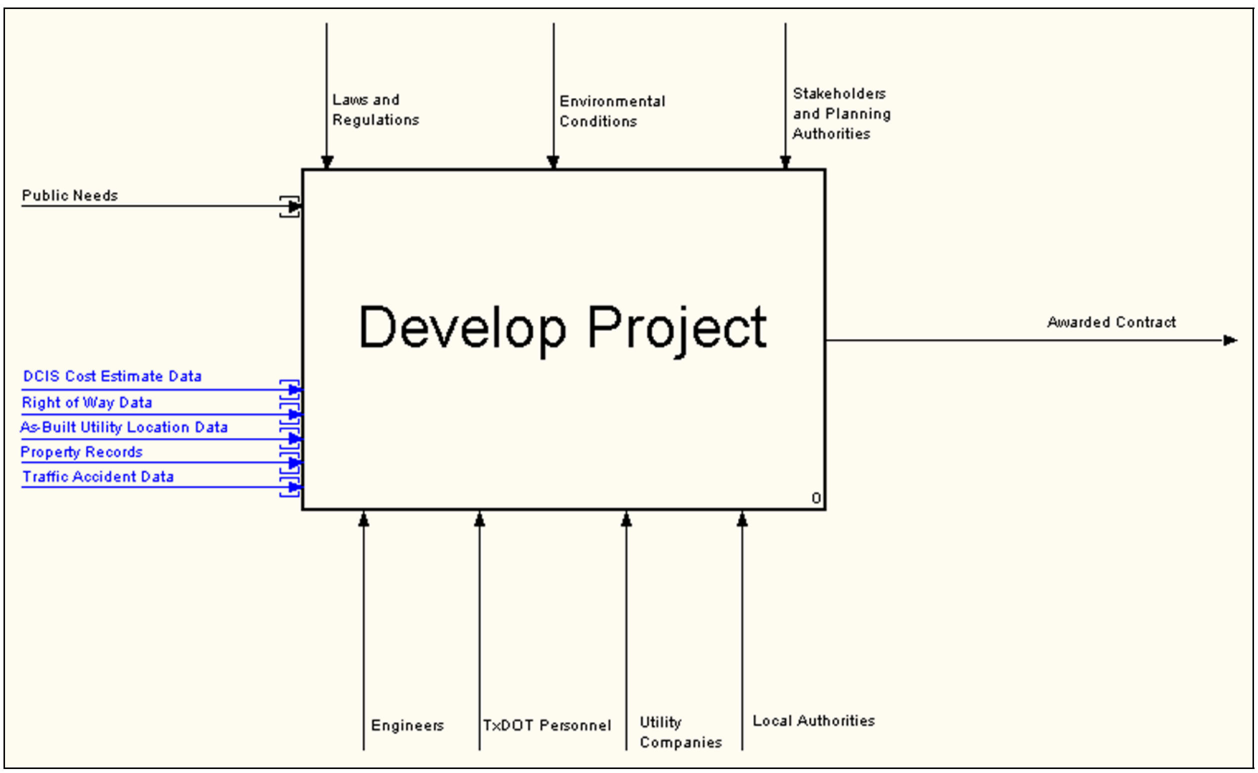


Figure 15. TxDOT PDP Top Level Context Diagram.

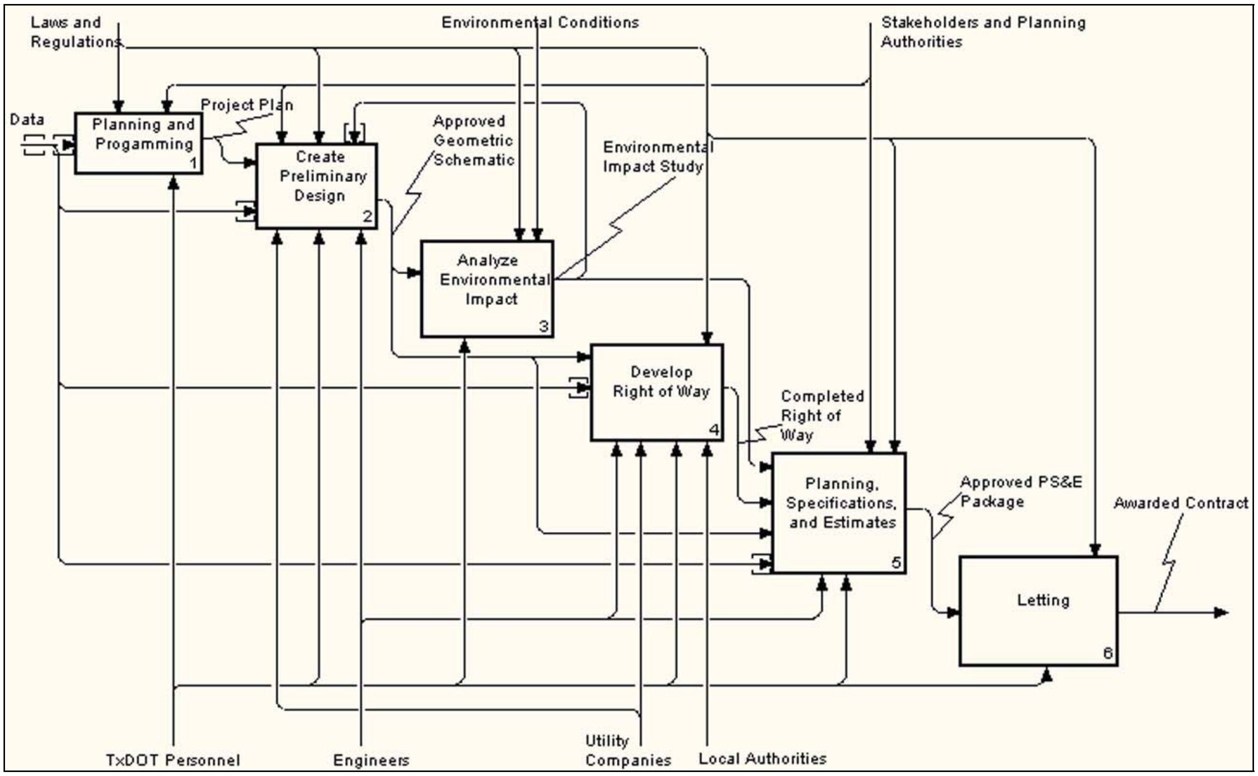


Figure 16. TxDOT PDP Decomposition Child Diagram.

IDEF3 is a technique to capture, manage, and display process-centered knowledge in a form of scenarios that are displayed as process schematics *(38)*. 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 this business process modeling notation is that all diagrams fit on letter sized sheets. For example, the PDP/UCMP Model that the researchers developed in IDEF0 format consisted of about 70 pages. Although this format makes it very easy to reproduce the model, the researchers quickly realized that the notation makes it difficult to understand the model relationships and discuss the model with practitioners that are unfamiliar with the notation. The researchers found that the charts were not fitting to receive useful feedback from practitioners. Researchers noted that users not familiar with the notation became lost in the hierarchical structure of parent and child diagrams. 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. As a result, the researchers decided to use Microsoft Visio to produce a more user-friendly business process model. Using Visio, the researchers were able to show the whole network on a (very large) 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.

Visio Business Process Models

The research team developed separate business process models in Microsoft Visio for the TxDOT Houston District and the TxDOT San Antonio District that focused on precedence of activities. The models consisted of boxes, representing activities, and arrows, representing outputs from the originating activity and inputs into the receiving activity. The business process models turned out to be very large drawings, e.g., the Houston model is about 3 feet by 15 feet at 100 percent resolution. The researchers also produced the business process model of the Houston and the San Antonio Districts in a different view called a swim lane diagram. Whereas the "normal" business process model arranges activities by precedence to display a chain of events, a swim lane 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 with typically longer arrows between activities, which may to some reviewers create the impression of a more complex model. The advantage of a swim lane diagram is that activities are sorted into the horizontal swim lane of the entity that performs the activity, and it becomes immediately evident when a certain entity becomes involved in the process. The overall size of the model, however, is equally large. Therefore, the researchers did not include the swim lane diagrams in this report. For inclusion in this report, the research team created a high-level view of the business process that combines both districts (Figure 17).

Visio Data Flow Diagram

Some of the activities that the research team described in the business process model have data attached to them that is created, read, updated, or deleted. Data flow diagrams (DFD) are useful to show only the flow of data or documents between activities and are therefore useful for the development of the information system. Similar to the IDEF0 notation, DFDs model systems as a network of activities connected by arrows that represent the movement of data between activities. Figure 18 shows the DFD of the system prototype.

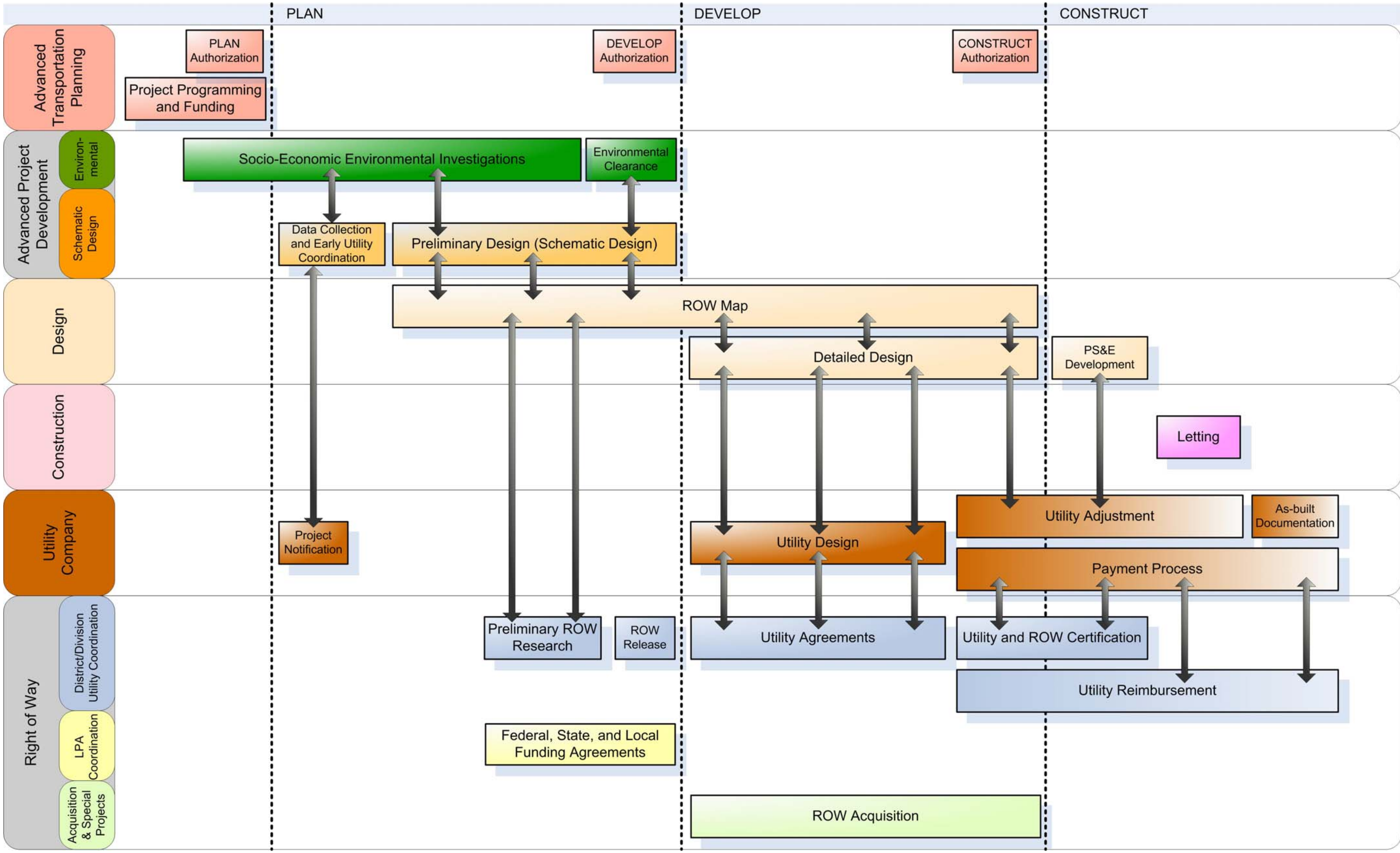


Figure 17. High-Level Business Process Model of Utility Relocation in the TxDOT Project Development Process.

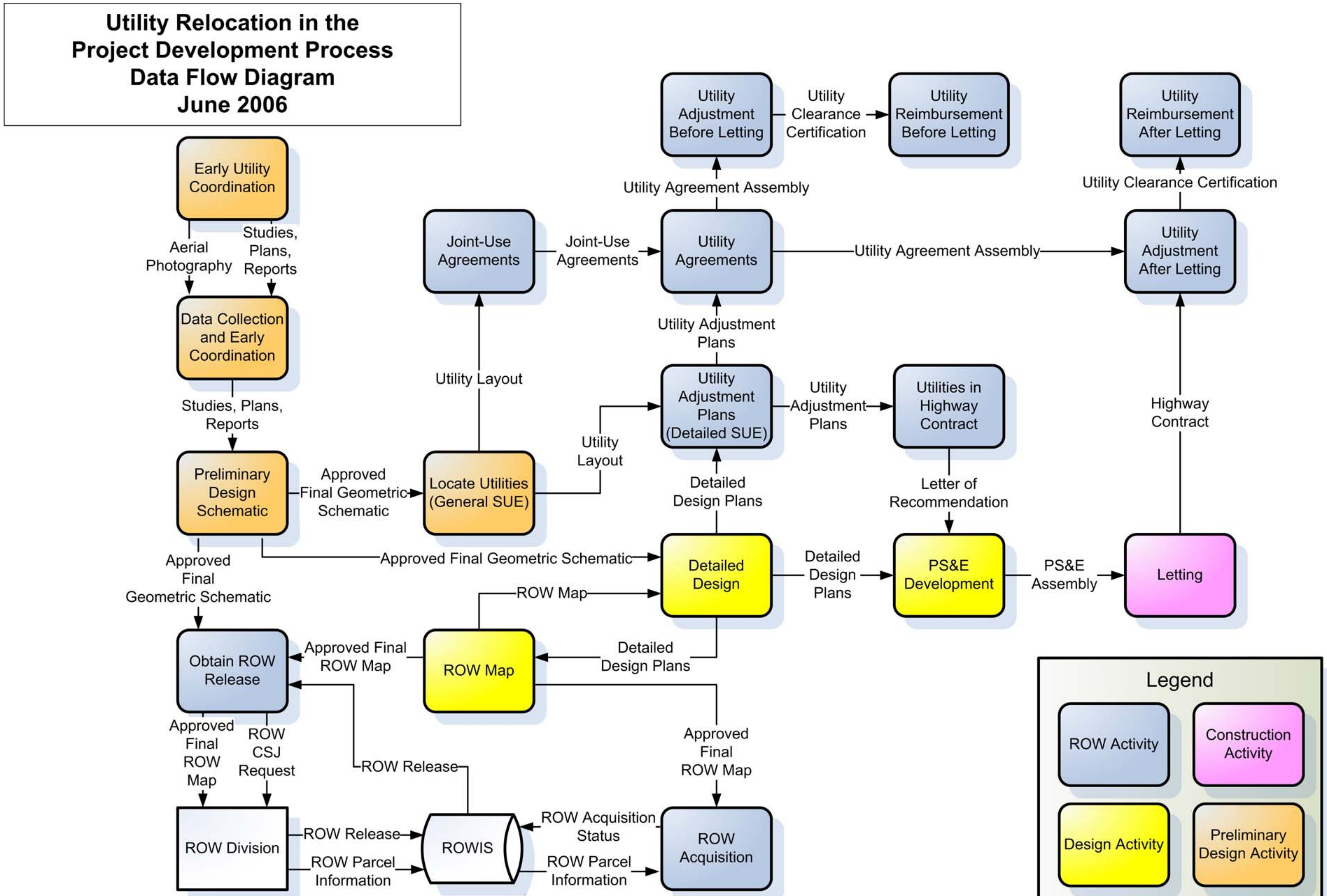


Figure 18. System Prototype Data Flow Diagram.

CHAPTER 4. UTILITY AND UTILITY CONSULTANT'S PERSPECTIVE OF THE UTILITY RELOCATION PROCESS

INTRODUCTION

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.

METHODOLOGY

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 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. TxDOT activities in the model are blue, utility activities are grey.

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 compare 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 joint-use acknowledgement. Either the consultant or the utility company can complete the agreement. The utility company submits the joint-use agreement 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 while 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 ROW 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 ROW line and a depth below the new grade. Utility companies reported three approaches to determine a utility's offset from the ROW 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 ROW 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 "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 5. DEVELOPMENT OF DATA MODELS FOR UTILITY RELOCATION PROTOTYPE

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 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.

In an effort to give the prototype utility conflict management system a more convenient name the researchers considered many alternatives. In response to a suggestion by the research advisory panel, the preliminary name of the prototype is "Utility Accommodation and Conflict Tracker" (UACT).

UACT USER REQUIREMENTS

The research team built the following list of user requirements from feedback received from TxDOT officials and 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 ROW 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 format.
- 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 was able to develop 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

- Manage TxDOT and utility company contact directory:
  - Allow users to update their profile
- Provide a customized interface for each user group:
  - TxDOT, and
  - utility company representative.
- 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:
  - administrator,
  - user, and
  - guest.
- Allow users to edit which data items are shown on their interface.
- Provide a project summary screen that shows current project progress:
  - Timeline and calendar of past and upcoming milestone dates.
- Manage and view utility facilities within each project's limits:
  - Assign documents or schematics to a utility facility.
  - Maintain owner and representative information for each utility facility.
  - Maintain conflict and adjustment status for each utility facility.

Document Exchange and Storage

- Upload, manage, and display CAD files:
  - Design plans and schematics:
    - Preliminary and detailed design.
  - Surveying data:
    - SUE surveys, and
    - topographic surveys.
  - Utility plans and schematics:
    - utility as-builts,
    - utility layouts, and
    - utility adjustment plans.
- Allow the exchange and coordination of utility-related documents and schematics between utility companies and TxDOT officials.

Communications

- Allow users to leave comments about documents or utility facilities.
- Provide a project calendar.
- Customizable e-mail notifications of upcoming events, new messages, and new documents.
- Provide management system for events:
    - Schedule and manage events.
    - Specify required or recommended attendance.
    - Associate documents with past or upcoming meetings:
        - Meeting agenda, meeting minutes, attendance list, etc.
    - Send out e-mail notifications of upcoming events.

Reporting

- Provide automated document generation:
    - utility conflict list,
    - letter of no conflict,
    - reimbursable utility adjustment billing reminders (may require ROWIS link),
    - utility clearance certifications, and
    - triple-zero special provisions.

Visualization

- Allow visualization of Microstation plot/composite files with attached reference files:
    - design schematics (preliminary design),
    - detailed design plans,
    - utility layouts,
    - utility adjustment plans,
    - SUE survey data,
    - other survey data,
    - current and proposed ROW limits, and
    - ROW parcel information and acquisition status.

Compatibility with Existing and Future TxDOT Information Systems

- Data architecture and structures compatible and integratable with TxDOT Relational Database Management System applications (e.g., ROWIS, FileNet, ProjectWise, and GAIP GIS):
    - Common use of relational logical/physical database models.
    - Consistent class of Relational Database Management Systems (RDBMS).
    - Consistent metadata fields (e.g., dates, authors, etc.) and data types (e.g., integer, string, date, etc.).
    - Consistent file folder naming conventions.
    - Consistent entity, relation, and attribute naming conventions.
    - TxDOT CAD level and cell library compliant.
    - TxDOT data architecture standard compliant.

    - Relations linking project data with application data.
    - Developed in context of application data models (if available).
- Data architecture and structures consistent with TxDOT ADABASE applications (e.g., DCIS):
    - Consistent naming, metadata fields and data types for data entities and associated attributes.
    - Data warehousing for data updates and downloads.
    - Interfacing touch points between ADABASE and relational data.
    - Developed in context of application data models (if available).

UACT SYSTEM REQUIREMENTS

Based on the list of functional requirement for the prototype data exchange system and feedback from the advisory panel, the researchers developed a list of system requirements for software, interface, document exchange and storage, communications, reporting, visualization, compatibility with existing and future TxDOT information systems, and hardware.

Software

- Operating System: Microsoft Windows Server 2003 Standard (purchased through other project).
- Web Server: Microsoft IIS with .NET Framework 2.0 (purchased through other project).
- Database: Oracle Database (purchased through other project).
- ArcIMS, ArcSDE (purchased through other project).
- AdLib Express (purchased through other project).
- AutoVue SolidModel (purchased through other project).
- Softartisans FileUp Professional (purchased through other project).
- New Atlanta ServletExec SE 5.0 ISAPI.
- Visual Studio .NET 2005 (purchased through other project).
- Macromedia Studio (purchased through other project).

Interface

- Compliant with HTML or XHTML markup languages.
- Compliant with Cascading Style Sheets.
- Compliant with W3C Web Content Accessibility Guidelines.

Document Exchange and Storage

- Microstation to PDF conversion: Adlib Express (purchased through other project).

Communications

- No additional software needed.

Reporting

- No additional software needed.

Visualization

- CAD file display alternatives:
    - Arc IMS (purchased through other project).
    - Java CAD viewer:
        - Bentley Publisher
        - Cimmetry AutoVue Basic Client/Server Edition
    - Bentley Viewer

Compatibility with Existing and Future TxDOT Information Systems

- No additional software needed.

Hardware

- Database Server (purchased through other project):
    - Intel Xeon processor 3.2 GHz
    - 2GB RAM, expandable to 8GB
    - 1 TB of SATA storage
    - Windows Server 2003 R2 Standard with 5 Client Access Licenses
- Web Server (purchased through other project):
    - Intel Xeon processor 3.6 GHz/2MB Cache
    - 2GB RAM, expandable to 8GB
    - 1 TB of SATA storage
    - Windows Server 2003 R2 Standard with 5 Client Access Licenses

UACT DATA MODEL

The researchers developed a logical model for the utility data exchange system prototype's database using Computer Associates AllFusion ERWin Data Modeler software. The development of the logical and physical model as well as the data dictionary followed the standards that TxDOT provided in version 3.0 of the TxDOT Data Architecture Manual *(39)*.

For convenience, the researchers divided the model into six subject areas: Project, Event, Document, Permissions, UIR Company User, and UIR TxDOT User, shown in Appendix B. The following provides a description of the main entities and relationships in each subject area.

Project Subject Area

The three main entities of the project subject area are PROJECT, UTILITY FACILITY, and CONFLICT. The PROJECT entity stores information about TxDOT construction projects. In the next development phase, these data will be retrieved from a TxDOT database, such as DCIS or ROWIS, to ensure correctness and to eliminate data duplication. Since the research team does not have access to either TxDOT information system, the researchers will simulate the connection to a database that contains sample project data. The UTILITY FACILITY entity enables users to maintain an inventory of utility facilities for each PROJECT. The CONFLICT entity stores records of instances where a UTILITY FACILITY is in conflict. A TxDOT user may indicate whether a CONFLICT will be solved through a UTILITY ADJUSTMENT or a design modification.

Event Subject Area

The event subject stores a history of changes to critical information in the data model. The system can record the time of the action, the user that performed the action, the type of action, and, in some cases, the data included in the action. For example, a user may create, revise, or annotate a DOCUMENT. In the case of an annotation, the system creates a REMARK record to store a user's comment. In the case of a revision, the system keeps a link to the old version of the document. Any event may have an associated REMARK to enable users to provide a reason for the action.

Document Management System

A DOCUMENT is the representation of a single logical document. For example, meeting attendance lists, construction change orders, or environmental assessments can be DOCUMENTS. 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 CAD file by creating a DOCUMENT COLLECTION, and marking all DOCUMENTS that are part of the collection. Another example for a DOCUMENT COLLECTION would be a list of approved change orders or a list of historical ROW surveys.

When a user uploads a DOCUMENT, the system also creates a SYSTEM FILE. A SYSTEM FILE represents a single file that is stored on the hard disk using a SYSTEM FILE PHYSICAL NAME, which is a unique, system-generated filename. The system keeps the original, user specified filename in SYSTEM FILE LOGICAL FILENAME. When a DOCUMENT is downloaded, it is served to the client as the SYSTEM FILE LOGICAL NAME such that users only see the familiar SYSTEM FILE LOGICAL NAME.

A SYSTEM FILE also records the file type, such as Microsoft Word, Adobe Acrobat, etc. A DOCUMENT also has document type data, which corresponds to document attributes set forth in the TxDOT Information System's Content Services Library Standards, which is stored in DOCUMENT FILENET TYPE (*18*). This entity allows a mapping between the UACT document management system and the TxDOT FileNet document management system.

DOCUMENTS may be associated with other entities through links such as PROJECT DOCUMENT and CONFLICT DOCUMENT. For example, an environmental assessment is associated with a PROJECT, and a utility agreement is associated with a CONFLICT.

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Permissions System

In the UIR system, permissions and access to documents are controlled by individual users that are part of a rigid 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 options that users can distribute a DOCUMENT at any given time 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 is based on strictly defined permissions. Every company and user has a set of assigned FUNCTIONS, which are essentially roles that users take on in a project. For example, a company may perform surveying, utility design, and roadway design. An individual user can perform a subset of FUNCTIONS that his or her company performs. As such, an administrator can assign one or more FUNCTIONS to each company user. Each user is also a member of a PRIVILEGE, which can be thought of as a group of users with similar system access, such as “administrator,” “standard user,” or “guest.”

The final determination of a user’s access level to the application is performed by the CAPABILITY entity. A CAPABILITY is an individual action that can be performed in the application, e.g., “add utility conflict,” “modify utility adjustment,” or “upload surveys.” By default, a user’s set of allowed CAPABILITIES is specified by the FUNCTIONS he or she performs and the PRIVILEGE of which he or she is a member. When a user is set up in UACT, the system prompts the administrator to assign a default PRIVILEGE stored in DEFAULT PRIVILEGE CAPABILITY. However, an administrator can also override these default permissions and assign a user a custom set of allowed CAPABILITIES that are stored in USER CUSTOM CAPABILITY.

TxDOT and UIR Company User

UACT shares 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 may 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 FUNCTION that is mapped to the company in the COMPANY FUNCTION entity. For example, a company may perform project design, roadway construction, and surveying. A certain utility company would only have a single assigned FUNCTION: 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.”

DATA MODEL IMPROVEMENTS IN BETA DEVELOPMENT PHASE

There are two main areas of data model improvement that the research team expects to complete in the beta development phase: extended GAIP support and TxDOT database integration. In order to comply with TxDOT standards and to accomplish the web-based visualization as specified in the project proposal, the PROJECT, CONFLICT, and UTILITY FACILITY entities will be converted to spatiotemporal, GAIP-enabled features. The data model should take advantage of existing TxDOT data. For example, PROJECT data can be pulled from DCIS, and entities such as COUNTY and ROUTE already exist in a usable form.

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CHAPTER 6. DESCRIPTION OF UTILITY DATA MANAGEMENT SYSTEM PROTOTYPE

INTRODUCTION

UACT is designed to maintain a utility facility inventory and track utility conflicts within highway projects. The web-based nature of the application allows easy 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 any task relevant to the role they play in the highway project. The alpha prototype of UACT contains a limited subset of features supported by the UACT data model and envisioned as part of the beta development phase. The upcoming beta prototype development phase will include the integration of GIS visualization support and a user permissions system that will support many kinds of external consultants.

SYSTEM ARCHITECTURE

Experience from the implementation of the UIR system has shown that maintaining a strict workflow-control system for the often district-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.

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.

UACT is a Microsoft ASP.NET 2.0 web application using an Oracle 9i or 10g RDBMS. The system makes use of many new features introduced in the .NET 2.0 framework, including ADO.NET 2.0 data access, forms authentication, membership, profiles, master page templates, and data-bound controls. The application is a three-tiered system, with a data access layer exclusively communicating with the RDBMS, a business logic layer imposing business-specific rules, and the presentation layer handling the display and interface. This architecture is used for its extensibility. For example, the development of a native Microsoft Windows application to interface with the system would require only the development of a new presentation layer. Likewise, changing to a new RDBMS would require only the redesign of the data access layer. Figure 19 provides a diagram of the system architecture.

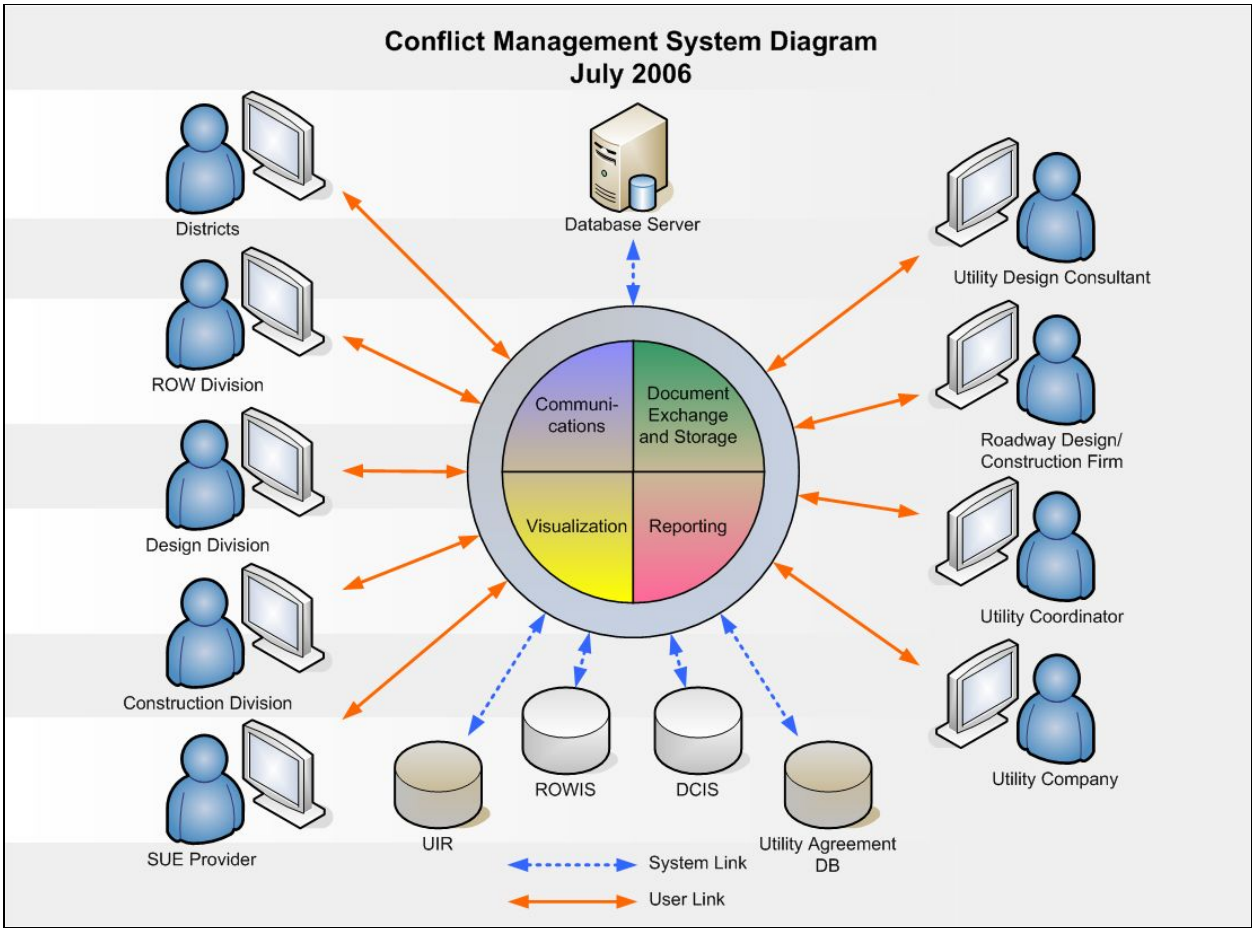

Figure 19. UACT System Architecture Diagram.

ALPHA PROTOTYPE FUNCTIONALITY

This section provides an overview of the capabilities of the prototype alpha version. The UACT system can be accessed using a standard Internet browser. Users can access the main functionalities of the application by clicking on one of the buttons provided at the top of each page of the application:

- Project: the start page that gives an overview of project information.
- Utility Inventory: provides an overview of utilities involved in the project.
- Conflict Tracking: provides an overview of the project's utility conflicts.
- Reporting: provides a tool to create customized reports of the data stored in UACT. This is a placeholder for a component of the beta version of the application.
- Visualization: provides the location of utility conflicts on a mapping component. This is a placeholder for a component of the beta version of the application.
- Calendar: provides a project calendar to schedule important coordination meetings and other dates. This is a placeholder for a component of the beta version of the application.
- Contacts: provides a link to the project contact database that the system shares with the UIR system.

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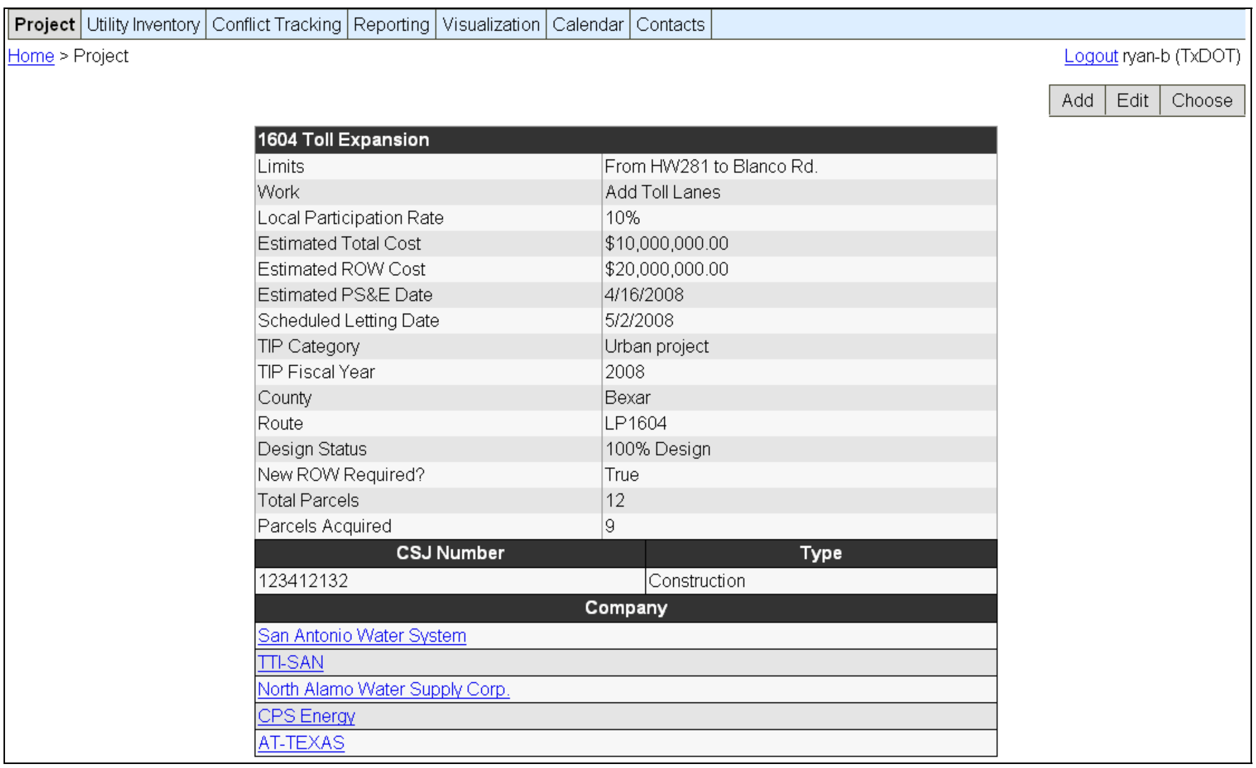
All screens display the user name and affiliation of the user that is currently logged into UACT. Similarly, all screens provide the user access to return to the project summary screen by clicking on the "Home" link in the top left corner. Users can log out of the application on any screen by clicking on the "Logout" link on the top right corner.

Project Summary Screen

The project summary screen provides a set of vital details to all parties involved with the project (Figure 20). Currently, the data that are displayed on the project summary screen are stored within the UACT system. However, UACT is designed to link to either ROWIS or DCIS in an implementation version of the system.

The companies that are listed on the project summary screen are data elements that cannot be retrieved from either DCIS or ROWIS. Instead, all companies must be entered by a UACT or UIR user with adequate project editing permissions, and all companies are entities of the UACT/UIR system. A company can be added, edited, or selected by clicking on a respective button in the top right corner of the project summary screen.



1604 Toll Expansion	
Limits	From HW281 to Blanco Rd.
Work	Add Toll Lanes
Local Participation Rate	10%
Estimated Total Cost	$10,000,000.00
Estimated ROW Cost	$20,000,000.00
Estimated PS&E Date	4/16/2008
Scheduled Letting Date	5/2/2008
TIP Category	Urban project
TIP Fiscal Year	2008
County	Bexar
Route	LP1604
Design Status	100% Design
New ROW Required?	True
Total Parcels	12
Parcels Acquired	9

CSJ Number	Type
123412132	Construction

Company
San Antonio Water System
TTI-SAN
North Alamo Water Supply Corp.
CPS Energy
AT-TEXAS

Figure 20. Project Summary Screen.

Utility Inventory Screen

The utility inventory screen shows a listing of all utility facilities within or around the project limits that system users have entered into UACT (Figure 21). The data may be entered by TxDOT, surveyors, or utility coordination personnel through the UACT application and are stored within the UACT data model. UACT allows system users to associate utility facilities with utility companies. Drop-down lists on the top of the screen allow the user to search the list of utility facilities using an attribute of one of the available parameters. Utility facilities can be added to the system by clicking on the "Add" button in the top right corner of the utility inventory screen.

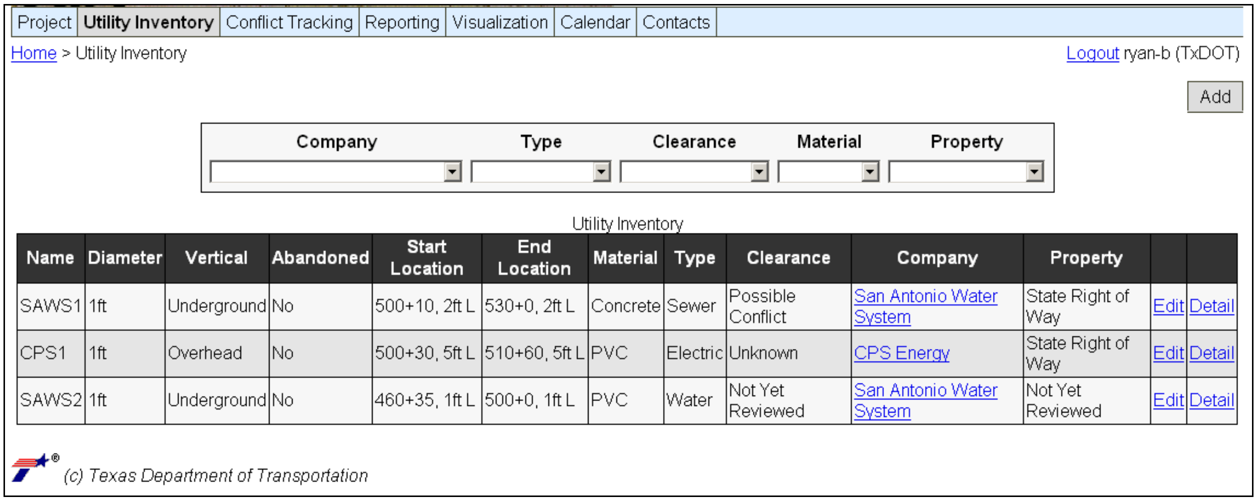


Figure 21. Utility Inventory Screen.

Conflict Tracking Screen

The conflict tracking screen shows a listing of all utility conflicts within or around the project limits that users have entered into the system (Figure 22). The conflict data, like the utility inventory data, is entered by TxDOT, surveying, utility coordination personnel, or other users with appropriate permission levels through the UACT application interface and stored within the UACT data model. Utility conflicts can have one or more affected utilities, i.e., a utility facility can be in conflict with a proposed highway design or with one or more other utilities. Drop-down lists on the top of the screen allow the users to search the list for utility conflicts using an attribute of one of the available parameters. Utility conflicts can be added by clicking on the "Add" button on the top right corner of the conflict tracking screen.

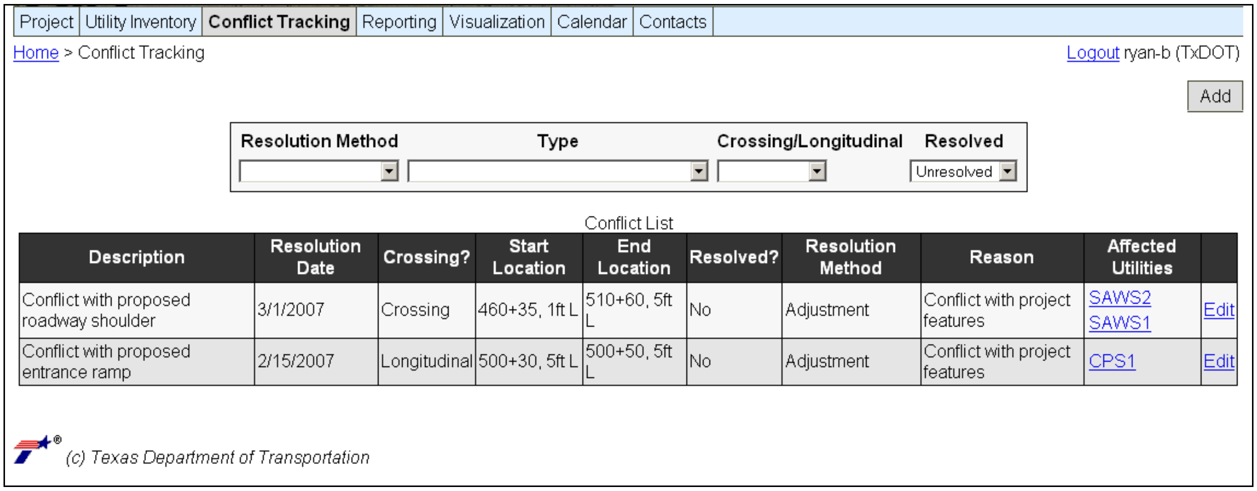


Figure 22. Conflict Tracking Screen.

Contacts Screen

The contacts screen displays TxDOT and utility contacts that are active in any of the UIR or UACT projects (Figure 23). Users with appropriate permissions can add companies or offices using the "Add" button in the top right corner of the screen. Users can sort TxDOT contacts by district, office type, or name. A drop-down list on the top of the page allows the user to limit the display of TxDOT offices to a user-selected district.

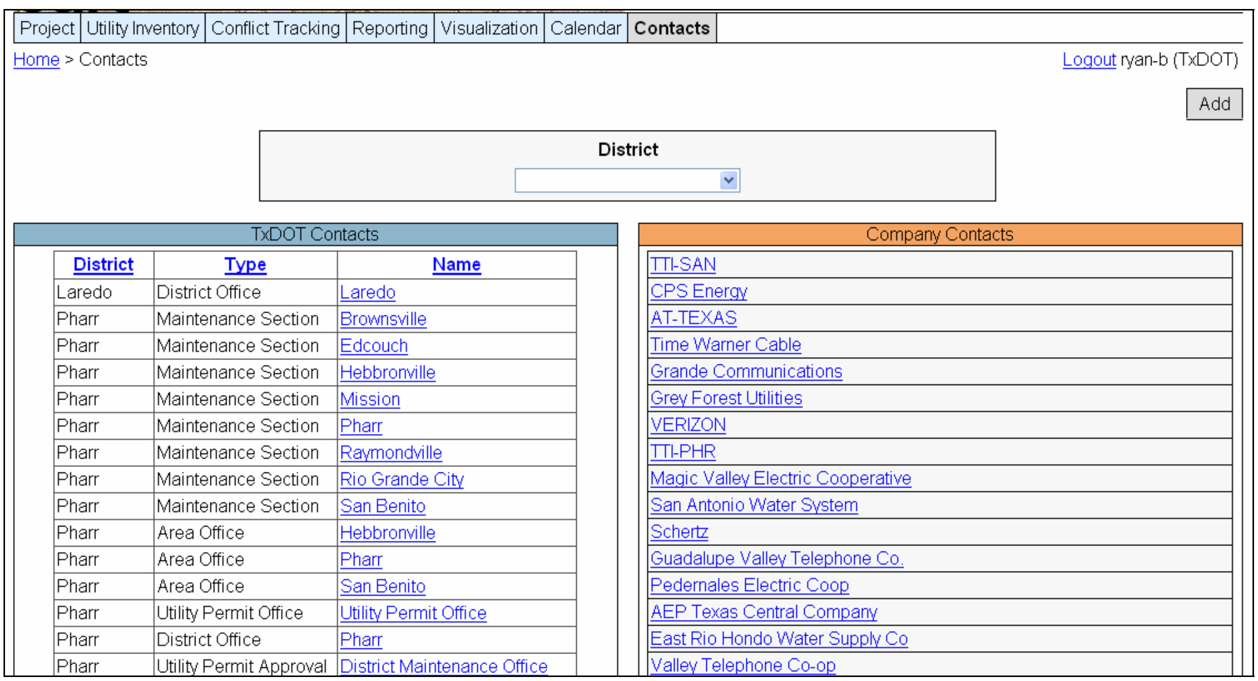


Figure 23. Contacts Screen.

CHAPTER 7. CONCLUDING REMARKS

From the perspective of utility companies, delays in ROW acquisition and frequent changes to the design are the main reasons for delays in utility relocation. Past experience with frequent design changes keeps utilities from getting involved earlier in the project development process, for fear of wasting time, effort, and money on a relocation that a project may no longer need after a design change. If TxDOT could provide design drawings in the earlier stages of a project that are less likely to change, it would encourage utility participation earlier in the process. The utilities' willingness to participate early in the process is also effected by TxDOT's progress on ROW acquisition in a project. Utility companies do not want to waste resources on a relocation effort that eventually will come to a halt because of ROW acquisition delays.

Aerial utility installations currently follow a hierarchy that may cause unneeded delays. TxDOT should investigate if it is feasible to request or require utility companies that own the poles to allow utilities that lease the poles to move their line as soon as they are capable. TxDOT may also consider investigating what changes in the PDP process would be needed to complete utility relocation coordination earlier in the process. Completing the utility relocation coordination earlier in the process will likely save time and resources of all parties involved.

As a proactive approach, TxDOT should consider requiring utility companies to provide to scale as-built design drawings after a completed utility relocation. TxDOT could use these drawings in the utility surveying stage of a future design process. A utility database would allow TxDOT to track utilities and give designers an opportunity to avoid current utilities in the preliminary design process. TxDOT could possibly archive utility drawings submitted during the process using the online data exchange system.

Utility companies could improve current utility coordination by offering more input on known utility locations earlier and pro-actively in the process. Utility companies could provide current drawings to TxDOT designers in an effort to reduce conflicts before coordination meetings.

BETA PROTOTYPE DEVELOPMENT

The researchers will continue to extend the features of UACT in the beta development phase of the project, implementing capabilities supported by the data model, and refining the interface based on user feedback. The UACT data model will integrate the utility feature data model developed for project 2110-01 in order to provide a detailed, reusable, and GAIP compliant utility inventory for highway projects (*40*). The researchers will evaluate in conjunction with the research advisory panel, which entities of the data model should be modified to develop a GAIP compliant data model to store highway projects and utility conflicts. The application will make use of existing TxDOT GAIP data whenever possible. The addition of spatiotemporal capabilities will provide the foundation for the planned utility facility and conflict visualization in the future beta development phase.

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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 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. LOGICAL DATA MODELS OF UTILITY DATA MANAGEMENT SYSTEM PROTOTYPE

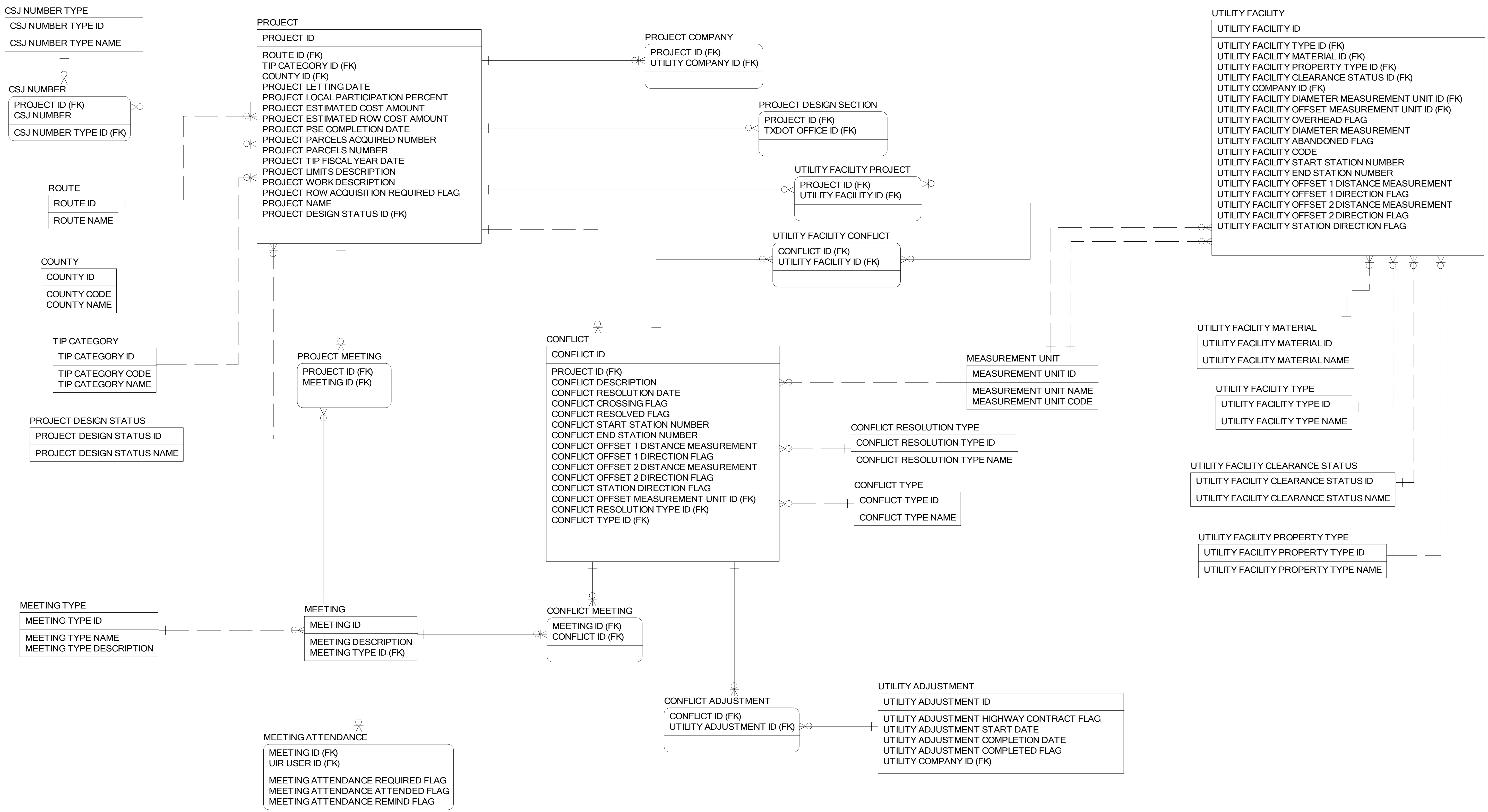

Figure 24. UACT Logical Data Model, "Project" Subject Area.

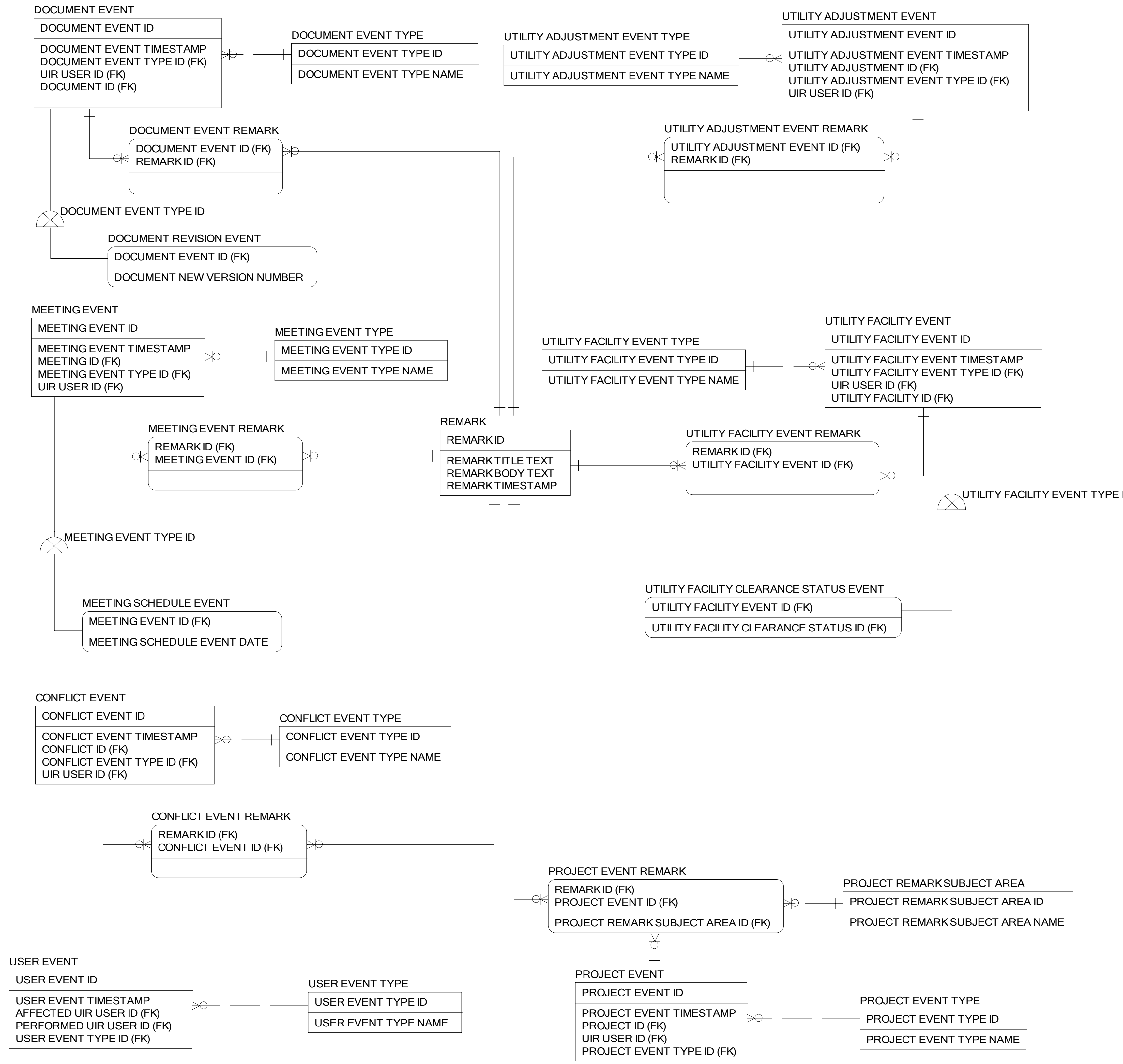

Figure 25. UACT Logical Data Model, "Event" Subject Area.

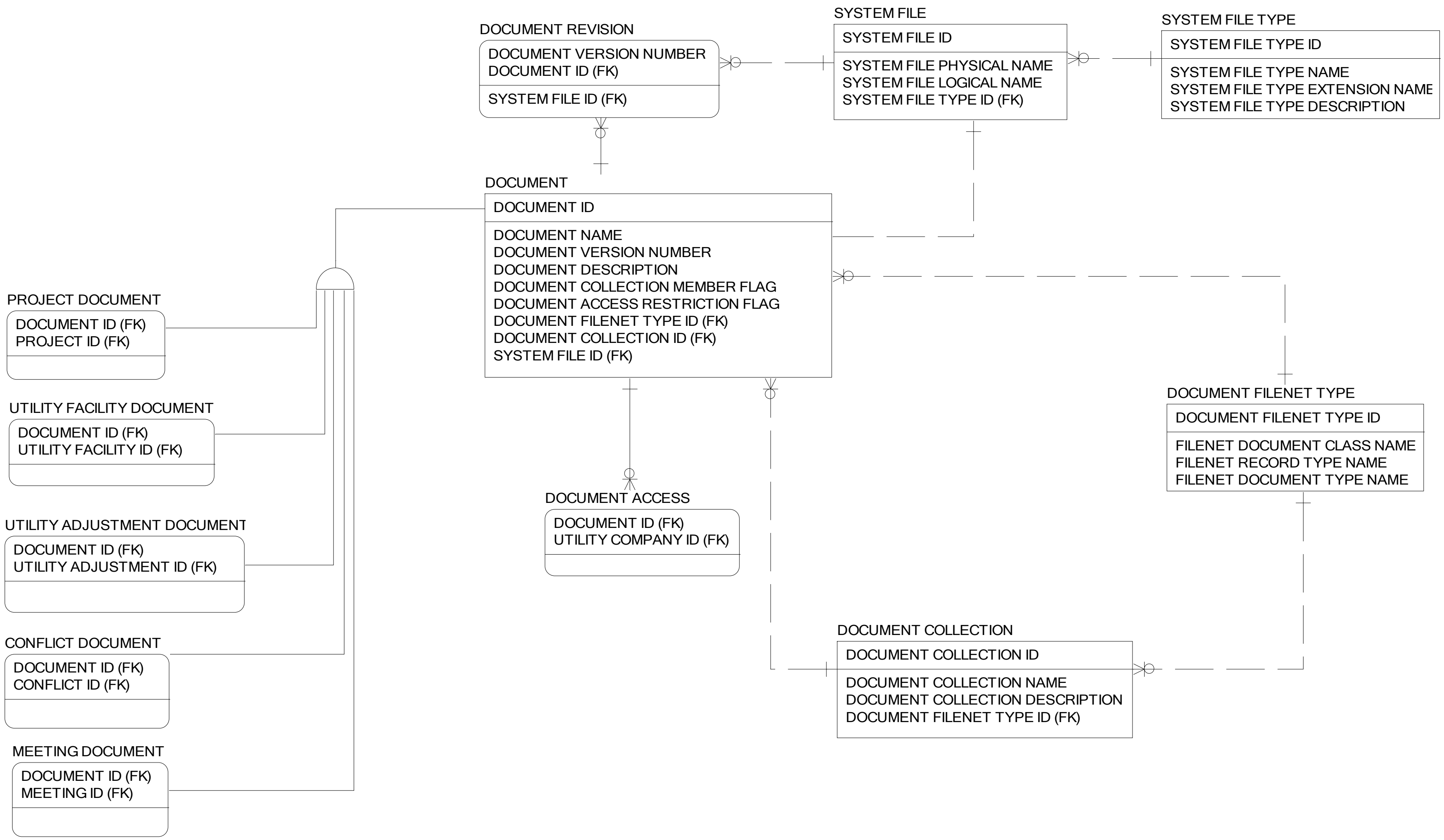

Figure 26. UACT Logical Data Model, “Document” Subject Area.

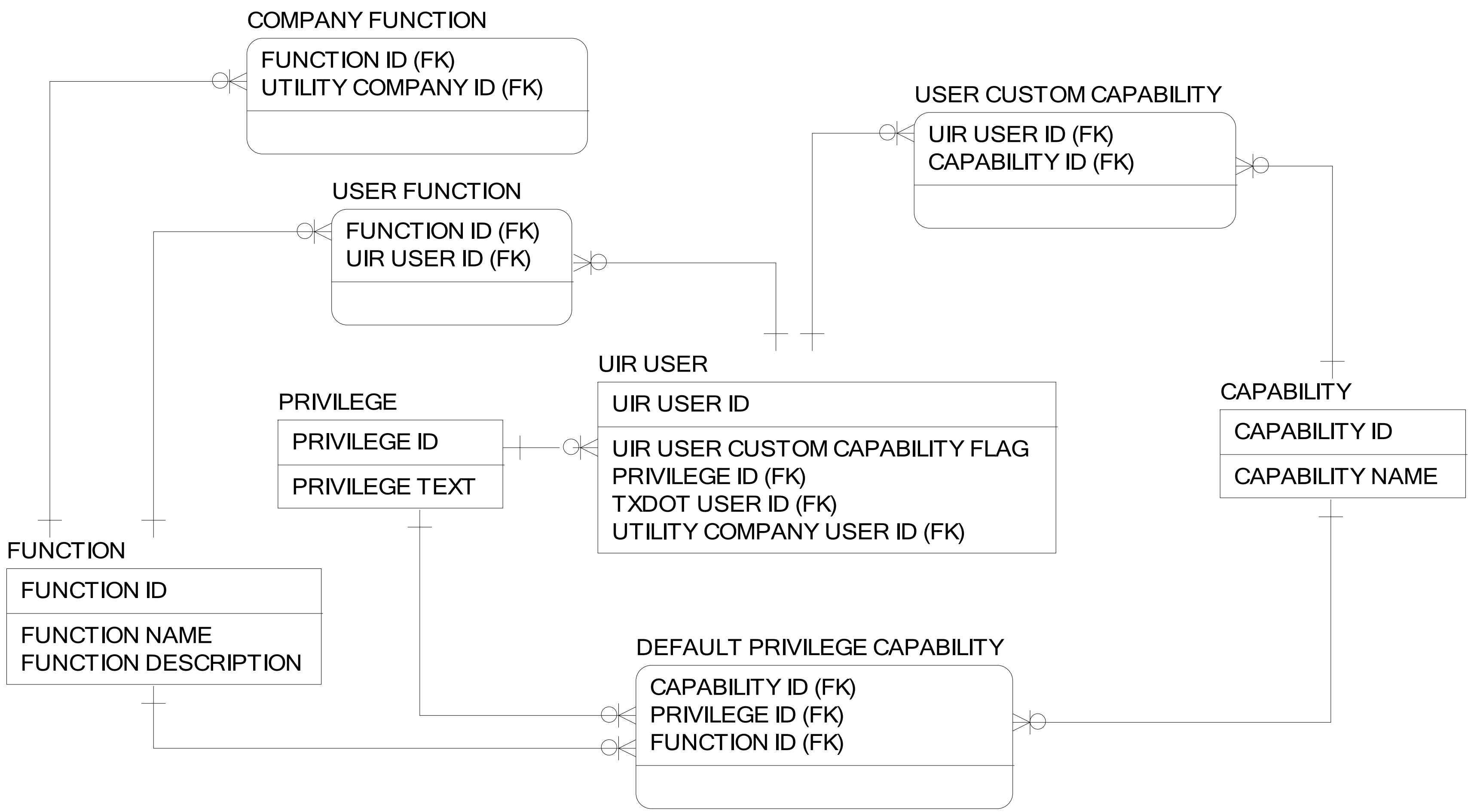

Figure 27. UACT Logical Data Model, "Permissions" Subject Area.

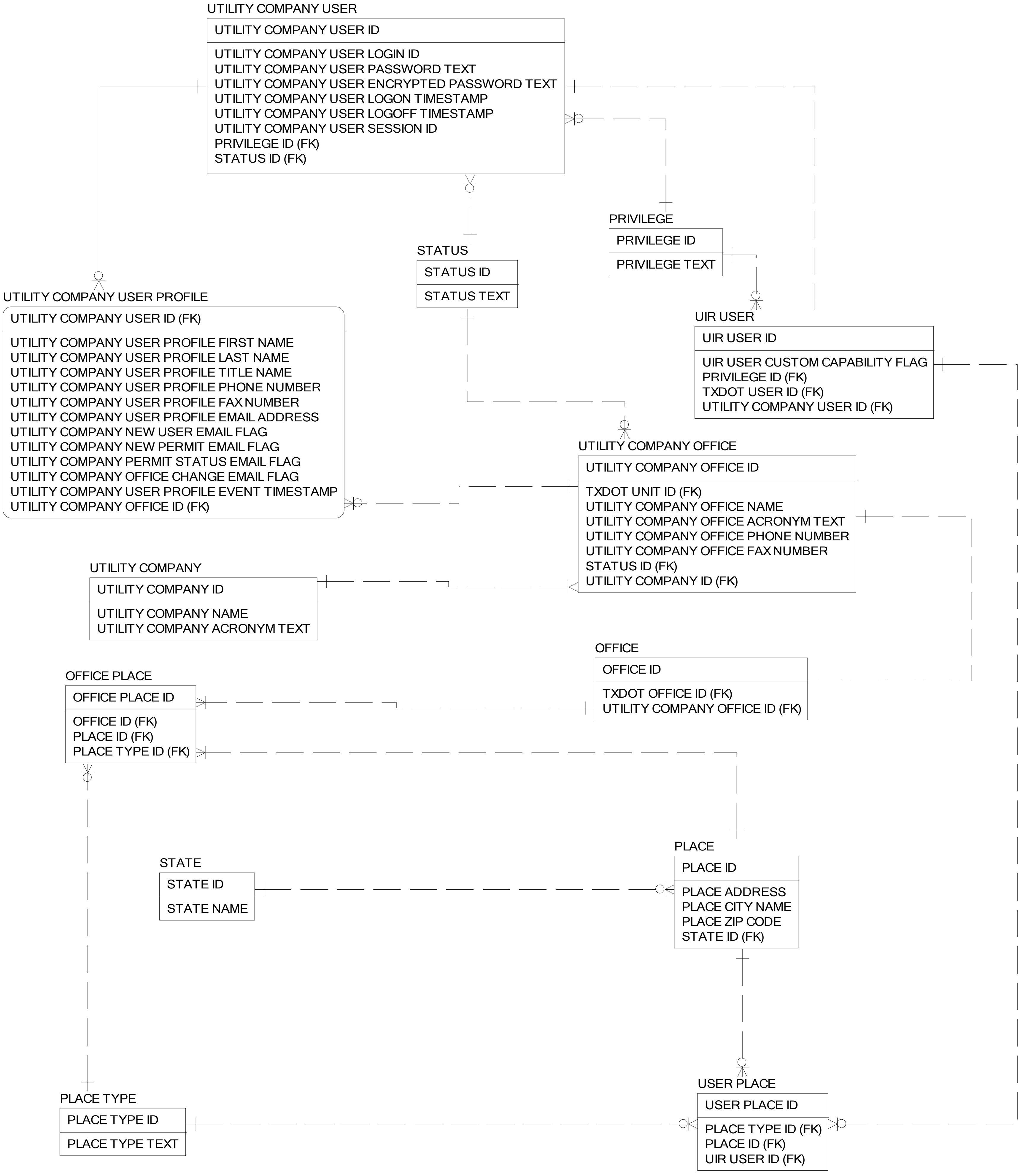

Figure 28. UACT Logical Data Model, “UIR Company User” Subject Area.

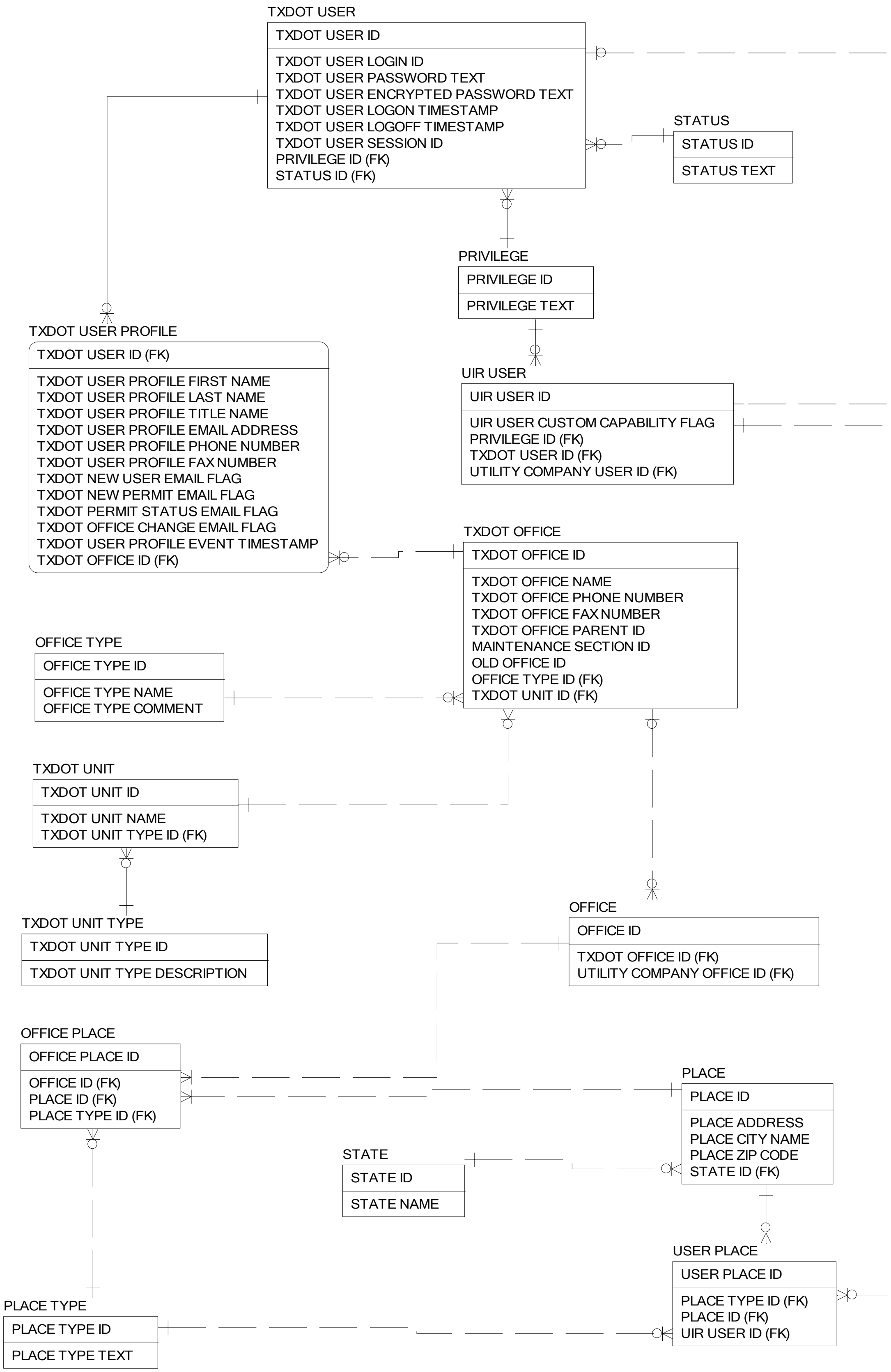

Figure 29. UACT Logical Data Model, "UIR TxDOT User" Subject Area.