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16. Abstract
The purpose of this research project was to provide a framework for the development of a Bridge Management Information System (BMIS). Researchers developed a synthesis of current BMIS development activities and identified sources of data available to develop a BMIS. Researchers also developed a short-term BMIS architecture, with a proof-of-concept prototype, which links bridge-related data sources at TxDOT that enables the production of queries and reports needed for a variety of analytical purposes. For development of a long-term enterprise-wide BMIS architecture, researchers presented features of a proposed BMIS to TxDOT personnel in the Bridge Division and six districts. Researchers obtained feedback from those presentations to help identify user and data needs for a BMIS. The report contains conclusions and recommendations for BMIS development. The appendices in the report include a synthesis of the findings and the methodology that the researchers used on how to make a fragmented system into a BMIS system that can provide needed data and results for users.

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FRAMEWORK FOR A COMPREHENSIVE BRIDGE MANAGEMENT AND INFORMATION SYSTEM

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DISCLAIMER

The contents of this report reflect the views of the authors, who is are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT).

This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Andrew Wimsatt, P.E., Texas License No. 72270.

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

ACKNOWLEDGMENT

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CHAPTER 1. INTRODUCTION

There are over 50,000 bridges in the state of Texas. TxDOT uses several different systems that are not interlinked to store different information on these bridges. Because these systems are not interconnected, information essential to the optimal management of these bridges is not readily available to TxDOT engineers and decision makers. Additionally, information on bridge-related maintenance expenditures is extremely limited to the most basic of categories, and links to SiteManager are effectively nonexistent with the current system.

An effective use of TxDOT resources would be to use the encompassing data sets currently available to manage bridge maintenance, rehabilitation, and reconstruction. TxDOT lacks the architecture to develop a comprehensive, reliable Bridge Management Information System (BMIS). An effective BMIS system would serve the needs of the districts, those responsible for developing and monitoring statewide letting of bridge projects, and TxDOT management personnel. This system should be user-friendly, accessible to a wide variety of users, and GIS enabled. An effective system must meet the needs of all users and provide information needed by all parties interested in bridge management.

Thus, the purpose of this project is to develop a framework for a comprehensive Bridge Management and Information System. To accomplish this, researchers:
- Prepared a synthesis of current BMIS development activities.
- Identified available data sources.
- Developed a prototype database application that could link available bridge-related data sources at TxDOT to enable the production of queries and reports needed for a variety of analytical purposes. TxDOT was particularly interested in a prototype application that could support short-term needs ahead of the potential development and implementation of a full-fledged BMIS.
- Identified BMIS user needs and data needs.
- Generated recommendations for development of models and decision trees.
- Generated conclusions and recommendations.

The following chapters are included in this report:
- Chapter 2 includes a review of existing bridge-related data sources at TxDOT.
- Chapter 3 describes the development of the prototype database application to extract summary bridge statistics.
- Chapter 4 describes the development of the prototype database application to extract bridge cost estimates and related quality control checks.
- Chapter 5 is a synthesis of current BMIS development activities.
- Chapter 6 describes BMIS user and data needs identified from the research.
- Chapter 7 contains illustrative examples of possible BMIS interface approaches
- Chapter 8 contains recommendations for development of models and decision trees.
- Chapter 9 contains conclusions and recommendations generated from this research.

The appendices in the report include a synthesis of the findings and the methodology that the researchers used on how to make a fragmented system into a BMIS system that can provide needed data and results for users.

CHAPTER 2. REVIEW OF EXISTING DATA SOURCES

INTRODUCTION

Several information systems at TxDOT contain data that pertain to the design, construction, operation, and maintenance of bridges, including the following:
- Design and Construction Information System (DCIS).
- Maintenance Management Information System (MMIS).
- Bridge Inventory, Inspection, and Appraisal System (BRINSAP).
- PonTex.
- Pontis®.
- Financial Information Management System (FIMS).
- Texas Permit Routing Optimization System (TxPROS).
- Permanent Structure Number (PSN) application.
- Bridge Shop Plan.

The following sections provide a summary of these information systems.

DESIGN AND CONSTRUCTION INFORMATION SYSTEM

TxDOT uses DCIS to facilitate project planning, programming, and development at the department. This legacy system supports the project development process through storage and management of project identification and evaluation data, project planning and finance data, project estimate data, and contract summary data (*1*). Over the years, TxDOT has developed linkages between DCIS and other TxDOT systems, such as the Bid Analysis Management System/Decision Support System (BAMS/DSS), the Bid Proposal System (BPS), the Contract Tracking System (CTS), and FIMS.

DCIS runs on an Adabas non-relational database platform, which stores data in files of variable length array structures. Relationships between these files are primarily through a control section job (CSJ) number that uniquely identifies projects. DCIS files include the following (*2*):
- **File 121 (DCIS -PROJECT-INFORMATION)**. This file contains basic data describing highway construction and maintenance projects during the planning and development phases (Table 1).
- **File 122 (DCIS-WORK-PROGRAM)**. This file contains data on highway construction work programs and the state transportation improvement program (STIP) (Table 2).
- **File 123 (DCIS-PROJECT-ESTIMATE)**. This file contains estimated cost data for individual projects, including bridges (Table 3).
- **File 124 (DCIS-CONTRACT-LETTING)**. This file contains the last three months' letting data for highway construction and maintenance projects (Table 4).
- **File 108 (DCIS-FUNDING-INFORMATION)**. This file contains project funding data (Table 5).

- **File 109 (DCIS-PROJECT-COST)**. This file contains data that pertain to the total cost of a project (Table 6).
- **File 110 (DCIS-PROVIDER-INFORMATION)**. This file contains data about project fund providers (Table 7).

DCIS includes a large number of screens that enable authorized users to complete data inputs and updates and run queries and reports. Of the various screens, the project evaluation–bridge screen (P3B) shows information on bridges that are included in transportation projects that involve removal, replacement, rehabilitation, or maintenance of an existing bridge. This screen is accessible through the project evaluation screen (P3). The P3B screen allows users to view and update the following bridge and related data (*1*):
- Project CSJ number.
- District number.
- Off system route number.
- Bridge sufficiency rating.
- Bridge deficiency class.
- Program qualification code.
- Texas eligible bridge selection system (TEBSS) score.
- National bridge inventory (NBI) number.
- Historical significance code.
- Structure type code.
- Critical deficiency indicator code.

Table 1. DCIS File 121 (DCIS-PROJECT-INFORMATION) Data Fields.

Field	Field	Field
COMMON-DATA	LANE-MILES	PROGRAM-QUALIFICATION-CODE
CONTROL-SECT-JOB	SHLDR-MILES	BRIDGE-DEFICIENCY-CLASS
DISTRICT-NUMBER	BRIDGE-DECK	CRITICALLY-DEF-INDICATOR
LAST-REVISION	NUMBER-BRIDGES	BRIDGE-WORK-TYPE
DATE-LAST-REV	PRES-ADT	BRIDGE-SUFFICIENCY-RATING
TIME-LAST-REV	PROJ-ADT-YEAR	KOW-BROAD-CODE
REQUIRED-ID-DATA	PROJ-ADT	SEG-ID
COUNTY-NUMBER	PERCENT-TRUCKS	MAINT-FUNCTION-CODE
HIGHWAY-NUMBER	KEQWL-18	PROJECT-INFO-METRIC-GROUP
PROJ-LENGTH	EXST-DSGN-SPD	ADDL-ROW-METRIC-MEAS
CATEGORY	PROP-DSGN-SPD	BRIDGE-DECK-METRIC-MEAS
ELIG-FED-FUND	EXST-CRNWDTH	PROP-BRIDGE-DECK-METRIC-MEAS
PROJ-CLASS	PROP-CRNWDTH	EXIST-LANE-WIDTH-METRIC-MEAS
MANAGER-NUMBER	CAP-GAP	EXIST-ROAD-WIDTH-METRIC-MEAS
EST-CONST-COST	GEOM-GAP	PROP-ROAD-WIDTH-METRIC-MEAS
DATE-EST-COST	PES1-LANES	EXIST-SHLDR-WIDTH-METRIC-MEAS
AUTO-LINE-NUMBER	PES1-SCORE	EXIST-CRNWDTH-METRIC-MEAS
TYPE-OF-WORK	PES2-LANES	PROP-CRNWDTH-METRIC-MEAS
LIMITS-FROM	PES2-SCORE	EXIST-DESGN-SPD-METRIC-MEAS
LIMITS-TO	OVRLAY	PROP-DESGN-SPD-METRIC-MEAS
LAYMAN-DESCRIPTION1	PVMT-QUAL	EXIST-LENGTH-METRIC-MEAS
LAYMAN-DESCRIPTION2	DSGN-LIFE	PROP-LENGTH-METRIC-MEAS
BEG-MILE-POINT	TERRAIN	KNESAL-80-METRIC-MEAS
END-MILE-POINT	CITY-CODE	LANE-LENGTH-METRIC-MEAS
OPTIONAL-ID-DATA	DIST-PRIOR	OVERLAY-METRIC-MEAS
CONTRACT-CSJ	ACC-YEAR1	PROJ-LENGTH-METRIC-MEAS
PROJ-SUSP	ACC-YEAR2	SHLDR-LENGTH-METRIC-MEAS
PRIORITY-CODE	ACC-TYPE	LOCAL-CONTRIBUTIONS-AMT
PDP-LET-DATE	ACC-FATAL	STATE-TRANS-IMPRV-PGM-GRP
DIST-LET-DATE	ACC-FATAL-TOTAL	STIP-PROJECT-ID
ORIGINAL-PLANNED-LET-DATE	ACC-INJ	STIP-PHASE-CODE
DIST-LET-CHANGES-NBR	ACC-INJ-TOTAL	STIP-REVISION-DATE
APPRVD-LET-DATE	ACC-TOTAL	STIP-IMPLEMENT-AGENCY-CMNT
ACTUAL-LET-DATE	ACC-TOTAL-TOTAL	STIP-REVISION-LOCK-FLAG
BACKLOG-PROJ	COMMENTS1	STIP-PROJECT-DESCRIPTION1
EST-ROW-COST	COMMENTS2	STIP-PROJECT-DESCRIPTION2
DATE-EST-ROW	COMMENTS4	STIP-PROJECT-DESCRIPTION3
RA-FLAG	PROP-BRIDGE-DECK	STATEWIDE-CSJ
OTHER-PART	ENGINEER-INFO	RESP-SECTION
PROJECT-NUMBER	ENGINEER-NO	NATIONAL-HIGHWAY-SYSTEM-FLAG
CONST-COMP	AUTHORIZATION-DATE	CONSULTANT-FLAG
PSE-COMP	HOUSE-DIST	DONATED-FLAG
ROW-COMP	SENATE-DIST	STATE-HOUSE-DISTRICTS
HIGHWAY-SYSTEM	NEW-HOUSE-DIST	STATE-SENATE-DISTRICTS
REMARKS	NEW-SENATE-DIST	FEDERAL-HOUSE-DISTRICTS
MISCELLANEOUS-FIELDS	LET-SCH-LOCK-FLAG	COMMENTS5
DIST-ENG-EST	LET-SCH-1	TAPERED-MATCH
D8-ENG-EST	LET-SCH-2	TOLL-CREDITS
MISC-COST	LET-SCH-3	PART-WAIVED-PROJECT
PROJ-BID-AMOUNT	SPEC-BOOK-YR	ECON-DIS-CO-PROJECT
TOT-OBG-AMOUNT	PROJECT-DEV-PLAN-GRP	STATE-LOA
EC-PERCENT	ROAD-LOCN-CODE	POPULATION-AREA
ITEM-500-AMOUNT	PDP-PROJECT-CODE	DESIGN-STANDARD
ANCESTOR-CSJ5	EXIST-IC-CODE	PE-FEDERAL-LOA
DESCENDENT-CSJ5	PROPOSED-IC-CODE	PE-APPN-CODE

Table 1. DCIS File 121 (DCIS-PROJECT-INFORMATION) Data Fields (Continued).

Field	Field	Field
WORK-PGM-ARRAY10	ADT-IC-CROSSROAD-NBR	PE-FEDERAL-DOLLARS
WORK-PROGRAM	IC-CROSSROAD-LANES-NBR	RG-FILLER
PROJ-COST	CROSSROAD-TYPE-CODE	PE-DISTRICT
PROJ-ID-SIGN	EXIST-LANE-WIDTH-MEAS	MAX-FED-FUNDS
ROW-AMOUNT	EXIST-SHLD-WIDTH-MEAS	TO-DISTANCE-FROM-ORIGIN
ROW-ID-SIGN	SIGNALS-PRESENT-FLAG	FROM-DISTANCE-FROM-ORIGIN
FIXED-FLAG	ADT-CRITICAL-CROSSROAD-NBR	ANNUAL-COST-GRP
CATEGORY-P2	SIG-CROSSROAD-LANES-NBR	ANNUAL-UTP-YEAR
PID	CIRCUM-RADIAL-CODE	ANNUAL-CONST-EST
APPORTIONMENT-CODE	COST-EFFECT-INDEX-NBR	ANNUAL-ROW-EST
MATCH-TYPE	PROJECT-RANK-NBR	ANNUAL-COST-DATE-RUN
MATCH-SOURCE	TRUNK-SYS-FLAG	BRIDGE-REMARKS1
APPLIED-PERCENT	REFERENCE-MARKER-GRP	BRIDGE-REMARKS2
FUNC-CODE-FROM	BEG-REF-MARKER-NBR	MATCH-AMOUNT-TOTAL
FUNC-CODE-TO	BEG-REF-MARKER-DISP	TOTAL-COST-DOLLAR-PE
MINUTE-ORDER-NUMBER	END-REF-MARKER-NBR	BOND-INTEREST-PAY-AMT
MINUTE-ORDER-DATE	END-REF-MARKER-DISP	INTEREST-TYPE-CODE
STATE-COST-PCT	ADHOC-REPORT-GRP	CMCS-LET-FLAG
LOCAL-COST-PCT	ADHOC-REPORT-ID	TRM-UPDATE-FLAG
EVAL-DATA	MPO-CODE	PRESERVATION-PERCENT
RDWY-FUNCT-CLS	TIP-FY	MOBILITY-PERCENT
URBAN-RURAL	COMMENTS3	ROW-CSJ
CONTROL-SECT-ACTUAL	BRIDGE-DATA-GRP	MEGA-PROJECT-ID
PVMT-TYPE	HISTORICAL-BRIDGE-FLAG	SUPER-ZA
EXST-MNLN-NUM	BRIDGE-LAST-UPDATED-DATE	SUPER-ZB
EXST-MNLN-TYPE	LINE-NUMBER-CARD12	SUPER-ZC
EXST-FTG-NUM	EXIST-ROAD-WIDTH-MEAS	SUPER-ZD
EXST-FTG-TYPE	PROP-ROAD-WIDTH-MEAS	SUPER-ZE
EXST-LENGTH	STRUCTURE-DATA-GRP	SUPER-ZF
PROP-MNLN-NUM	STRUCTURE-NBR	SUPER-ZG
PROP-MNLN-TYPE	ON-STATE-ID	SUPER-ZH
PROP-FTG-NUM	OFF-STATE-ID	SUPER-ZI
PROP-FTG-TYPE	NBI-NBR	SUPER-ZM
PROP-LENGTH	STRUCTURE-TYPE	SUPER-ZN
EVAC-RTE	HISTORICAL-SIGNIFICANCE	SUPER-ZO
ADDL-ROW	TEBSS-SCORE-PCT	

Table 2. DCIS File 122 (DCIS-WORK-PROGRAM) Data Fields.

Field	Field	Field
WORK-PROGRAM	STIP-PROJECT-ID	STIP-LAYMANS-DESC
CONTROL-SECT-JOB	STIP-PROJECT-NBR	STIP-PROJECT-CMNT
DISTRICT-NUMBER	STIP-PHASE-CODE	STIP-REVISION-DATE
DATE-LAST-REV	STIP-FEDERAL-COST-PCT	STIP-LOCK-FLAG
TIME-LAST-REV	STIP-STATE-COST-PCT	STIP-IMPLEMENT-AGENCY-CMNT
TOTAL-DATA	STIP-LOCAL-CONTRIBUTIONS-AMT	STIP-PROGRAM-COST
FIS-YEAR	STIP-LOCAL-COST-PCT	STIP-APPORTIONMENT-CODE
YEARS-ACTIVE	STIP-EST-CONSTRUCTION-AMT	STIP-FEDERAL-COST-TOTAL
TOTAL-OBLIG-AMT	STIP-FUNCTIONAL-CLASS-CODE	STIP-STATE-COST-TOTAL
TOTAL-ALLOC-AMT	STIP-STATE-CATEGORY-CODE	STIP-LOCAL-COST-TOTAL
DISTRICT-ARRAY25	STIP-DISTRICT-EST-LET-DATE	STIP-PROJ-LENGTH-METRIC
DIST-ALLOC-AMT	STIP-EXISTING-LANE-AMT	STIP-FHWA-APPROVAL-DATE
DIST-OBLIG-AMT	STIP-PROPOSED-LANE-AMT	MINUTE-ORDER-GRP
CZ-FILLER-FIELD	STIP-PROJECT-LENGTH-MEAS	MINUTE-ORDER-NBR
STATE-TRANS-IMPRV-PGM-GRP	STIP-LOCATION-FROM-DESC	MINUTE-ORDER-DATE
STIP-MPO-CODE	ST)IP-LOCATION-TO-DESC	MINUTE-ORDER-REMARKS
STIP-FY		

Table 3. DCIS File 123 (DCIS-PROJECT-ESTIMATE) Data Fields.

Field	Field	Field
COMMON-DATA	ENG-ESTIMATE-PRICE	NEW-NBI-NUMBER
CONTROL-SECT-JOB	UNIT-PRICE	BRIDGE-WORK-TYPE
LAST-REVISION	BIDITEM-FLAG	OLD-BRIDGE-TYPE
USER-LAST-REV	BIDITEM-DESCRIPTION	NEW-BRIDGE-TYPE
DATE-LAST-REV	UNIT-WORK	ROADWAY-CLEAR-WIDTH
TIME-LAST-REV	COMMENT	BRIDGE-NAME
PLANS-ESTIMATE-DATA	CATGWORK-DESC	BRIDGE-SYSTEM-ID
LINE-NUMBER	CATGWORK-MILES	BRDG-COST-GRP
CARD-TYPE	FUND-SOURCE-GROUP3	BRDG-LENGTH
ALTERNATE-GROUP-NO	FUND-SOURCE	BRDG-NBI-NUMBER
BIDITEM-SPECPROV	PERCENT-PART	BRDG-TYPE
BIDITEM-NO	BRIDGE-COST-DATA	BRDG-SYSTEM-ID
BIDITEM-DESC-CODE	BRIDGE-LENGTH-EXISTING	BRDG-DECK-AREA
SPECIAL-PROV-NO	BRIDGE-LENGTH-PROPOSED	BRDG-COST-PERCENT
BIDITEM-REF-NO	BRIDGE-WIDTH-EXISTING	SUPER-ZA
SPCL-000-PROV-TEXT	BRIDGE-WIDTH-PROPOSED	SUPER-ZC
SPECIAL-ACCT-NO	BRIDGE-REMOVAL-BREAKBACK	SUPER-ZD
ENG-QUANTITY	OLD-NBI-NUMBER	SUPER-ZE

Table 4. DCIS File 124 (DCIS-CONTRACT-LETTING) Data Fields.

Field	Field	Field
COMMON-DATA	ENG-PHONE	NOTICE-DESC
CONTRACT-CSJ	MBE-WBE-FLAG	NOTICE-STATUS-CODE
LAST-REVISION	PROPOSAL-GUARANTY-AMT	D48-ROSCP-PDS-NAMES-GRP
DATE-LAST-REV	WAIVER-FLAG	PDS-GNRL-NOTES-NAME
TIME-LAST-REV	DIVISION-RESPONSIBLE	PDS-REVISION-NOTE-NAME
RECORD-TYPE	INCLUDED-PROJECTS191	PDS-SPEC-LIST-NAME
BIDITEM-SUMMARY-DATA	COMBINED-FLAG191	BID-TAB-DOTS-STATUS-CODE
BIDITEM-SEQUENCE-NO	TOTAL-MISC	CNTRCT-EST-LET-DAY
ALTERNATE-GROUP-NO	TYPE-OF-WORK	AD-GRP
BIDITEM-NO	LIMITS	AD-STATUS-CODE
BIDITEM-DESC-CODE	EST-CODE	USER-NAME
SPECIAL-PROV-NO	RESP-DIST	USER-DATE
SPECIAL-ACCT-NO	LOCAL-LET	USER-TIME
QUANTITY	INCENTIVE-FIELDS	INITIAL-AD-DATE
ESTIMATED-PRICE	USER-COST-AMT	CONTRACT-COUNTIES
DUP-PRICE-INDICATOR	RU-BID-DAYS	CONTRACT-LOCK-DATA
BIDDER-CONTROL-DATA	USER-COST-INCOMP-FLAG	LOCK-CICS-OPERATOR-ID
BIDDER-SEQNO	USER-COST-TOTAL	LOCK-UPDATE-DATE
TOTAL-BID	INC-DIS-WORK-DAYS	LOCK-UPDATE-TIME
VERIFY-CODE	CONTRACT-OJT-GOAL	LOCK-ACTION-CODE
BIDDER-RANKNO	CONTRACT-DBE-GOAL-PCT	LOCK-FLAG
INCOMPLETE-FLAG	WORK-CAL-FLAG	WAGE-RATE-ID
VENDOR-NOS	PROP-REVISION-DATES10	BLDG-CONTRACT-CSJ-GRP
BI-SEQNO-DISCREP31	PLAN-SHEET-REVISION-DATES10	BLDG-CONTRACT-CSJ-4
BIDITEM-ALT-FLAG9	D48-PROJECT-STATUS-FLAG	BLDG-CONTRACT-CSJ-5
BIDITEM-ALT-FLAG	GRAPHICS-FLAG	BLDG-CONTRACT-CSJ-7
BIDITEM-DETAIL-11	REVISION-NOTE-LOC	BLDG-CONTRACT-CSJ-9
UNIT-PRICE	REVIEW-ENGINEER-ARRAY	AUS-HQ-MAINT-FLAG
BID-AMOUNT	REVIEW-ENGINEER-NO	AUS-HQ-BLDG-FLAG
ALTERNATE-GROUP	REVIEW-AUTHORIZATION-DATE	TOTAL-CONTRACT-COST
BI-INCOMPLETE-FLAG	LATEST-PROP-RELEASE-DATE	CMCS-LET-FLAG
CONTRACT-SUMMARY	CONTRACT-REMARKS	TOTAL-BID15
CONTRACT-NUMBER	PRE-BIDDERS-MEETING-GRP	SUPER-ZA
WORKING-DAYS	PRE-BIDDERS-MEETING-DATE	SUPER-ZB
LETTING-STATUS-CODE	PRE-BIDDERS-MEETING-TIME	SUPER-ZC
RECEIVED-UNTIL-TIME	PRE-BIDDERS-MANDATORY-FLAG	SUPER-ZD
RECEIVED-UNTIL-DATE	PRE-BIDDERS-MEETING-SP-CODE	SUPER-ZE
ENGINEER-INFO	PRE-BIDDERS-SPECIAL-TEXT-FLAG	SUPER-ZF
ENG-NO	CNTRCT-EST-LET-GRP	SUPER-ZG
ENG-NAME	CNTRCT-EST-LET-DATE	SUPER-ZH
ENG-ADDRESS	CNTRCT-EST-LET-TIME	SUPER-ZI
ENG-CITY	NOTICE-TO-CNTRCTR-GRP	SUPER-ZM
ENG-ZIPCODE	INITIAL-NOTICE-DATE	SUPER-ZN

Table 5. DCIS File 108 (DCIS-FUNDING-INFORMATION) Data Fields.

Field	Field	Field
CONTROL-SECT-JOB	ROW-AMOUNT	MINUTE-ORDER-DATE
FUND-TYPE-CD	FIXED-FLAG	FEDERAL-COST-PCT
COST-LINE-NBR	CATEGORY-P2	STATE-COST-PCT
COST-FEDERAL-AMT	PID	LOCAL-COST-PCT
COST-STATE-AMT	APPORTIONMENT-CODE	CHANGE-ORDER-DATE
COST-LOCAL-AMT	APPLIED-PERCENT	DISTRICT-NUMBER
COST-LOCAL-CNTRB-AMT	FUNC-CODE-FROM	SUPER-ZA
WORK-PROGRAM	FUNC-CODE-TO	SUPER-ZB
PROJ-COST	MINUTE-ORDER-NUMBER	

Table 6. DCIS File 109 (DCIS-PROJECT-COST) Data Fields.

Field	Field	Field
CONTROL-SECT-JOB	TOTL-BOND-AUTH-AMT	TOTAL-LOCAL-CONTR-AMT
CORRIDOR-NBR	TOTL-BOND-COST-LETTING-AMT	TOTAL-OTHER-PART
RECORD-TYPE	TOTL-CE-AUTH-AMT	ROW-EST-JOINT-BID
EST-PE-PCT	TOTL-CE-COST-LETTING-AMT	EST-ROW-COST15
EST-CE-PCT	TOTL-CNTGCY-AUTH-AMT	ROW-FEDERAL-DOLLARS
EST-CNTGCY-PCT	TOTL-CNGTCY-COST-LETTING-AMT	ROW-DATE-LAST-REV
EST-INDIRECT-PCT	TOTL-INDRCT-AUTH-AMT	TOT-OBG-AMOUNT15
TOTAL-COST-AMT	TOTL-INDRCT-COST-LETTING-AMT	DIST-ENG-EST15
PE-CURR-EST-PCT	INFLATION-PERCENT	PROJ-BID-AMOUNT15
PE-CDA-STIPEND-AMT	ENGINEERING-PERCENT	CDA-NBR
PE-LN1-COMMENT	CONTINGENCIES-PERCENT	PROJ-BEG-LAT
PE-LN2-COMMENT	INDIRECT-PERCENT	PROJ-END-LAT
PE-LN3-COMMENT	TOLL-FLAG	PROJ-BEG-LON
PE-TAPERED-MATCH-FLAG	CDA-CODE	PROJ-END-LON
PE-TOLL-CREDITS-AMT	PTF-FLAG	ROW-FEDERAL-LOA
ROW-PROGRAM-CHARGE-AMT	RMA-FLAG	ROW-APPN-CODE
ROW-TAPERED-MATCH-FLAG	TOTAL-FEDERAL-AMOUNT	AFA-DATE
ROW-TOLL-CREDITS-AMT	TOTAL-STATE-AMOUNT	HIST-UTP-YEAR
TOTL-PE-AUTH-AMT	TOTAL-LOCAL-AMOUNT	HIST-CONST-EST
TOTL-PE-COST-LETTING-AMT	TOTAL-AUTH-AMOUNT	HIST-ROW-EST
TOTL-CST-AUTH-AMT	EST-CONST-COST15	HIST-COST-DATE
TOTL-CST-COST-LETTING-AMT	AUTH-INFLATION-PERCENT	HIST-EST-TYPE
TOTL-ROW-AUTH-AMT	LUMP-SUM-ROW	HIST-EST-ACID
TOTL-ROW-COST-LETTING-AMT	LUMP-SUM-PE	

Table 7. DCIS File 110 (DCIS-PROVIDER-INFORMATION) Data Fields.

Field	Field	Field
CONTROL-SECT-JOB	FUNDING-DETAIL-TYPE	ISSUANCE-COST
RECORD-TYPE	FUNDING-DETAIL-CODE	CAPITALIZED-INTEREST
COST-LINE-NBR	FUNDING-DETAIL-PROVIDER	BOND-FINANCE-COST
FUNDING-DETAIL-AMT	BOND-INTEREST	SUPER-ZA

Common methods to access DCIS data at TxDOT include the following:

- **Direct access** (*1*). With this method, users log into ROSCOE and type RJEJCL (Remote Job Entry Job Control Language) to access a menu screen of TxDOT legacy information systems, such as DCIS, FIMS, and Pavement Management Information System (PMIS). In ROSCOE, data entry, query, processing, and report generation are completed using keyboard commands. DCIS has a set of predefined Natural reporting language-based report templates. The direct access mode is the most commonly used mode to access DCIS.
- **RJEJCL script** (*1*). With this method, users run customized RJEJCL scripts containing Natural report templates within the DCIS environment to produce custom reports. DCIS saves custom reports as text files that can be used later in reports, spreadsheets, or desktop databases.
- **SAS script**. With this method, users run PC SAS scripts using a SAS host connected to DCIS to retrieve data. The script saves the results in a file that can be used later in reports, spreadsheets, or desktop databases.

As mentioned previously, the DCIS Adabas environment is not compatible with relational database structures, particularly in relation to repeating groups. A repeating group is composed of attributes of the same type with values stored in an array. An example of a repeating group in DCIS is the list of ancestor and descendent CSJ numbers in File 121. Instead of using a separate file to handle ancestor and descendent CSJ numbers (with one record per ancestor or descendent CSJ number), historically, TxDOT has stored these CSJ numbers in single attribute arrays in File 121. A difficulty with this approach is how to track all the CSJ numbers associated with any CSJ in the database effectively. Another difficulty of using repeating groups is that the maximum size of an attribute array may be fixed, making it necessary to remove an attribute (e.g., the oldest one) to provide storage space for the latest value if there are more attribute values than the size of the array.

In recent years, TxDOT has begun to use an Adabas replicator utility to export Adabas data files to a Microsoft® SQL Server® environment. TxDOT has replicated all DCIS files into a SQL Server COMMON_DSGN schema. This process has involved converting non-relational Adabas data into a relational database structure. Although the resulting database does not fully comply with relational database industry standards, it is a huge improvement. Using replicated data in a relational database environment offers numerous benefits, including the following:
- Compatibility with industry-standard database applications and streamlined data access protocols.
- Lower costs associated with retrieving, managing, and maintaining data.
- Lower demand on Technology Services Division (TSD) to develop customized Adabas scripts because users can have direct access to DCIS tables.
- Use of relational database structures that facilitate the development of queries and reports.
- Near real time access to replicated DCIS data.

In the current implementation mode, every time there is a transaction that adds a new record or updates an existing record in DCIS, the replicator mimics that transaction in SQL Server, making the replicated tables near real time. Normally, users are provided read-only access to table views (i.e., indexed queries) of replicated tables. A number of options exist for accessing the data, including open database connectivity (ODBC) and SQL Server Management Studio.

Districts have started to develop applications using replicated tables. For example, Corpus Christi District officials replaced their Highway Project Task Management System (HPTMS), which used SAS scripts, with the Project Development Management System (PDMS), which relies on Adabas replicated tables.

MAINTENANCE MANAGEMENT INFORMATION SYSTEM

Maintenance Management Information System (MMIS) is a legacy data system the TxDOT Maintenance Division implemented in the late 1980s for managing highway maintenance data. MMIS contains data on 76 (of 116) routine maintenance functions, which together account for the majority of maintenance expenditures (*3*). The Daily Activity Report Form 1757 and the Weekly Activity Report Form 1784 record maintenance activity data. Currently, MMIS does not

track maintenance activities pertaining to damage claims or maintenance of facilities (*4*). Types of maintenance activities tracked in MMIS include the following:

- Approaches and miscellaneous shoulder maintenance.
- Asphaltic surfaces.
- Base and subgrade.
- Bridge and bridge channels.
- Concrete pavement.
- Extraordinary maintenance.
- Roadside and other, and
- Traffic Operations.

Table 8 lists 14 function codes for bridge and bridge channel maintenance activities tracked by MMIS (*4*). Originally, MMIS had four function codes for bridge maintenance activities. Over time, TxDOT combined two function codes (i.e., Bridges, Rail [628] and Bridges, Rail Painting [633]), and added 11 MMIS function codes.

MMIS uses reference markers to identify the location of a maintenance activity. If a maintenance activity involves a bridge, it is possible to add a NBI number to the MMIS database. MMIS links to other TxDOT systems such as the Salary and Labor Distribution System (SLD), the Material Supply Management System (MSMS), and the Equipment Operations System (EOS). FIMS Segment 78 file stores MMIS cost data.

Like DCIS, MMIS runs on an Adabas platform and stores maintenance activity data in separate files. MMIS uses a combination of attributes (i.e., HWY_INFO, REFERENCE_MARKER, and FUNCTION_CODE) to identify relationships between separate files. MMIS files include the following (*5*).

- **File 96 (MMIS-AUDIT-FILE)**. This file stores changes, such as additions, deletions, and revisions, to the MMIS-MASTER-FILE (Table 9).
- **File 98 (MMIS-TRANSACTION-FILE)**. This file stores reference marker data along with contract and non-contract maintenance work. File 98 is updated daily and contains a record of amount of work performed and costs for each highway location (Table 10).
- **File 99 (MMIS-MASTER-FILE)**. This file stores maintenance activity data for a specific highway location. File 99 is updated at the end of the month upon completion of the FIMS end-of-month process (*5*) (Table 11).

Table 8. MMIS Bridge and Bridge Channel Function Codes (*4*).

Function Code	Unit	Function	Description
610	-	Bridge, Movable Span	Operation, routine maintenance, and inspection of movable span bridges (swing barge, lift, or turn). Restricted use: Beaumont, Houston, Pharr, and Yoakum Districts only.
611	EA	Bridge, Portable	Installation, removal, maintenance, and inspection of portable bridges.
620	CY	Bridge Channel Maintenance	Removal of silt and drift, filling eroded areas, channel maintenance (including easements), and maintenance and repair of jetties and dikes.
628*	LF	Bridge Rail	Maintenance of bridge rail, posts, and post connections to deck, including painting.
645*	LF	Bridge Joint Maintenance	Repair of bridge joints, including cleaning and sealing.
646	LF	Bridge Joint Replacement	Replacement of bridge joints.
650*	SF	Bridge Deck	Repair to bridge decks.
660	SF	Bridge Superstructure, Concrete	Routine maintenance of the concrete components of the bridge superstructure, including bearings, concrete diaphragms, and beams.
665	SF	Bridge Superstructure, Steel	Routine maintenance of the steel components of the bridge superstructure, including steel diaphragms and beams.
670	SF	Bridge Substructure, Concrete	Routine maintenance of the concrete components of the bridge substructure, including caps, columns, abutments, wingwalls, pilings, etc.
675	SF	Bridge Substructure, Steel and Timber	Routine maintenance of the steel or timber components of the bridge substructure, including caps, abutments, pile extensions, etc.
680	SF	Bridge Painting	Cleaning and painting of superstructure or substructure.
690	-	Bridge, Mechanical and Electrical	Maintenance and repair of the electrical and mechanical components of a bridge.
695	EA	Fender Systems	Installation and maintenance of fender systems.

CY = Cubic Yard; SF = Square Foot; LF = Linear Foot; EA = Each; * = Original Function Code

Table 9. MMIS File 96 (MMIS-AUDIT-FILE) Data Fields.

Field	Field	Field
USER-INFO	COUNTY	AREA-INFO
USER-ID	HWY-INFO	OLD-AREA
SYSTEM-DATE-DT	HWY-LIMIT-INFO	NEW-AREA
SYSTEM-TIME	OLD-BEG-REF-MARKER	FUNC-CODE-INFO
FILE-CHANGE	OLD-END-REF-MARKER	OLD-FUNC-CODE
LOCATION-INFO	NEW-BEG-REF-MARKER	NEW-FUNC-CODE
YR-DIST-MAINTSECT-ID	NEW-END-REF-MARKER	TASK-NUMBER

Table 10. MMIS File 98 (MMIS-TRANSACTION-FILE) Data Fields.

Field	Field	Field
KEYS	COUNTY	MATERIAL-QUANTITY
ACCOUNT-NUMBER	HWY-INFO	CONTRACTOR-AMOUNT
DISTRICT	BEG-REF-MARKER	MISC-AMOUNT
MAINT-SECT	END-REF-MARKER	SES-DOCUMENT-NUMBER
TASK-NUMBER	AREA-UNIT	NBI-NBR
TRANS-DATE-DT	AREA	SUPERZA
TRANS-INFO	TASK-NUMBER-AMOUNTS	SUPERZB
DATE-WORK-PERFORMED-DT	LABOR-AMOUNT	SUPERZC
CONTRACT-NUMBER	LABOR-MANHOURS	SUPERZD
TYPE-OF-WORK	EQUIPMENT-AMOUNT	SUPERZE
FUNCTION-CODE	MATERIAL-AMOUNT	

Table 11. MMIS File 99 (MMIS-MASTER-FILE) Data Fields.

Field	Field	Field
KEYS	AREA-UNIT	MTD-COUNTRACTOR-AMOUNT
YR-DIST-MAINTSECT-ID	CONTRACT-NUMBER	MTD-PREPARATION-AMOUNT
COUNTY	TYPE-OF-WORK	MESSAGE
HWY-INFO	MMDD-STORE-DT	NBI-NBR
DEL-HWY-INFO-FLAG	MTD-AMOUNT	SUPERZA
REFERENCE-MARKER-INFO	MTD-LABOR-AMOUNT	SUPERZB
REFERENCE-MARKER	MTD-LABOR-MANHOURS	SUPERZC
BEG-REF-MARKER	MTD-EQUIPMENT-AMOUNT	SUPERZD
END-REF-MARKER	MTD-MATERIAL-AMOUNT	SUPERZE
FUNCTION-INFO	GF-FILLER	SUPERZF
FUNCTION-CODE	MTD-MATERIAL-AREA	
MMDD-UPDATE-DT	MTD-MISC-AMOUNT	

MMIS has two report generation options: Maintenance Efficiency and Analysis Reporting System (MEARS) report generation and MMIS report generation (*3*). The MEARS report compares in-house maintenance costs with the cost of maintenance performed under contract. MMIS report generation includes reports in the following categories:

- Cost summaries, by highway type and function.
- Production rates, by function, function rates by highway, and function rate comparison.
- Rankings, by highway cost, function code cost, and highway type cost.
- Miscellaneous reports, such as daily transaction report, crew report, roadway inventory, job cost summary, expenditures by function code, function cost by reference marker, and maintenance section unit cost comparison.

Methods to access MMIS data include the following (*3*):

- Sign on to Customer Information Control System (CICS) and access the "Natural V2" Teleprocessing Applications Menu, which includes MMIS.
- Enter maintenance activity data through the Single Entry Screen System (SES). SES sends the appropriate data to four systems (i.e., MMIS, SLD, EOS, and MSMS).
- Sign on to ROSCOE to access the MMIS Report Print and View Menu, which allows users to view or print portions of MMIS reports.

TxDOT is implementing a new system, called the Maintenance Management System (MMS) to replace MMIS (*6*). MMS will support performance measures, high-level analyses of

maintenance funding, needs identification at a general level (e.g., increase ride quality), and alternative analyses ("what if"). MMS will run on a relational database platform. The anticipated rollout date is mid 2011. The vendor (i.e., AgileAssets, Inc.) produced a draft application data plan for interfacing MMS with 17 TxDOT systems (*7*). These systems included Pontis, DCIS, Texas Maintenance Assessment Program (TxMAP), PMIS, FIMS, Construction/Maintenance Contract System (CMCS), and Texas Reference Marker System (TRM). MMS will store maintenance location by reference marker and displacement. If a maintenance activity involves a bridge, MMS can retrieve bridge data (e.g., NBI) from a Pontis interface.

The life cycle of a bridge can involve several of the following stages: replacement, removal/new location, widening, maintenance/repair, and rehabilitation. In DCIS, these stages are classified into work types. Generally DCIS stores data for project based bridge maintenance/repair; however, DCIS does not record routine bridge maintenance/repair activities. Currently routine bridge maintenance and repair activities and associated data are recorded in MMIS; in the future, these data will be recorded in MMS.

Bridge maintenance activities and associated data are a critical component in determining the life cycle stage of a bridge and for system-wide bridge management. These data are crucial in determining the anticipated life of bridge elements, in providing an initial assessment of critical bridges, and as an aid in identifying potential treatments and future work. Locations with excessive bridge maintenance costs can be identified and examined. These locations can be compared with other locations with similar bridge elements to identify trends, as well as low performing or positive treatments. Replacement of low-performing treatments can be prioritized based on impact and cost.

BRIDGE INVENTORY, INSPECTION, AND APPRAISAL SYSTEM

Title 23, Part 650 of the Code of Federal Regulations (CFR) requires states to prepare and maintain an inventory of all bridge structures (*8*). Federal Highway Administration's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* specifies data items and their coding for this inventory (*9*). FHWA collects data from the states to develop the NBI database.

BRINSAP stores and maintains inspection data for on- and off-system bridges and tunnels on Texas public roadways (*10*) and contains the data items required for the national bridge structure inventory. BRINSAP includes roadway structure characteristics, traffic data, inspection data, and ratings. Table 12 lists data fields stored in BRINSAP. On an annual basis, TxDOT converts BRINSAP bridge inventory files for off- and on-system bridges to the actual NBI format and submits this file to FHWA.

BRINSAP runs on a Virtual Storage Access Method (VSAM) data management system (*11*). TxDOT maintains separate BRINSAP files for on- and off-system structures. BRINSAP documentation includes format and coding guides, but not a data dictionary.

BRINSAP uses 13 data templates, called "card types" to update, delete, or add BRINSAP records (*10*). Table 12 shows the card type number for each BRINSAP data item. Card type 13 is not included in the coding guide. Consultant and district users run programs to update records (Program 120213), calculate sufficiency ratings (Program 120404), and edit bridge inspection files (Program 120409) (*12*).

Table 12. BRINSAP Data Fields (*10*).

Item No.	Item Name	Card Type	Number of Digits
Item 2	State Highway Department District	Card 01	2 Digits
Item 3	County Code	Card 01	3 Digits
Item 4	City, Town, or Place Code (Census Place Code)	Card 01	5 Digits
Item 5	Inventory Route	Card 01	10 Digit
Item 5.1	Structure Function	Card 01	1 Digit
Item 5.1A	Intersecting Route Structure Function	Card 10	1 Digit
Item 5.2	Principal Inventory Route	Card 01	2 Digit
Item 5.2A	Intersecting Route System	Card 10	2 Digits
Item 5.3	Designated Level of Service	Card 01	1 Digit
Item 5.4	Route Number	Card 01	4 Digit
Item 5.4A	Intersecting Route Highway Number	Card 10	4 Digit
Item 5.5	Directional Suffix	Card 01	1 Digit
Item 5.5A	Intersecting Route Direction	Card 10	1 Digit
Item 5.6	Business Route Suffix	Card 01	1 Digit
Item 5.6A	Intersecting Business Route Suffix	Card 10	1 Digit
Item 6	Features Intersected	Card 01	25 Digit
Item 7	Facility Carried By Structure	Card 02	18 Digit
Item 8	Structure Number	Card 01	10 Digit
Item 8.3	Duplicate Route Over	Card 01	1 Digit
Item 8.3A	Intersecting Duplicate Route Over	Card 10	1 Digit
Item 8.4	Control	Card 01	(Off System) 6 Digits; (On System) 4 Digits
Item 8.4A	Intersecting Route Control	Card 10	(Off System) 6 Digits; (On System) 4 Digits
Item 8.5	Section	Card 01	2 Digit
Item 8.5A	Intersecting Route Section Number	Card 10	2 Digit
Item 8.6	Permanent Bridge Number	Card 01	3 Digit
Item 8.6A	Intersecting Route Bridge Number	Card 10	3 Digit
Item 9	Location	Card 02	25 Digit
Item 10	Inventory Route, Minimum Vertical Clearance (XX feet XX inches)	Card 02	4 Digit
Item 10A	Intersecting Route Vertical Clearance (XX feet XX inches)	Card 11	4 Digit
Item 11	Inventory Route Milepoint (XX.XXX Miles)	Card 02	5 Digit
Item 11A	Intersecting Route Milepoint (XX.XXX)	Card 10	5 Digit
Item 11.1	Inventory Route Milepoint Date	Card 01	4 Digit
Item 11.1A	Intersecting Route Milepoint Date	Card 01	4 Digit
Item 11.1B	Inventory Route Reference Marker and Displacement	Card 01	11 Digit
Item 11.2B	Intersecting Route Reference Marker and Displacement	Card 10	11 Digit
Item 12	Base Highway Network	Card 13	1 Digit
Item 16	Latitude (XX Degrees XX.X Minutes)	Card 03	5 Digit
Item 17	Longitude (XXX degrees XX.X minutes)	Card 03	6 Digit
Item 19	Bypass, Detour Length (XX Miles)	Card 03	2 Digit
Item 19A	Intersecting Route Bypass Detour Length (XX Miles)	Card 11	2 Digit
Item 20	Toll	Card 03	1 Digit

Table 12. BRINSAP Data Fields (Continued).

Item No.	Item Name	Card Type	Number of Digits
Item 20A	Intersecting Route Toll Code	Card 11	1 Digit
Item 21	Maintenance Responsibility	Card 03	2 Digit
Item 22	Owner	Card 03	2 Digit
Item 22.1	Maintenance Section Number	Card 03	2 Digit
Item 23.1	Project Type	Card 03	1 Digit
Item 23.2	Job Description	Card 03	9 Digit
Item 26	Inventory Route Functional Classification	Card 03	Digits
Item 26A	Intersecting Route Functional Classification	Card 11	2 Digit
Item 27	Year Built	Card 03	2 Digit
Item 28	Lanes On and Under the Structure	Card 03	4 Digit
Item 29	Average Daily Traffic	Card 03	6 Digit
Item 29A	Intersecting Route Average Daily Traffic (ADT)	Card 11	6 Digit
Item 30	Year of Average Daily Traffic	Card 03	2 Digit
Item 30A	Intersecting Route Date of ADT	Card 11	2 Digit
Item 31	Design Load	Card 03	1 Digit
Item 32	Approach Roadway Width (XXX feet)	Card 03	3 Digit
Item 33	Bridge Median	Card 04	1 Digit
Item 34	Skew (XX Degrees)	Card 04	2 Digit
Item 35	Structure Flared	Card 04	1 Digit
Item 36	Traffic Safety Features	Card 04	4 Digit
Item 37	Historical Significance	Card 04	1 Digit
Item 38	Navigation Control	Card 04	1 Digit
Item 39	Navigation Vertical Clearance (XXX feet)	Card 04	3 Digit
Item 40	Navigation Horizontal Clearance (XXXX feet)	Card 04	4 Digit
Item 41	Structure Open, Posted, or Closed to Traffic	Card 04	1 Digit
Item 41.1	Loading Restriction	Card 04	1 Digit
Item 41.2	Load Restriction in Thousands Of Pounds	Card 04	3 Digit
Item 42	Type of Service	Card 04	2 Digit
Item 43	Structure Type		
Item 43.1	Main Span	Card 04	4 Digit
Item 43.2	Structure Type, Major Approach Spans	Card 04	4 Digit
Item 43.3	Structure Type, Minor Approach Spans	Card 04	4 Digit
Item 43.4	Structure Type, Culvert	Card 04	2 Digit
Item 43.5	Structure Type, Tunnel	Card 04	1 Digit
Item 44.1	Substructure Type, Main Spans	Card 04	3 Digit
Item 44.2	Substructure Type, Major Approach Spans	Card 04	3 Digit
Item 44.3	Substructure Type, Minor Approach Spans	Card 04	3 Digit
Item 45.1	Number of Main Spans	Card 05	3 Digit
Item 45.2	Number of Major Approach Spans	Card 05	3 Digit
Item 45.3	Number of Minor Approach Spans	Card 05	3 Digit
Item 46	Total Number of Spans	Card 05	4 Digit
Item 47	Inventory Route, Total Horizontal Clearance (XXX.X feet)	Card 05	4 Digit
Item 47A	Intersecting Route Horizontal Clearance (XXX.X feet)	Card 11	4 Digit
Item 48	Length of Maximum Span (XXXX feet)	Card 05	4 Digit
Item 49	Structure Length (XXXXXX feet)	Card 05	6 Digit
Item 50	Sidewalk Widths (XX.X feet, XX.X feet)	Card 07	6 Digit
Item 51	Bridge Roadway Width, Curb-to-Curb (XXX.X feet)	Card 05	4 Digit
Item 52	Deck Width, Out-to-Out (XXX.X feet)	Card 05	4 Digit
Item 53	Minimum Vertical Clearance Over Bridge Deck (XX feet, XX inches)	Card 05	4 Digit
Item 54	Minimum Vertical Underclearance (X code, XX feet, XX inches)	Card 05	5 Digit
Item 55	Minimum Lateral Underclearance on Right (X code, XX.X feet)	Card 05	4 Digit
Item 56	Minimum Lateral Underclearance on Left (XX.X feet) (for divided highway, 1-way streets, and ramps; not applicable to railroads)	Card 05	3 Digit
Item 58	Deck	Card 06	1 Digit
Item 59	Superstructure	Card 06	1 Digit
Item 60	Substructure	Card 06	1 Digit

Table 12. BRINSAP Data Fields (Continued).

Item No.	Item Name	Card Type	Number of Digits
Item 61	Channel and Channel Protection	Card 06	1 Digit
Item 62	Culverts	Card 06	1 Digit
Item 64	Operating Rating	Card 06	3 Digit
Item 65	Roadway Approach	Card 06	1 Digit
Item 66	Inventory Rating	Card 06	3 Digit
Item 67	Structural Evaluation	Card 06	1 Digit
Item 68	Deck Geometry	Card 06	1 Digit
Item 69	Underclearances, Vertical and Horizontal	Card 06	1 Digit
Item 70	Bridge Posting	Card 06	1 Digit
Item 71	Waterway Adequacy	Card 06	1 Digit
Item 72	Approach Roadway Alignment	Card 06	1 Digit
Item 75	Type of Work	Card 07	3 Digit
Item 76	Length of Structure Improvement (XXXXXX feet)	Card 07	6 Digit
Item 88	Special Flags	Card 07	6 Digit
Item 88A	Underwater Inspection	Card 07	1 Digit
Item 88B	Fracture Critical Areas	Card 07	2 Digit
Item 88C	Steel Type	Card 07	1 Digit
Item 88D	Year Steel Painted	Card 07	2 Digit
Item 90	Inspection Date (mm-dd-yy)	Card 06	6 Digit
Item 91	Designated Inspection Frequency	Card 06	2 Digit
Item 92	Critical Feature Inspection	Card 06	9 Digit
Item 93	Critical Feature Inspection Date	Card 06	12 Digit
Item 94	Bridge Improvement Cost	Card 07	6 Digit
Item 95	Roadway Improvement Cost	Card 07	6 Digit
Item 96	Total Project Cost	Card 07	6 Digit
Item 97	Year of Improvement Cost Estimate	Card 07	2 Digit
Item 98	Border Bridge	Card 08	5 Digit
Item 99	Border Bridge Structure Number	Card 08	15 Digit
Item 100	Defense Highway Designation	Card 08	1 Digit
Item 100A	Intersecting Route Defense Highway Designation	Card 11	1 Digit
Item 101	Parallel Structure Designation	Card 08	1 Digit
Item 101A	Intersecting Route Parallel Structure	Card 11	1 Digit
Item 102	Direction of Traffic	Card 08	1 Digit
Item 102A	Intersecting Route Direction of Traffic	Card 11	1 Digit
Item 103	Temporary Structure Designation	Card 08	1 Digit
Item 103A	Intersecting Route Temporary Structure Designation	Card 11	1 Digit
Item 104	Highway System of the Inventory Route	Card 08	2 Digit
Item 104A	Intersecting Route Highway System	Card 11	2 Digit
Item 106	Year Reconstructed or Widened	Card 08	4 Digit
Item 106.1	Widening Code	Card 08	1 Digit
Item 107.1	Deck Structure Type, Main Span	Card 08	1 Digit
Item 107.2	Deck Structure Type, Major Approach Span	Card 08	1 Digit
Item 107.3	Deck Structure Type, Minor Approach Span	Card 08	1 Digit
Item 108.1	Wearing Surface/Protective System, Main Span	Card 08	3 Digit
Item 108.2	Wearing Surface/Protective System, Major Approach Span	Card 08	3 Digit
Item 108.3	Wearing Surface/Protective System, Minor Approach Span	Card 08	3 Digit
Item 109	Average Daily Truck Traffic (XX percent)	Card 08	2 Digit
Item 109A	Intersecting Route Average Daily Truck Traffic	Card 11	2 Digit
Item 110	Designated National Network	Card 08	1 Digit
Item 110A	Intersecting Route Designated National Network	Card 11	1 Digit
Item 111	Pier or Abutment Protection (for Navigation)	Card 08	1 Digit
Item 112	NBIS Bridge Length	Card 08	1 Digit
Item 113	Scour Critical Bridges	Card 08	1 Digit
Item 113.1	Scour Vulnerability	Card 08	1 Digit
Item 114	Future Average Daily Traffic	Card 09	6 Digit
Item 114A	Intersecting Route Future Average Daily Traffic (ADT)	Card 11	6 Digit

Table 12. BRINSAP Data Fields (Continued).

Item No.	Item Name	Card Type	Number of Digits
Item 115	Year of Future Average Daily Traffic	Card 09	2 Digit
Item 115A	Intersecting Route Year of Future Average Daily Traffic (ADT)	Card 11	2 Digit
Item 116	Minimum Navigation Vertical Clearance Vertical Lift Bridge (xxx feet)	Card 09	3 Digit
Item 119	Cost of Original Construction	Card 07	8 Digit
Item 120	Deficient/Obsolete Code	Card 09	1 Digit
Item 121	Sufficiency Rating	Card 09	4 Digit
Item 126	District Use Fields	Card 09	20 Digit
Item 127	Inventory Route Reason for Change	Card 12	1 Digit
Item 127A	Intersecting Route Reason for Change	Card 12	1 Digit
Item 128	Over Height Load Damage	Card 06	1 Digit
Item 12	Base Hwy Network	Card 13	1 Digit
Item 13.1	LRS Inventory Route	Card 13	10 Digit
Item 13.2	LRS Sub-route	Card 13	2 Digit
Item 12A	I.R. Base Hwy Network	Card 13	1 Digit
Item 13.1A	I.R. LRS Inventory Route	Card 13	10 Digit
Item 13.2A	I.R. LRS Sub-route	Card 13	2 Digit
Item 16.1	GPS Latitude	Card 13	11 Digit
Item 17.1	GPS Longitude	Card 13	12 Digit
Item 17.2	Method Collected	Card 13	1 Digit
Item 63	Method Operating Rate	Card 13	1 Digit
Item 65.1	Method Inventory Rate	Card 13	1 Digit
Item 105	Federal Lands Hwy	Card 13	1 Digit

Methods to access BRINSAP data outside of the mainframe include the following:

- **Microsoft Access®**. The BRINSAP application can export on- and off-system bridge data to text files, which then can be imported into a Microsoft Access template. Details of this procedure are provided in the TxDOT Bridge Inspection Manual (*12*).
- **ESRI® ArcGIS^{TM}**. The BRINSAP application can export bridge data to text files for load restricted bridges and for all bridges. A TxDOT script converts these text files to Geographic Information System (GIS) feature classes and stores these feature classes on an Oracle® server. TxDOT users can view, query, and analyze these feature classes in ArcGIS desktop.
- **Main Street Texas (MST)**. TxDOT users can also view query, and analyze BRINSAP feature classes through MST. MST is a TxDOT intranet application that allows users to access agency spatial data without needing GIS software.

PONTEX

PonTex is a standalone client-server application developed by TxDOT for collecting and managing bridge inspection data (*13*). TxDOT inspects all on-system and off-system bridges in Texas and collects additional information beyond NBI requirements, such as data on all elements of a bridge (*14*). The PonTex interface consists of menu items and tabbed forms (Figure 1, Table 13). PonTex groups bridge inspection activities according to the following phases:

- **Assignment**. During this phase, a TxDOT bridge inspection office assigns a bridge for inspection to a contractor, which assigns the bridge to a team leader or subcontractor.

- **Inspection**. During this phase, the team leader enters and submits inspection results.
- **Review**. During this phase, the outside party and the district inspection office review the inspection.
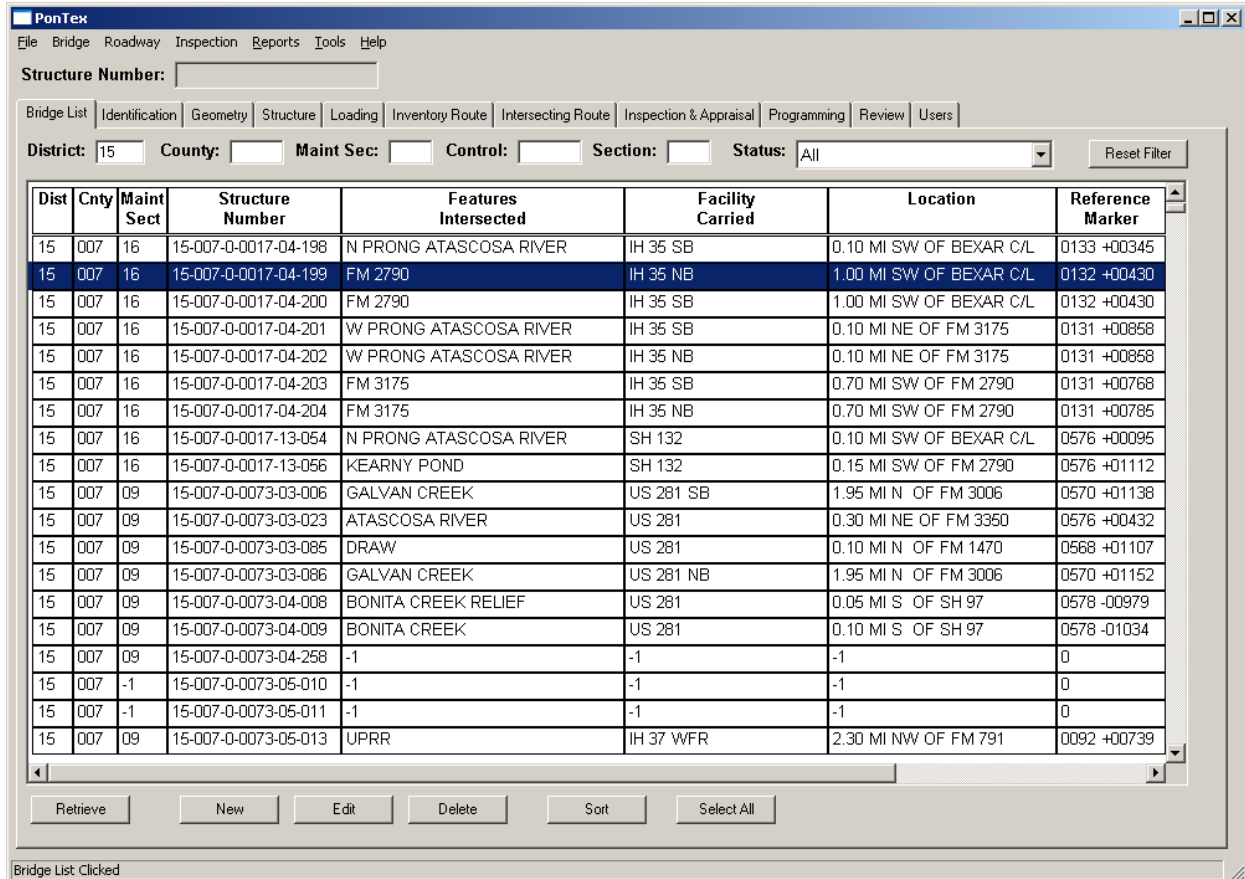
Figure 1. PonTex Version 1.10 Interface (*13*).

Table 13. PonTex Tab Forms (*13*).

Tab Name	Tab Description
Bridge List	This tab contains a list of all bridges and associated data accessible to a specific user.
Identification	These tabs contain permanent structure data, such as location, age, service, and management.
Geometry	
Structure	
Loading	
Programming	
Inventory Route	This tab contains data for the inventory route such as federal system classification and traffic data.
Intersecting Route	This tab contains data for the intersecting route (if it exists), such as federal system classification.
Inspection & Appraisal	This tab contains inspection data, such as condition ratings, inspection histories, and appraisal ratings.
Review	This tab allows an authorized user to accept or reject database changes, such as blocked fields, changed fields, deleted bridges, renamed bridges, renamed routes, submitted and rejected inspections.
Users	This tab contains PonTex user data, such as roles, and contact information.
Assignments*	This tab contains assignments to bridge inspectors, contractors, subcontractors, and team leaders.
Company*	This tab contains data for companies performing bridge inspections.
Components*	This tab contains bridge inspection component and element data. Components include abutments, approaches, bents, culverts, and spans.
Contracts*	This tab contains bridge inspection contract data, such as work authorizations, team leaders, and subcontractors.
Element Condition*	This tab contains the condition for each individual TxDOT or NBI bridge element.

* Indicates a second-level tab not shown in Figure 1.

Figure 2 shows a high-level view of the PonTex physical data model (*15*). This model is an adaptation of the Pontis database schema (*16*). The next section describes Pontis in more detail. PonTex uses modified versions of the following three Pontis tables:

- **INSPEVNT**. In PonTex this table contains one record for each structure inspection, including the inspection type, inspector identification, and structure level inspection results. This table contains attributes from the Pontis INSPEVNT table with no modifications.
- **USERBRDG.** In PonTex this table contains agency-defined bridge-level data (Table 14). This table contains attributes, data types, and definitions from the Pontis USERBRDG and BRIDGE tables, as well as several TxDOT-defined attributes. Many of these additional TxDOT attributes are used in the Permanent Structure Number application, described later, and include data elements such as structure function, service type, and control section numbers for main, adjacent, and crossing roadways and culverts.
- **USERRWAY**. In PonTex this table contains agency-defined roadway-level data. This table contains attributes from the Pontis USERRWAY and ROADWAY tables, as well as TxDOT-defined attributes, such as control number, section number, and job number.
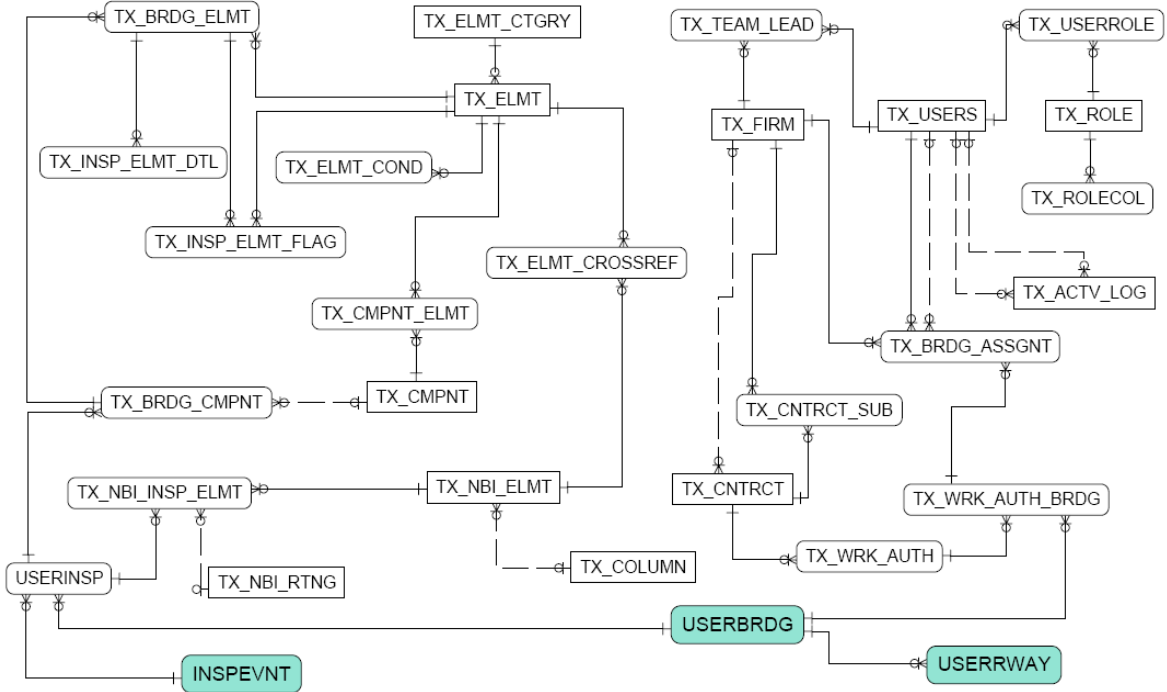
Figure 2. PonTex High-Level Physical Data Model (*15*).

Table 14. PonTex USERBRDG Data Fields (*15*).

Name	Data Type	Definition
APPSPANS	NUMBER(4)	Number of approach spans
ASSGN_TEAM_LDR_ID	VARCHAR(12)	
ASSGNT_DIST	CHAR(2)	
BB_BRDGEID	VARCHAR(15)	Border bridge ID
BB_PCT	NUMBER(2)	Percent in other state
BRDG_DSCR	VARCHAR(250)	
BRIDGE_ID	VARCHAR(30)	Agency Bridge ID - Entered by agency
BRIDGE_ID_CHNG	CHAR(1)	
BRIDGEMED	CHAR(1)	Bridge Median
BRKEY	VARCHAR(15)	Primary Pontis structure key--uniquely identifies the structure in the system.
CONTROL	CHAR(4)	
COST_EST_MTHD	CHAR(1)	
COUNTY	VARCHAR(3)	County
CULV_MEM_CD	CHAR(1)	
CULV_SPAN_CD	CHAR(1)	
CURR_INSPT_STAT_CD	VARCHAR(15)	
CUSTODIAN	VARCHAR(2)	Custodian
DCK_MAJR_APR_CD	CHAR(1)	
DCK_MINR_APR_CD	CHAR(1)	
DECKWIDTH	FLOAT	Deck width, Out-to-Out
DESIGNLOAD	CHAR(1)	Live load for which the structure was designed
DIST_USE_FLD	VARCHAR(2000)	
DISTRICT	VARCHAR(2)	Highway agency district
DKMEMBTYPE	CHAR(1)	Deck membrane type
DKPROTECT	CHAR(1)	Deck protection
DKSTRUCTYP	CHAR(1)	Deck structure type
DKSURFTYPE	CHAR(1)	Deck surface type
FACILITY	VARCHAR(18)	Facility Carried
FEATINT	VARCHAR(24)	
FHWA_REGN	CHAR(1)	FHWA Region
FIPS_STATE	VARCHAR(2)	Federal Information Processing Standard (FIPS) State
GPS_COLLN_MTHD	CHAR(1)	
HCLRULT	FLOAT	Minimum lateral underclearance on left
HCLRURT	FLOAT	Minimum lateral underclearance on right
HISTSIGN	CHAR(1)	Historical Significance
IMPLEN	FLOAT	Length of structure improvement
INITIAL_LOAD_DT	DATE	
INV_RTNG_LD_CD	CHAR(1)	
IR_KEY_CHNG_RESN_CD	CHAR(1)	
IRLOAD	FLOAT	Inventory rating load
IRTYPE	CHAR(1)	Inventory rating type
JOB	CHAR(3)	
KEY_CHNG_RESN_CD	CHAR(1)	
LAND_LOCK_FLAG	CHAR(1)	
LANES_ON_STRUC	CHAR(2)	
LANES_UNDER_STRUC	CHAR(2)	
LASTINSP	DATE	
LATITUDE	NUMBER(8,2)	Latitude
LD_RSTRCN	FLOAT	

Table 14. PonTex USERBRDG Data Fields (Continued).

Name	Data Type	Definition
LENGTH	FLOAT	Structure Length
LFTBRNAVCL	FLOAT	Minimum navigation vertical clearance
LFTCURBSW	FLOAT	Left curb side walk width
LOCATION	VARCHAR(25)	Location
LONGITUDE	NUMBER(9,2)	Longitude
MAIN_SPAN_MEMB	VARCHAR(2)	
MAIN_SPAN_RDWAY	CHAR(1)	
MAIN_SPAN_TYPE	CHAR(1)	
MAINSPANS	NUMBER(3)	Number of main spans
MAINT_SECT_NBR	VARCHAR(2)	
MAJ_ASPAN_MEMB	VARCHAR(2)	
MAJ_ASPAN_RDWAY	CHAR(1)	
MAJ_ASPAN_TYPE	CHAR(1)	
MAJ_ASPN_SUB_ABV	CHAR(1)	
MAJ_ASPN_SUB_BLW	CHAR(1)	
MAJ_ASPN_SUB_CAP	CHAR(1)	
MAJR_APRCH_QTY	NUMBER(3)	
MAXSPAN	FLOAT	Length of maximum span
MIN_ASPAN_MEMB	VARCHAR(2)	
MIN_ASPAN_RDWAY	CHAR(1)	
MIN_ASPAN_TYPE	CHAR(1)	
MIN_ASPN_SUB_ABV	CHAR(1)	
MIN_ASPN_SUB_BLW	CHAR(1)	
MIN_ASPN_SUB_CAP	CHAR(1)	
MINR_APRCH_QTY	NUMBER(3)	
MN_SPAN_SUB_ABV	CHAR(1)	
MN_SPAN_SUB_BLW	CHAR(1)	
MN_SPAN_SUB_CAP	CHAR(1)	
MODTIME	DATE	Time the record was last modified. Reserved for future use.
N_FHWA_REG	CHAR(1)	
NAVCNTROL	CHAR(1)	Navigation Control
NAVHC	FLOAT	Navigation horizontal Clearance
NAVVC	FLOAT	Navigation vertical clearance
NBIIMPCOST	NUMBER(9)	Cost of proposed action - construction portion only
NBIRWCOST	NUMBER(9)	Right of way cost for proposed action
NBISLEN	CHAR(1)	NBIS Length Met
NBITOTCOST	NUMBER(9)	NBI total cost
NBIYRCOST	NUMBER(4)	Year of Improvement Cost Estimate
NSTATECODE	VARCHAR(3)	Neighbor state code of a border bridge
ON_OFF_SYS	VARCHAR(1)	Flag indicates whether bridge is on or off the system of the agency. Usually but not always determined as a function of bridge owner.
OPR_RTNG_LD_CD	CHAR(1)	
OPRTL_STAT_CD	CHAR(1)	
ORLOAD	FLOAT	Operating rating load
ORTYPE	CHAR(1)	Method Used to Determine Operating Rating
OWNER	VARCHAR(2)	Owner
PARALSTRUC	CHAR(1)	Parallel Structure
PLACECODE	VARCHAR(5)	Place Code
POSTING	CHAR(1)	Bridge Posting

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Table 14. PonTex USERBRDG Data Fields (Continued).

Name	Data Type	Definition
PREV_IR_STRUC_FUNC_CD	CHAR(1)	
PREV_IR_STRUC_ID	VARCHAR(10)	
PREV_STRUC_FUNC_CD	CHAR(1)	
PREV_STRUC_ID	VARCHAR(10)	
PROJ_FUND_TYPE	CHAR(1)	
PROPWORK	VARCHAR(2)	Proposed Work
REFHUC	CHAR(1)	Reference feature for lateral underclearance
REFVUC	CHAR(1)	Reference feature for underclearance measurement
RSTRCN_CD	CHAR(1)	
RTCURBSW	FLOAT	Right curb side walk width
SECTION	CHAR(2)	
SERVTYPON	CHAR(1)	Type of service on bridge
SERVTYPUND	CHAR(1)	Type of service under bridge
SKEW	NUMBER(2)	Skew
SRSTATUS	CHAR(1)	Bridges where SR status has changed
STRFLARED	CHAR(1)	Structure flared
STRUC_COST	NUMBER(8)	
STRUC_FUNC_CD	CHAR(1)	
STRUC_LAT	NUMBER(11,8)	
STRUC_LON	NUMBER(11,8)	
STRUCNAME	VARCHAR(50)	Agency structure name
STRUCT_NUM	VARCHAR(15)	FHWA Structure Number - NBI 8
TEMPSTRUC	CHAR(1)	Temporary structure designation
TUN_STRUC_CD	CHAR(1)	
TX_CHECKED_OUT	VARCHAR(20)	
TX_LAST_UPDT_DT	DATE	
TX_LAST_UPDT_USER	VARCHAR(20)	
TX_RUN_DATE	CHAR(6)	
TX_STATUS	VARCHAR(20)	
TX_VALID	VARCHAR(20)	
USERKEY	VARCHAR(4)	Primary key to the users table. Key of user that last modified record.
VCLROVER	FLOAT	Minimum vertical clearance over bridge roadway
VCLRUNDER	FLOAT	Minimum vertical underclearance
WEAR_PROT_MAJR	CHAR(1)	
WEAR_PROT_MINR	CHAR(1)	
WEAR_SRFC_MAJR	CHAR(1)	
WEAR_SRFC_MINR	CHAR(1)	
WEAR_WPROF_MAJR	CHAR(1)	
WEAR_WPROF_MINR	CHAR(1)	
WHN_BLT_CTR_NBR	VARCHAR(4)	
WHN_BLT_JOB_NBR	VARCHAR(4)	
WHN_BLT_SCT_NBR	VARCHAR(4)	
WIDENING_CD	CHAR(1)	
WORKBY	CHAR(1)	Work done by
YEARBUILT	NUMBER(4)	Year built
YEARRECON	NUMBER(4)	Year reconstruction

Note: Blank definitions indicate null description values in available technical documentation.

PonTex data reside on Oracle servers hosted by TSD. As opposed to BRINSAP, PonTex can store elemental bridge data collected during bridge inspections. PonTex also accepts inspection imagery and other digital files. PonTex is accessible to TxDOT internal users and external consultants through Citrix® products.

TxDOT's plan is to phase out BRINSAP when PonTex is implemented statewide. However, TxDOT will maintain BRINSAP data, with updates from PonTex, since other TxDOT legacy systems use BRINSAP data.

PONTIS

Pontis is a bridge management system developed in the late 1980s. Currently, Pontis is part of the American Association of State Highway and Transportation Officials (AASHTO) BRIDGEWare product suite (*17*). The current version of Pontis is 5.1. Pontis 5.2 is under development and is expected to be released in 2012.

Pontis describes bridges using structural elements, such as girders, stringers, and beams; truss components; arches; pin and hanger assemblies; decks and deck slabs; railings and traffic barriers; deck joints; bearings; piers and columns; abutments, approach slabs, and wing walls; and footings and pilings. Pontis includes structure condition, preservation treatments or actions, bridge deterioration models, cost modules, and environmental conditions for each structural element. By comparison, NBI describes bridges using more generic components, such as superstructure, substructure, and deck. Pontis includes the following modules (*16*):
- **Inspection module**. This module handles the review and analysis of bridge data, including bridge inventory and inspection data. Figure 3 shows the interface for this module.
- **Project Planning Module**. This module provides tools for project development. These tools include identification of structure needs, analysis of future structure performance based on work type, project scheduling of individual structures, create budget-constrained programs of structure projects, and record project completion information.
- **Programming Module**. This module sets up structure improvement policies and standards, and runs simulations of alternative multi-year, budget-constrained program scenarios.
- **Preservation Module**. This module develops and runs models for optimal long-term preservation policies that minimize life cycle costs and risk of element failures.
- **Results Module**. This module provides graphical reports of predicted network costs and performance associated with different scenarios and project programs.
- **Gateway Module**. This module imports and exports data between Pontis and other systems.
- **Configuration Module**. This module customizes Pontis according to individual agency needs.

Pontis 4.3.1 - You are currently logged in as PONTIS

File View Tools Window Help

Desktop - Inspection

Inspection | Layout | Count | Find... | Select... | Save... | Select All | Just Selected

Rows 1 to 28 of 1432   Layout: -- Default Structure Layout --

New
☑ Duplicate
☑ Element
Open Past
Translate
Suff Rate
Validate
Transfer Data
Check Out...
Check In...
Structure
Create
Remove
Reports
Retrieve
Limit to 0
? |< < > >|

Bridge ID	Feature Intersected	Dist	Cnty	Own	Maint.	Area	Meters	Built	Structure Nam
1001 279	BRANDYWINE CREEK	orth Distri	3 New Castl	State Highway Agen	State Highway Agen	02	39	1928	-1
1001A279	BRANDYWINE CREEK	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	8	1900	-1
1001B009	WATERWAY	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	9	1919	-1
1002 232	BRANDYWINE CREEK	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	50	1933	-1
1003 225	BRANDYWINE CREEK	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	59	1990	THOMPSON'S
1004P000	RD 50 NORTHEAST BL	orth Distri	3 New Castl	City/Municipal Hwy Ag	City/Municipal Hwy Ag	00	31	1972	-1
1005P000	RD 19 NEW CASTLE A	orth Distri	3 New Castl	City/Municipal Hwy Ag	City/Municipal Hwy Ag	00	31	1972	-1
1006P000	SR 2	orth Distri	3 New Castl	City/Municipal Hwy Ag	City/Municipal Hwy Ag	00	31	1972	-1
1007P000	RD 358 OGLETOWN RD	orth Distri	3 New Castl	26 Private(nonRailroad	26 Private(nonRailroad	00	54	1987	MBNA PEDEST
1008 221	BEAVER VALLEY CREE	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	13	1960	-1
1009 221	BRANDYWINE CREEK	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	42	1900	SMITH'S BRIDG
1010P000	I 495, RD 60	orth Distri	3 New Castl	State Highway Agency	31 State Toll Authority	99	182	1982	-1
1011N267	RD 232, ROCKLAND RC	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	17	1997	-1
1011S267	RD 232, ROCKLAND RC	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	17	1997	-1
1012 223	HURRICANE RUN	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	4	1900	-1
1013P000	I 495	npike Dist	3 New Castl	State Highway Agency	31 State Toll Authority	99	137	1975	-1
1014 221	BEAVER VALLEY CREE	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	10	1962	-1
1016 221	BEAVER VALLEY CREE	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	8	1988	-1
1017 221	BEAVER VALLEY CREE	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	7	1987	-1
1018 221	BEAVER VALLEY CREE	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	7	1987	-1
1019 232	WATERWAY	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	2	1900	-1
1020 232	HUSBAND RUN	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	8	1932	-1
1022 229	WILLOW RUN	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	4	1957	-1
1023A231	READING RR	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	20	1918	-1
1024 004	ROCKY RUN	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	9	1987	-1
1025 004	WATERWAY	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	02	4	1941	-1
1026 203	NAAMANS CREEK	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	01	17	1965	-1
1027P000	US 13	orth Distri	3 New Castl	State Highway Agency	State Highway Agency	05	58	1973	-1

1432 structures were retrieved.   Training (pontis)   N/A   03/04/2005

Figure 3. Screen Capture of Pontis Inspection Module (*18*).

Pontis uses a relational database schema that groups data into the following categories (*19, 20*):

- **Physical inventory**. These tables support the Pontis Inspection Module and include data such as bridges, roadways, inspection events, and element inspections. As an illustration, Table 15 provides a list of Pontis bridge table attributes. Attributes shown in italics indicate attributes also contained in the PonTex USERBRDG table (Table 14).
- **Program simulation**. These tables support the Pontis Program simulation module and include data such as scenarios, scenario parameters, agency policy rules, rehabilitation rules, and scope rules.
- **Project planning**. These tables support the Pontis Project planning module and include data such as projects, project funding sources, and programs.
- **Definition tables**. These tables include definitions for elements, materials, and costs.
- **System tables**. These tables include user information, preferences, and logs.

Table 15. Pontis Bridge Data Fields (*20, 21*).

Name	Datatype	Definition
BRKEY	*VARCHAR(15)*	*Primary Pontis structure key—uniquely identifies the structure in the system.*
BRIDGE_ID	*VARCHAR(30)*	*Agency Bridge ID - Entered by agency*
STRUCT_NUM	*VARCHAR(15)*	*FHWA Structure Number - NBI 8*
STRUCNAME	*VARCHAR(50)*	*Agency structure name*
FEATINT	*VARCHAR(24)*	
FHWA_REGN	*CHAR(1)*	*FHWA Region*
DISTRICT	*VARCHAR(2)*	*Highway agency district*
COUNTY	*VARCHAR(3)*	*County*
FACILITY	*VARCHAR(18)*	*Facility Carried*
LOCATION	*VARCHAR(25)*	*Location*
CUSTODIAN	*VARCHAR(2)*	*Custodian*
OWNER	*VARCHAR(2)*	*Owner*
ADMINAREA	VARCHAR(2)	Geographic stratification—administrative area—of a state
BRIDGEGROUP	VARCHAR(20)	Agency defined bridge group for a bridge. Used to group sets of bridges for assignment to inspectors or for other review purposes. Not unique
NSTATECODE	*VARCHAR(3)*	*Neighbor state code of a border bridge*
N_FHWA_REG	*CHAR(1)*	
BB_PCT	*NUMBER(2)*	*Percent in other state*
BB_BRDGEID	*VARCHAR(15)*	*Border bridge ID*
PROPWORK	*VARCHAR(2)*	*Proposed Work*
WORKBY	*CHAR(1)*	*Work done by*
NBIIMPCOST	*NUMBER(9)*	*Cost of proposed action - construction portion only*
NBIRWCOST	*NUMBER(9)*	*Right of way cost for proposed action*
NBITOTCOST	*NUMBER(9)*	*NBI total cost*
NBIYRCOST	*NUMBER(4)*	*Year of Improvement Cost Estimate*
YEARBUILT	*NUMBER(4)*	*Year built*
YEARRECON	*NUMBER(4)*	*Year reconstruction*
HISTSIGN	*CHAR(1)*	*Historical Significance*
DESIGNLOAD	*CHAR(1)*	*Live load for which the structure was designed*
SERVTYPON	*CHAR(1)*	*Type of service on bridge*
SERVTYPUND	*CHAR(1)*	*Type of service under bridge*
SUMLANES	NUMBER(2)	Sum of all lanes for all NBI routes passing under the structure
MAINSPANS	*NUMBER(3)*	*Number of main spans*
APPSPANS	*NUMBER(4)*	*Number of approach spans*
MAXSPAN	*FLOAT*	*Length of maximum span*
LENGTH	*FLOAT*	*Structure Length*
DECK_AREA	FLOAT	Deck Area
BRIDGEMED	*CHAR(1)*	*Bridge Median*
SKEW	*NUMBER(2)*	*Skew*
MATERIALMAIN	CHAR(1)	Material
DESIGNMAIN	VARCHAR(2)	Design
MATERIALAPPR	CHAR(1)	Material of the approach span
DESIGNAPPR	VARCHAR(2)	Design of the approach span
DKSTRUCTYP	*CHAR(1)*	*Deck structure type*
DKMEMBTYPE	*CHAR(1)*	*Deck membrane type*
DKSURFTYPE	*CHAR(1)*	*Deck surface type*
DKPROTECT	*CHAR(1)*	*Deck protection*
DECKWIDTH	*FLOAT*	*Deck width, Out-to-Out*

Table 15. Pontis Bridge Data Fields (Continued).

Name	Datatype	Definition
LFTCURBSW	*FLOAT*	*Left curb side walk width*
RTCURBSW	*FLOAT*	*Right curb side walk width*
STRFLARED	*CHAR(1)*	*Structure flared*
REFVUC	*CHAR(1)*	*Reference feature for under-clearance measurement*
REFHUC	*CHAR(1)*	*Reference feature for lateral under-clearance*
HCLRURT	*FLOAT*	*Minimum lateral under-clearance on right*
HCLRULT	*FLOAT*	*Minimum lateral under-clearance on left*
LFTBRNAVCL	*FLOAT*	*Minimum navigation vertical clearance*
NAVCNTROL	*CHAR(1)*	*Navigation Control*
NAVHC	*FLOAT*	*Navigation horizontal Clearance*
NAVVC	*FLOAT*	*Navigation vertical clearance*
PARALSTRUC	*CHAR(1)*	*Parallel Structure*
TEMPSTRUC	*CHAR(1)*	*Temporary structure designation*
NBISLEN	*CHAR(1)*	*NBIS Length Met*
LATITUDE	*NUMBER(8,2)*	*Latitude*
LONGITUDE	*NUMBER(9,2)*	*Longitude*
VCLROVER	*FLOAT*	*Minimum vertical clearance over bridge roadway*
VCLRUNDER	*FLOAT*	*Minimum vertical under-clearance*
PLACECODE	*VARCHAR(5)*	*Place Code*
IMPLEN	*FLOAT*	*Length of structure improvement*
FIPS_STATE	*VARCHAR(2)*	*FIPS State*
TOT_LENGTH	FLOAT	Total length
NEXTINSPID	VARCHAR(4)	Userkey of the person who will do the next inspection
CREWHRS	NUMBER(5,2)	Number of crew hours required for an inspection
FLAGGERHRS	NUMBER(5,2)	Number of flagger hours required for an inspection
HELPERHRS	NUMBER(5,2)	Number of helper hours required for an inspection
SNOOPERHRS	NUMBER(5,2)	Number of snooper hours required for an inspection
SPCREWHRS	NUMBER(5,2)	Number of special crew hours required for an inspection
ON_OFF_SYS	*VARCHAR(1)*	*Flag indicates whether bridge is on or off the system of the agency. Usually but not always determined as a function of bridge owner.*
RATINGDATE	DATE	Date Load Rated
RATER_INI	VARCHAR(3)	Load Rater/Engineer Responsible
ORLOAD	*FLOAT*	*Operating rating load*
ORTYPE	*CHAR(1)*	*Method Used to Determine Operating Rating*
IRLOAD	*FLOAT*	*Inventory rating load*
IRTYPE	*CHAR(1)*	*Inventory rating type*
POSTING	*CHAR(1)*	*Bridge Posting*
REQ_OP_RAT	NUMBER(2)	Required Operating Rating
DEF_OP_RAT	CHAR(1)	Deficiency Operating Rating Flag
FC_DETAIL	VARCHAR(5)	FC Detail on Structure
ALTORLOAD	FLOAT	Alternate Load Rating
ALTORMETH	VARCHAR(4)	Alternate Operating Rating Method
ALTIRLOAD	FLOAT	Alternate Inventory Load Rating
ALTIRMETH	VARCHAR(4)	Alternate Inventory Rating Method
OTHERLOAD	FLOAT	Other load rating
TRUCK1OR	FLOAT	Operating rating for truck type 1
TRUCK2OR	FLOAT	Operating rating for truck type 2
TRUCK3OR	FLOAT	Operating rating for truck type 3
TRUCK1IR	FLOAT	Inventory rating for truck type 1
TRUCK2IR	FLOAT	Inventory rating for truck type 2

Table 15. Pontis Bridge Data Fields (Continued).

Name	Datatype	Definition
TRUCK3IR	FLOAT	Inventory rating for truck type 3
SRSTATUS	*CHAR(1)*	*Bridges where SR status has changed*
USERKEY1	VARCHAR(30)	User defined key fields
USERKEY2	VARCHAR(30)	User defined key fields
USERKEY3	VARCHAR(30)	User defined key fields
USERKEY4	VARCHAR(30)	User defined key fields
USERKEY5	VARCHAR(30)	User defined key fields
USERKEY6	VARCHAR(30)	User defined key fields
USERKEY7	VARCHAR(30)	User defined key fields
USERKEY8	VARCHAR(30)	User defined key fields
USERKEY9	VARCHAR(30)	User defined key fields
USERKEY10	VARCHAR(30)	User defined key fields
USERKEY11	VARCHAR(30)	User defined key fields
USERKEY12	VARCHAR(30)	User defined key fields
USERKEY13	VARCHAR(30)	User defined key fields
USERKEY14	VARCHAR(30)	User defined key fields
USERKEY15	VARCHAR(30)	User defined key fields
BTRIGGER	CHAR(1)	Flag to trigger missing value formulas
TRACEFLAG	CHAR(1)	When checked, bridge is traced in log file during program simulation routine.
CREATEDATETIME	DATE	
CREATEUSERKEY	VARCHAR(4)	
MODTIME	*DATE*	*Time the record was last modified. Reserved for future use.*
USERKEY	*VARCHAR(4)*	*Primary key to the users table. Key of user that last modified record.*
DOCREFKEY	VARCHAR(255)	Document reference key
NOTES	VARCHAR(2000)	Entry comments
TX_STATUS	*VARCHAR(20)*	
TX_CHECKED_OUT	*VARCHAR(20)*	
TX_VALID	*VARCHAR(20)*	

Note: Data fields in italics are also contained in the PonTex USERBRDG table.

Although many states have Pontis licenses (*22*), it is common for agencies to customize Pontis to meet their needs. Pontis allows some customization of bridge element and bridge action definitions and classifications, cost indices, data processing formulas, user interfaces, user privileges, data input forms and reports. TxDOT has a Pontis license, but the agency has not used Pontis other than for providing tables to the data model needed to support the development of PonTex. Concerns about the current version of Pontis include the following:

- TxDOT does not have access to Pontis source code, which affects the agency's ability to customize the application to meet TxDOT's needs.
- Pontis does not have deterioration models for states with very large north-south and east-west spans and considerable weather variety such as Texas.
- TxDOT needs to test Pontis to determine if the system can handle the number of bridges located in Texas.
- TxDOT needs to test Pontis for user friendliness and stability.

In the short term, TxDOT plans to continue to use PonTex. When the new version of Pontis is released, TxDOT plans to evaluate its functionality for items such as functions to model bridge

deterioration and prediction of future conditions. Realistically, most users will still interact with PonTex for data collection, but Pontis will provide the tools for analysis and planning. If TxDOT adopts the new Pontis version, the agency will need to address the issue of whether to modify the database schema that is currently providing support to PonTex.

FINANCIAL INFORMATION MANAGEMENT SYSTEM

The Financial Information Management System (FIMS), which runs on an Adabas platform, records TxDOT accounting events and is the basis for all official departmental financial information (*23*). In addition to DCIS and MMIS, FIMS interfaces with other TxDOT systems such as the Contract Information System (CIS), Construction/Maintenance Contract System (CMCS), Material Supply Management System (MSMS), and Equipment Operations System (EOS). FIMS includes the following segment files (*23*).

- Segment 01 (FIMS-CSH01) – Cash.
- Segment 02 (FIMS-LTY0229) – Bank Retainage Deposits.
- Segment 04 (FIMS-REC04) – Accounts Receivable/Task Reimbursement.
- Segment 07 (FIMS-REC07) – Accounts Receivable/Miscellaneous.
- Segment 09 (FIMS-LTY09) – Warehouse Stock.
- Segment 10 (FIMS-LTY1011) – Capitalized Equipment.
- Segment 12 (FIMS-BAL12) – Buildings and Land.
- Segment 25 (FIMS-VOUCHERS) – Online Cash Voucher Data Entry.
- Segment 25 (FIMS-VPP) – Vouchers Payable.
- Segment 26 (FIMS-LTY26) – Accounts Payable.
- Segment 27 (FIMS-REC27) – Funds in Trust.
- Segment 29 (FIMS-LTY0229) – Retainage Liabilities.
- Segment 30 (FIMS-LTY30) – Payroll Deduction.
- Segment 31 (FIMS-LTY31) – Miscellaneous Deduction.
- Segment 41 (FIMS-ENC41) – Miscellaneous Contract.
- Segment 45 (FIMS-EQT) – Fund Balance.
- Segment 48 (FIMS-EQT) – Reserve for Investment in Inventories and Capitalized Assets.
- Segment 49 (FIMS-EQT) – Reserve for Accrued Unbillable Costs.
- Segment 60 (FIMS-CSH60) – Cash Receipts Revenue.
- Segment 61 (FIMS-CSH61) – Revenue Earned/Not Collected.
- Segment 70 (FIMS-CLR70) – Clearing Accounts.
- Segment 71 (FIMS-FUN71) – Functional Expenditure.
- Segment 72 (FIMS-RES72) – Research.
- Segment 74 (FIMS-PUB74) – Public Transportation.
- Segment 76 (FIMS-CNS76) – Construction and Maintenance Projects.
- Segment 77 (FIMS-CNS76) – Special Maintenance and Facility Projects.
- Segment 78 (FIMS-RMT78) – Routine Maintenance.
- Segment 79 (FIMS-OFF79) – Traffic Safety.
- Segment 99 (FIMS-GEN99) – General Ledger.

Of particular interest are the following segment files:

- **Segment 76 (FIMS-CNS76) – Construction and Maintenance Projects**. This segment contains financial data for highway construction projects and maintenance projects managed using construction program procedures (*24*). Input data for this segment is DCIS cost data. Table 16 lists Segment 76 data fields. Of these fields, FUNCTION and OBJECT-EXP (Object of Expenditure) are of special significance. The FUNCTION field indicates the type of work financed by a specific fund. The OBJECT-EXP field indicates the types of goods or services purchased or consumed for the work type specified by the FUNCTION field. For example, Function Code 170 includes bridge inspection. Expenditure Object Code 134 includes allowances for underwater bridge inspection.

- **Segment 78 (FIMS-RMT78) – Routine Maintenance**. This segment contains direct expenses and associated indirect costs for routine roadway maintenance (*28*). MMIS cost data are an input for this file. Table 17 lists Segment 78 data fields. Of these fields, FUNCTION and OBJECT-EXP (Object of Expenditure) are of special significance. Segment 78 function codes differ from Segment 76 function codes. Segment 78 function codes for bridges are similar to MMIS function codes shown in Table 8. Object of Expenditure codes are the same in Segment 78 and Segment 76.

Table 16. FIMS Segment 76 (FIMS-CNS76) Data Fields (*24*).

Field	Field	Field
AMOUNT-TIME-INFO	HIGHWAY-NUMBER	PROJECT-NO
AUTHORITY-DESCR	ID-FILLER-FIELD	PRORATE-CHARGES-FLAG
BIRA-DCMNT-CMNT	IE-FILLER-FIELD	RURAL-CODE
BIRA-DCMNT-FY-YY-DT	INDICATOR-INFO	SEGMENT-ID
BIRA-DCMNT-SEQN-NBR	INVOICE-DESCR	SETUP-INFO
BIRA-DCMNT-TYPE-CD	KEEP-FLAG	SETUP-INFO-2
BIRA-EFFCTV-YYYYMM-DT	KEYS	SFIN-FI
BOND-PGM-TYPE-ID	KIND-OF-PROJECT	SOURCE-COST-CTR
BUDGET-ACCOUNT	LAPA-CODE	SOURCE-DIST-DIV
BUDGET-ACTIVITY	LAST-UPDT-DT	SOURCE-UNIT
BUDGET-DIST	LAST-UPDT-TM	STATUS
CE-PCT	LAST-UPDT-USER-ID	STATUS-CHANGE-DATE-DT
CONTRACT-NO	LOW-BID-AMOUNT	STATUS-CHANGE-DATE-YYMM
COST-CENTER-INFO	LTD-ADMIN-AMT	SUPERZA
COST-CTR	LTD-ADMIN-AMT2	SUPERZB
COUNTY-NUMBER	LTD-AMOUNT	SUPERZC
CSJ	LTD-MANHRS	SUPERZD
DCIS-INFO	LTD-RETAINAGE-AMOUNT	SUPERZE
DELETE-FLAG	MANAGER-NO	SUPERZF
DH-FILLER-FIELD	MAN-HOURS	SUPERZG
DIST-DIV	MASTER-UPDATE-FLAG	SUPERZH
EFFECTIVE-DATE-DT	MTD-AMOUNT	SUPERZI
EFFECTIVE-DATE-YYMM	MTD-ARRAYS	SUPERZJ
FI-FILLER-FIELD	MTD-MANHRS	SUPERZK
FINAL-BILLING-CODE	NEW-FUND-SOURCE	SUPERZP
FUNCTION	OBJECT-EXP	SUPERZQ
FUNCTION-RANGE	OBLIGATION-AMOUNT	TASK-NO
FUNDING-INFO	OBSOLETE-IND	TRANS-ID
FUND-PCT	POSTING-AMOUNT	TRUST-FUND-IND
FUND-SOURCE	POSTING-DATE	TYPE-NEW
GL-FISCAL-YR	POSTING-DATE-DT	TYPE-OLD
GL-FISCAL-YR-DT	POSTING-INFO	TYPE-WORK
GL-INFO	PREV-FY-INFO	VOUCH-KIND
GL-LEDGER-NO	PRIMARY-CSJ	VOUCH-NO
GL-STATE-FUND	PRIOR-YTD-AMOUNT	YTD-AMOUNT
GL-TRANS20-AMOUNT	PRIOR-YTD-MANHRS	YTD-AMT-PREV1-FY
GL-TRANS24-AMOUNT	PRIOR-YTD-OBLIGATION	YTD-AMT-PREV2-FY

Table 17. FIMS Segment 78 (FIMS-RMT78) Data Fields (*25*).

Field	Field	Field
ACTUAL-CLASS	GL-LEDGER-NO	POSTING-DATE
AMOUNT-TIME-INFO	GL-STATE-FUND	POSTING-DATE-DT
AUTHORITY-DESCR	GL-TRANS20-AMOUNT	POSTING-INFO
BKEND-GEN-FY1	GL-TRANS24-AMOUNT	PREV-FY-INFO
BKEND-GEN-FY2	HWY-CNTY-DDO-FUNC-KEY	PRIOR-YTD-AMOUNT
BOUCH-NO	HWY-DESCR	PRIOR-YTD-MANHRS
BUDGET-ACCOUNT	HWY-INFO	RECORD-KEYS
BUDGET-ACTIVITY	HWY-MAP-INFO	SETUP-INFO
BUDGET-DIST	HWY-MILEAGE	SOURCE-COST-CTR
COST-CTR	HWY-SETUP-INFO	SOURCE-DIST-DIV
COST-CTR-INFO	ID-FILLER-FIELD	SOURCE-UNIT
COUNTY	INDICATOR-INFO	STATUS
DELETE-FLAG	INVOICE-DESCR	SUPER-ZA
DIST-DIV	KEEP-FLAG	SUPER-ZB
EFFECTIVE-DATE-DT	LAST-UPDT-DT	SUPER-ZC
EFFECTIVE-DATE-YYMM	LAST-UPDT-TM	SUPER-ZE
EI-FILLER-FIELD	LAST-UPDT-USER-ID	SUPER-ZF
ENABLE-IND	MAINT-SECTION	SUPER-ZG
FISCAL-YR	MAN-HOURS	SUPER-ZH
FUNCTION	MASTER-UPDATE-FLAG	TASK-NO
FUNCTION-RANGE	MTD-AMOUNT	TRANS-ID
FUNDING-INFO	MTD-ARRAYS	VOUCH-KIND
FUND-PCT	MTD-MANHRS	VOUCH-NO
FUND-SOURCE	NEW-FUND-SOURCE	YTD-AMOUNT
GL-FISCAL-YR	OBJECT-EXP	YTD-AMT-PREV1-FY
GL-FISCAL-YR-DT	OBSOLETE-IND	YTD-AMT-PREV2-FY
GL-INFO	POSTING-AMOUNT	YTD-MANHRS

TEXAS PERMIT ROUTING OPTIMIZATION SYSTEM

Texas Permit Routing Optimization System (TxPROS) is a web-based application that TxDOT is developing to improve oversize/overweight (OS/OW) routing and permitting tasks (*26, 27*). TxPROS will replace the existing Central Permitting System (CPS), using a TxDOT customization of the ProMiles web-based permitting system (*28*).

The TxPROS application stores data in an Oracle database. Using integrated GIS mapping and real-time restriction management, TxPROS will provide automated routing and route validation assistance (*27*). Major TxPROS features include the following (*26*):

- **Mapping**. TxPROS uses Tele-Atlas®' street network, which covers the entire state, conflated with TxDOT roadway inventory data.
- **Restrictions management**. TxPROS supports web-based updates to permanent (e.g., height, width, weight, maneuvering), temporary (e.g., construction), and directive (e.g., flagmen needed to traverse a certain bridge) restrictions affecting OS/OW routing.
- **Routing**. TxPROS generates routes using restriction management and route points. A key TxPROS functionality will be the capability to generate and evaluate alternate OS/OW routes.
- **Reporting**. TxPROS supports report templates and ad hoc queries, such as "How many X ton loads have traversed this segment?"

PERMANENT STRUCTURE NUMBER

PSN is an intranet-based application that accepts requests from districts for new permanent bridge structure numbers (*18*). PSN data reside in an Oracle schema. The TxDOT Bridge Division manages PSN data content to ensure that a structure has only one PSN value, while TSD maintains the PSN application and database. PSN values are unique and are an essential component of a structure ID. A structure ID uniquely identifies a structure within the NBI database. In Texas, structure IDs are concatenations of PSN values with control sections and county codes. By knowing the structure ID, TxDOT staff can retrieve data and the status of a structure within BRINSAP.

Depending on user permissions, the PSN application allows users to retrieve, request, and assign on-system PSN values. To request a PSN value, users enter the following information (*29, 30*):
- CSJ number.
- Backlogged flag.
- Letting date.
- County.
- Replaced structure ID.
- Type of service under/on the bridge.
- Structure function of roadway under/on the bridge.
- Control section of roadway under/on the bridge.
- Type of roadway under/on the bridge.
- Number of roadway under/on the bridge.
- Additional name/description of what is under/on the bridge.
- Route direction.
- Beginning station number.
- Ending station number.
- Comments.

PSN is intended for use during the project development process. When districts log in a new structure number request, the system checks the replicated DCIS data warehouse in SQL Server to determine if the project is within one year of letting. If the project is within one year of letting, the PSN application assigns a PSN value to the specific structure.

Users can also search for PSN values, replaced PSN values, rejected PSN values, and CSJ values and can export the results to a text file or a Microsoft Excel file (*29, 30*). The PSN search results include structure number, facility carried, facility crossed, CSJ, and job status. Users can also view memorandums documenting the assignment of specific PSN values.

BRIDGE SHOP PLAN

TxDOT is developing a web-based application called Bridge Shop Plan that records and tracks data about shop plans that fabricators and contractors submit to TxDOT electronically. This application, which uses a SQL Server platform, is currently in development by TSD.

In several states, asset management information systems, such as bridge management, have suffered from data and communication disconnects from design and construction systems. These disconnects occur after bridges are opened to traffic but bridge inspectors are not notified. Linking the Bridge Shop Plan application to a BMIS could reduce this disconnect, in that bridge inspectors would be notified when shop plans for a bridge have been submitted to TxDOT, when the plans are available for use by the inspectors after bridge construction, and if the schedule for an anticipated bridge inspection needs to be updated.

GIS-BASED PRACTICES, PLANS, AND APPLICATIONS

TxDOT primarily uses GIS technology to support programming, planning, and maintenance activities—although the use of GIS to support design, construction, and operations is growing. TxDOT GIS production data reside on an Oracle database. Table 18 provides a summary of production GIS data sets at TxDOT, with an indication of the source (TxDOT or other agency). TxDOT GIS data must conform to TxDOT GIS Standards (*31*) and the TxDOT Data Architecture (*32*).

Table 18. Production GIS Data Sets at TxDOT (*33*).

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

The Structures production data sets include the following (*33*):
- **BRINSAP_MST_PNT**. This data set contains points that represent the location of bridges and structures. The data set includes structures that are on the TxDOT route system (on system) and that are not on the TxDOT route system (off system). This data set was created to be used in MST intranet application (*33*). These data are extracted from the BRINSAP mainframe VSAM file and contain 233 fields. No changes to data names have been made to comply with TxDOT data naming conventions.

- **BRINSAP_PNT**. This data set also contains points that represent the location of on- and off-system bridges or structures. These data are extracted from the BRNSAP mainframe VSAM file and contain a subset of five out of 233 fields.

- **LRBM**. This data set is a set of points that identify the location of structures that have safety load restrictions, are closed, or are land locked. The data set includes on- and off-system structures. These data are extracted from the BRNSAP mainframe VSAM file and contain a subset of 21 out of 233 fields.

SYSTEM DIAGRAM AND RELATIONSHIPS

Figure 4 shows high-level relationships between several bridge-related systems described in this chapter. For completeness, this figure shows existing, potential, and research project prototype linkages. Systems not depicted in Figure 4 include FIMS, TxPROS, and Bridge Shop Plan. FIMS reprocesses bridge-related data, TxPROS is a consumer of bridge-related data, while Bridge Shop Plan is in development. In general, DCIS, BRINSAP, Pontis, PonTex, and BridgeLog provide core data for bridge infrastructure management. Other systems, notably, MMIS, MST, and FIMS, provide supplemental or supporting data for bridge infrastructure management.

Figure 4 uses the TxDOT's system interface diagram (TSID) notation found in the TxDOT Data Architecture document (*32*). The header of Figure 4 provides system data sources the researchers used to develop this figure. In Figure 4, system applications, including programs, functions, tools, interfaces, front ends, and other similar elements are represented by rectangles; user access is represented by workstations; and database file storage is represented by cylinders. Database files are grouped together based on database system or architecture. For example, DCIS and MMIS use the Adabas environment. Data for Pontex, Main Street Texas, and BridgeLog are stored in Oracle, while replicated Adabas data are stored in SQL Server.

In Figure 4, existing linkages are shown by solid lines, future linkages are shown by dashed lines, and linkages for the research prototypes are shown by dotted lines. In general, TxDOT staff runs programs and functions from workstations that populate, query, and retrieve data from databases. Some programs are accessible internally through TxDOT's Crossroads intranet or externally with the assistance of a Citrix gateway (e.g., PonTex). Data warehouses (e.g., COMMON_DSGN, ArcSDE STRUCTURES) are populated and updated from legacy systems (e.g., DCIS, BRINSAP). Currently, PonTex populates a modified-Pontis schema that updates BRINSAP data records. In the future, it is expected that TxDOT will be using the latest version of Pontis and will populate a Pontis schema.

The 0-6389 prototype applications, described in Chapters 3 through 5, plus Appendices A and B, access DCIS tables located in the COMMON_DSGN schema in SQL Server. This access is done by using ODBC with Microsoft Access or by using Microsoft SQL Server Management Studio, both through TxDOT's web-based Citrix gateway connection.
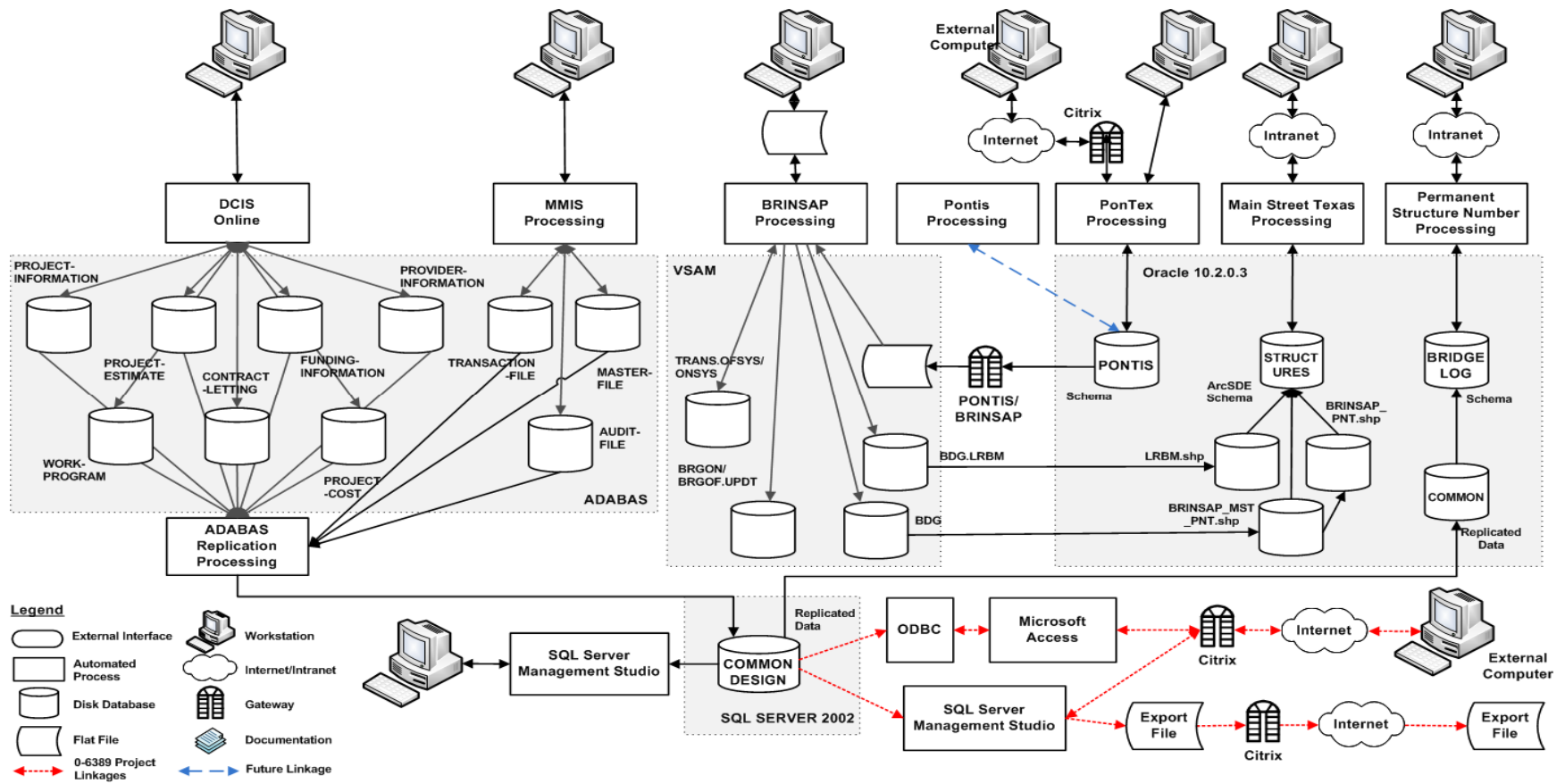
Figure 4. Bridge-Related Systems at TxDOT.

CHAPTER 3. PROTOTYPE DATABASE APPLICATION TO EXTRACT SUMMARY BRIDGE STATISTICS

INTRODUCTION

This chapter describes the development of the prototype database application to extract summary bridge statistics needed for the annual bridge report and other similar queries. It includes a discussion about data reporting and other requirements that guided the development effort and a description of the process to build the prototype database application. Chapter 5 includes the corresponding installation and user guide. Appendix A includes details on the queries to produce the prototype bridge report tables.

REQUIREMENTS FOR THE SUMMARY BRIDGE STATISTICS PROTOTYPE

The overall objective of the prototype database application was to replicate statistics published in the *Report on Texas Bridges* (*34*). This report describes the condition of all publicly-owned vehicular bridges in Texas at the end of each fiscal year and helps TxDOT track progress toward the goals established by the Texas Transportation Commission to make 80 percent of bridges in Texas in good or better condition and eliminate structurally deficient on-system bridges (*35*). Table 19 lists the tables and figures included in the 2008 *Report on Texas Bridges*. The researchers replicated all the tables and figures in the report, with the exception of the following:

- **Table 3-3 Land-Locking Bridges as of September 2008.** This table requires the use of information that is not available in DCIS or BRINSAP (e.g., a visual examination of TxDOT highway maps to determine whether a bridge is a land-locking bridge).

- **Table 6-5 PWP/EMP Projects in FY 2008 by District.** This table is based on data from a separate TxDOT Bridge Division annual report (*36*) that tracks participation-waived projects (PWPs) and equivalent-match projects (EMPs).

- **Figure A-1 Map of Texas Counties with TxDOT Districts.** This figure does not use bridge data.

Table 19. Tables and Figures in the 2008 *Report on Texas Bridges*.

Page	Table/Figure	Caption	Note
Chapter 2 - Characteristics of Texas Bridges			
11	Figure 2-1	Count of On- and Off-System Texas Bridges as of September 2008 (50,572 Total)	Based on Table 2-1
12	Table 2-1	Count of On- and Off-System Bridges	-
13	Table 2-2	Age of Bridges in FY 2008	-
13	Figure 2-2	Age of On- and Off-System Texas Bridges in FY 2008 (50,572 Total)	Based on Table 2-2
14	Table 2-3	Change in Age of Bridges from September 2006 to September 2008	-
14	Figure 2-3	On-System Timber Bridges by Year	-
Chapter 3 - Condition of Texas Bridges			
16	Table 3-1	Condition of Texas Bridges by Count in September 2008 (50,572 Total)	-
16	Figure 3-1	Condition of Texas Bridges by Count in September 2008 (50,572 Total)	Based on Table 3-1
18	Figure 3-2	Change in Condition of Non-Sufficient Bridges from FY 2006–2008	-
19	Table 3-2	Load Posted and Closed Bridges as of September 2008	-
20	Table 3-3	Land-Locking Bridges as of September 2008	Not replicated
Chapter 5 - On-System Contract Awards			
27	Table 5-1	On-System Bridges Awarded in Highway Bridge Program (HBP) Projects, by District	-
27	Table 5-2	On-System Bridges Awarded in Non-HBP Projects, by District	-
28	Table 5-3	On-System Bridges Replaced or Rehabilitated in FY 2008	-
28	Table 5-4	On-System Bridges in Bridge Projects Awarded in FY 2008	-
29	Figure 5-1	Distribution of Funds Spent on On-System Bridges in FY 2008	Based on Table 5-4
Chapter 6 - Off-System Contract Awards			
31	Table 6-1	Off-System Bridges Awarded in HBP Projects, by District	-
31	Table 6-2	Off-System Bridges Awarded in Non-HBP Projects, by District	-
32	Table 6-3	Off-System Bridges Replaced or Rehabilitated in FY 2008	-
32	Table 6-4	Off-System Bridges in Bridge Projects Awarded in FY 2008	-
33	Figure 6-1	Distribution of Funds Spent on Off-System Bridges in FY 2008	Based on Table 6-4
34	Table 6-5	PWP/EMP Projects in FY 2008 by District	Not replicated
Chapter 7 - Meeting the Challenges			
36	Table 7-1	Bridges that Must Be Improved to Reach the 80%-Sufficient-by-End-of-2011 Goal	-
Appendices A - C			
39	Figure A	Map of Texas Counties with TxDOT Districts	Not replicated
41	Table B	Condition of On-System Bridges by TxDOT District and County as of September, 2008	-
49	Table C	Condition of Off-System Bridges by TxDOT District and County as of September, 2008	-

Specific requirements for the development of the prototype included the following:

- Replicate as many 2008 *Report on Texas Bridges* tables and figures as possible.
- Use a standalone database environment (more specifically Microsoft Access 2003).
- Use generic query structures for the prototype to use any combination of years of interest.
- Use snapshot views of BRINSAP representing end-of-year bridge inventory conditions.
- Use snapshot views of DCIS representing end-of-year project funding conditions.

The researchers received copies of the BRINSAP database from the Bridge Division representing "end-of-year" conditions for fiscal years 2001–2008. The researchers also received a partial BRINSAP database for fiscal year 2009. Each database file (in Microsoft Access 2003 format) includes two tables, BRGOF and BRGON, which represent off-system and on-system bridges, respectively. The Bridge Division extracts end-of-year inspection files from BRINSAP files on the mainframe to develop the annual bridge report. The practice of extracting end-of-year files is necessary because the mainframe does not store historical data.

The researchers also received partial DCIS tables that facilitated the development of preliminary queries. However, TxDOT did not have reliable copies of snapshot DCIS views to replicate the annual bridge report. As described in Chapter 2, TxDOT has replicated all DCIS files into the SQL Server COMMON_DSGN schema. The researchers received live read-only access to select table views through a web-based Citrix gateway. "Live" data are not the same as end-of-year data since some DCIS data may have changed after the end of the fiscal year. Although differences between query results and the published report were found, the researchers felt these differences were minor.

The web-based Citrix gateway (Figure 5) is a mechanism TxDOT uses to provide consultants and contractors restricted access to its non-legacy systems and databases. After a user has successfully entered a user name and password, an icon for the RA CITRIX2 Citrix Desktop application is presented (Figure 6). Clicking on the icon launches the Citrix Desktop environment, where users can access DCIS data in the COMMON_DSGN schema using SQL Server Enterprise Manager (Figure 7) or using Microsoft Access through an ODBC driver (Figure 8).
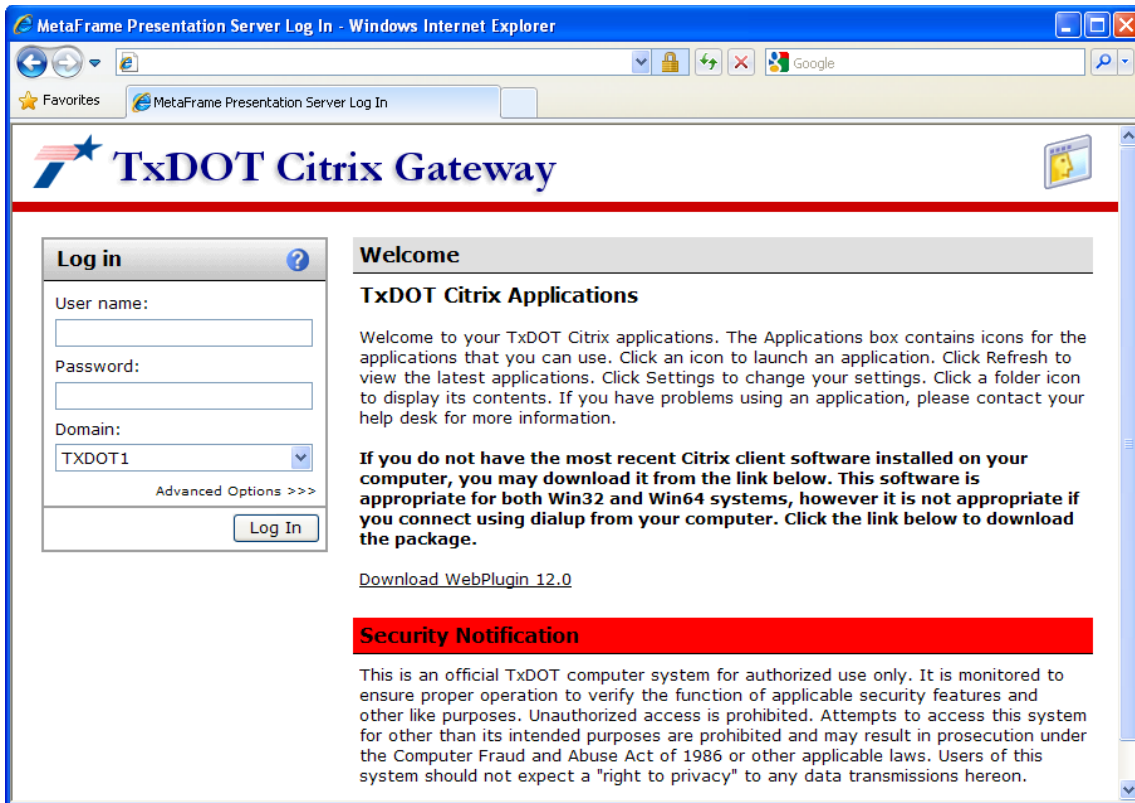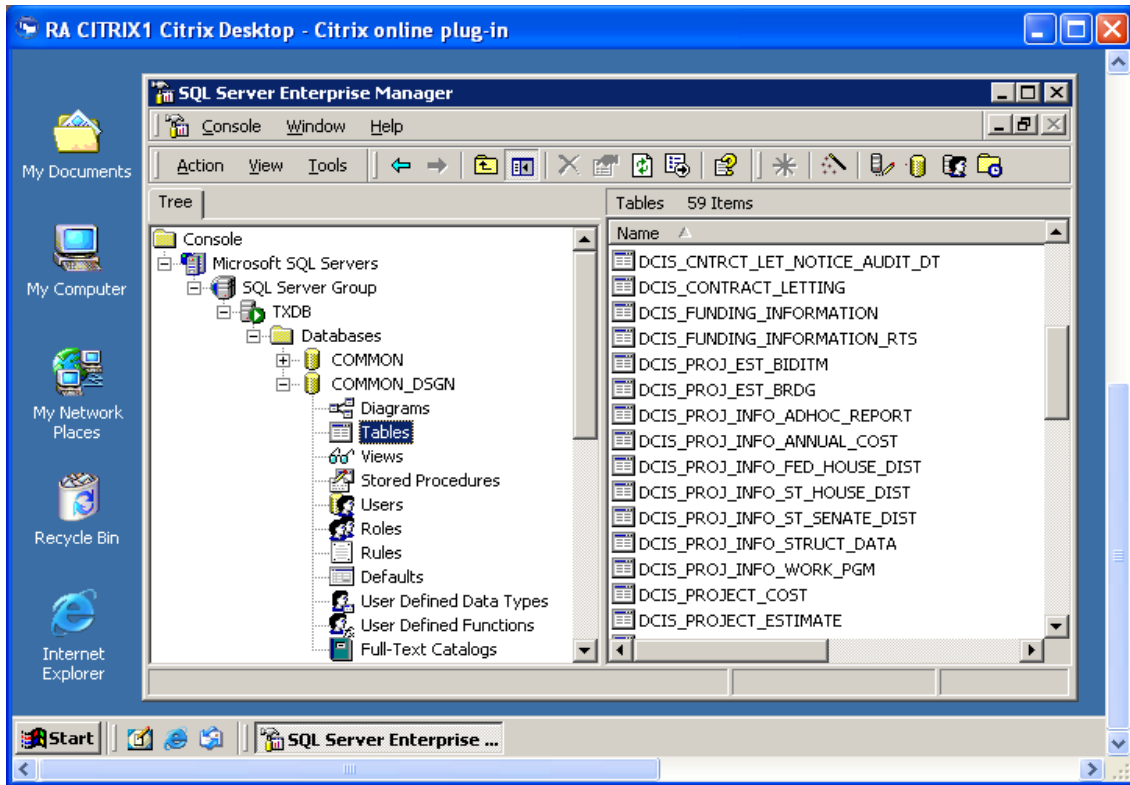
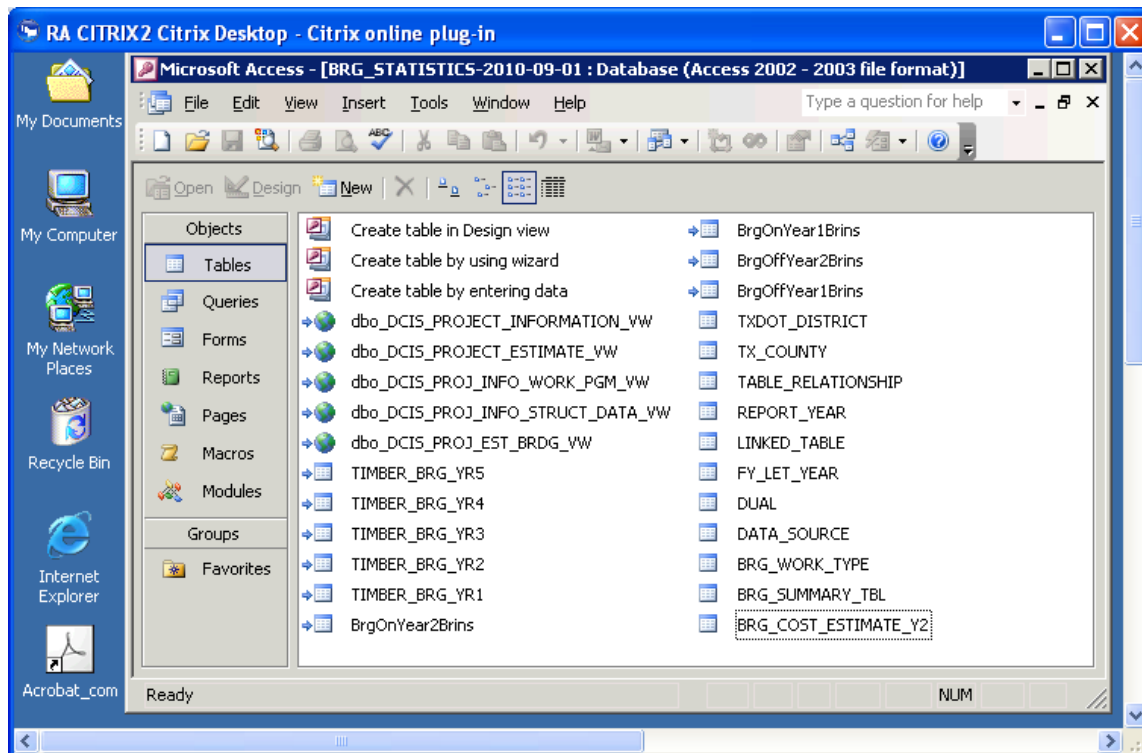**Figure 5. TxDOT Citrix Gateway Login Screen.**

Figure 6. TxDOT Citrix Gateway Applications Screen.

Figure 7. RA CITRIX2 Citrix Desktop with SQL Server Enterprise Manager.

Figure 8. Citrix Desktop with Microsoft Access Summary Bridge Statistics Prototype.

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DEVELOPMENT OF BRIDGE STATISTICS PROTOTYPE APPLICATION

Development of the prototype database application involved the following major steps:
- Identify data elements for each table or figure in the 2008 *Report on Texas Bridges*.
- Create queries that replicate the tables and figures in this report.
- Develop a form-based database application interface.

The following are detailed descriptions of the issues and challenges during these steps.

Identifying Data Elements

TxDOT publishes the *Report on Texas Bridges* annually based on data primarily from BRINSAP and DCIS. For each table or figure in the 2008 report, the research team first identified the data sources (i.e., BRINSAP and/or DCIS) and then identified the data elements with TxDOT assistance. The level of TxDOT assistance with data element identification varied based on the data sources and complexity of the data fields contained in a report table. In general, as part of the data element identification, the researchers categorized tables from the *Report on Texas Bridges* into the following:
- **Report tables and figures based on one end-of-year BRINSAP database**. These tables and figures use data either from a single table (e.g., Appendix B – Condition of On-System Bridges by TxDOT District and County as of September 2008) or from multiple tables (e.g., Table 2-2 Age of Bridges in FY 2008) from a single end-of-year BRINSAP database. For this category, the research team identified the data source (i.e., BRINSAP) and data elements with minimum TxDOT assistance.
- **Report tables and figures based on multiple BRINSAP databases or subject matter expertise.** Some report tables or figures use data from multiple tables in multiple BRINSAP databases (e.g., Table 2-3 Change in Age of Bridges from September 2006 to September 2008). Some involve calculations that are difficult to understand without firsthand knowledge (e.g., Table 7-1 Bridges that Must Be Improved to Reach the 80%-Sufficient-by-End-of-2011 Goal). For this category, the researchers had to use TxDOT assistance to identify all data elements or clarify the calculation procedures.
- **Report tables and figures based on DCIS data**. A number of report tables involve DCIS data (e.g., Table 5-4 On-System Bridges in Bridge Projects Awarded in FY 2008). DCIS is relatively complex and contains a large number of data files and data fields. DCIS has new, obsolete, or modified attributes, which can cause confusion during the data identification process. For many of these tables, the research team had to rely on TxDOT assistance in order to identify correct data elements.
- **Report tables and figures involving data not available in existing data sources**. Some report tables (i.e., Table 3-3 Land-Locking Bridges as of September 2008 and Table 6-5 PWP/EMP Projects in FY 2008 by district) require information that is not readily available in TxDOT data systems. The research team spent significant resources on data identification for these tables but discovered that the necessary data were not in the available data sources. Upon approval from TxDOT, these tables were not included in the developed prototype.

Table 20 lists the data sources and data elements identified for each of the replicated tables and figures in the 2008 *Report on Texas Bridges*. For report tables with BRINSAP as a data source, Table 20 includes how many years of data are needed and what roadway systems are used (i.e., on- and/or off-system). Additionally, in this table, data elements from DCIS table views and DCIS-generated tables are bulleted.

Table 20. Major Data Elements for Bridge Statistics Prototype.

Table/Figure	Data Source	Data Elements
Table 2-1	BRINSAP (two years, on- and off- system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner
Table 2-2	BRINSAP (one year, on- and off- system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner Item 27 – Year Built
Table 2-3	BRINSAP (two years, on- and off- system)	Same as Table 2-2
Figure 2-3	BRINSAP (five years, on- system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner Item 44.1 – Substructure Type, Main Spans Item 44.2 – Substructure Type, Major Approach Spans Item 44.3 – Substructure Type, Minor Approach Spans
Table 3-1	BRINSAP (one year, on- and off- system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner Item 41 – Structure Open, Posted, or Closed to Traffic Item 120 – Deficient/Obsolete Code
Figure 3-2	BRINSAP (two years, on- and off- system)	Same as Table 3-1
Table 3-2	BRINSAP (one year, on- and off- system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner Item 41 – Structure Open, Posted, or Closed to Traffic
Table 3-2	Table Accounting Code System (TACS)	TxDOT District name and number
Table 5-1	DCIS	DCIS_PROJ_EST_BRDG_VW • BRDG_NBI_NUMBER • BRDG_SYSTEM_ID DCIS_PROJECT_INFORMATION_VW • DISTRICT_NUMBER • ACTUAL_LET_DATE DCIS_PROJ_INFO_WORK_PGM_VW • CATEGORY_P2
Table 5-2	DCIS	Same as Table 5-1

Table 20. Major Data Elements for Bridge Statistics Prototype (Continued).

Table/Figure	Data Source	Data Elements
Table 5-3	BRINSAP	Bridge Structure ID Item 27 – Year Built Item 120 – Deficient/Obsolete Code Operation Status

	DCIS	DCIS_PROJ_EST_BRDG_VW
		  • BRDG_NBI_NUMBER
		  • BRDG_SYSTEM_ID
		  • BRDG_WORK_TYPE
		DCIS_PROJECT_INFORMATION_VW
		  • ACTUAL_LET_DATE
		DCIS_PROJ_INFO_WORK_PGM_VW
		  • CATEGORY_P2
		DCIS_PROJ_INFO_STRUC_DATA
		  • NBI_NUMBER

Table 5-4	DCIS	DCIS_PROJ_EST_BRDG_VW
		  • BRDG_NBI_NUMBER
		  • BRDG_SYSTEM_ID
		  • BRDG_WORK_TYPE
		DCIS_PROJECT_INFORMATION_VW
		  • ACTUAL_LET_DATE
		DCIS_PROJ_INFO_WORK_PGM_VW
		  • CATEGORY_P2
		  • PROJ_COST
		BRG_COST_ESTIMATE_Y2 (table generated by the Bridge Cost Estimate prototype; see Total Bridge Cost Estimate section of Appendix B)
		  • Contract CSJ
		  • Project Winning Bid
		  • Winning Bid for Bridge Project

Table 6-1	DCIS	Same as Table 5-1
Table 6-2	DCIS	Same as Table 5-1
Table 6-3	BRINSAP DCIS	Same as Table 5-3
Table 6-4	DCIS	Same as Table 5-4
Table 7-1	BRINSAP (one year, on and off- system)	Same as Table 3-1
Table B	BRINSAP (one year, on system)	Bridge Structure ID Item 5.1 – Structure Function Item 22 – Owner Item 41 – Structure Open, Posted, or Closed to Traffic Item 120 – Deficient/Obsolete Code
	TACS	TxDOT District name and number County name and TxDOT number
Table C	BRINSAP (one year, off system) TACS	Same as Table B

Creating Summary Bridge Statistics Prototype Queries

Query creation verified the identification of data elements. The researchers started creating most queries at the same time their data elements were being identified. Creating the queries that only involve BRINSAP data were straightforward. Queries involving DCIS data were more difficult to replicate and frequently required a time-consuming trial-and-error process. The major challenges during the process included:

- There was a selection of data elements that could be used for a data field in a query. This challenge was common for some complicated queries involving DCIS data due to the following factors:
  - The same data field is included in multiple tables. Without sufficient documentation, it is difficult to know which data field and corresponding table contains the original field and if all fields are updated regularly. It is critical that the application uses the original field that is regularly updated.
  - Certain data fields in DCIS became obsolete over time and were replaced by new fields. In this case, the challenge was to identify if the data contained in the old field were transferred to the new replacement field. Many queries require access to the complete data in order to produce accurate results.
- Some queries with DCIS data produced significantly different results compared to the 2008 report. Reasons for this issue included one or more of the following:
  - TTI used live DCIS data instead of end-of-year DCIS data, which were used in the 2008 report. The live data contained updates made after the end of the fiscal year that were not reflected in the 2008 report.
  - The replicated queries were not correct due to indiscernible errors associated with the identified data elements or calculation procedures.
  - The 2008 report included problematic tables associated with bridge costs. Numerous discrepancies in DCIS data were resolved through a manual process by BRG. Thus, certain tables in the report could contain problematic results that were not replicable.
- A few replicated queries produced slightly different results compared to the 2008 report. These queries had correct structures and data elements as verified by relevant TxDOT BRG officials. The differences could be due to discrepancies between the BRINSAP and DCIS data that the research team used and the data TxDOT originally used for the 2008 report. Nevertheless, these queries were considered correct as the differences were insignificant.

To address these challenges, the research team routinely met with BRG and/or TSD to verify the data elements and calculation procedures used in the queries. As a result, the research team was able to resolve all the challenges and successfully replicated all necessary queries in the final prototype application.

Developing Summary Bridge Statistics Prototype Interface

In conjunction with query creation for the prototype, the researchers developed a graphical user interface (GUI) to assist users in the production of summary bridge statistic reports. The application was developed in Microsoft Access 2003 and used the Access Form function for development of the user interface. The major objectives of the interface were:

- Provide basic user guidance for the application.
- Facilitate users in selecting necessary data files.
- Provide user-friendly access to all queries.

The major considerations during the interface development included:
- **Interface design**. To meet the major objectives of the prototype user interface, the researchers decided to use a multi-tab interface that includes the following five tabs:
  o Introduction, which provides brief background information on the application.
  o BRINSAP Data Sources, which allows users to specify the BRINSAP data files for creating the annual bridge report.
  o DCIS Data Sources, which allows users to specify the years for which DCIS data will be used.
  o Timber Bridge Data Sources, which allows users to specify the data files for the timber bridge analysis.
  o Bridge Statistics, which allows users to generate the desired tables or figures from the annual *Report on Texas Bridges*.
- **BRINSAP data linkage**. In the annual *Report on Texas Bridges*, many of the tables require two years of BRINSAP data for comparison; however, the timber bridge analysis requires data for five years. For simplicity and flexibility, the researchers decided to provide separate tabs for selecting the end-of-year BRINSAP database files: one tab for selecting the two BRINSAP database files that are needed for most tables and the other tab for selecting the five BRINSAP database files for the timber bridge analysis. The application passes the specified years to corresponding queries that in turn would select the desired BRINSAP data
- **DCIS data linkage**. The prototype application has a direct linkage to live DCIS data. For simplicity and flexibility, the research team decided to create a separate tab for users to specify the two DCIS data years needed for the queries. The application passes the specified years to corresponding queries that in turn would select the desired DCIS data.

DEVELOPED SUMMARY BRIDGE STATISTICS PROTOTYPE APPLICATION

The Summary Bridge Statistics prototype application is a Microsoft Access 2003 database application consisting of tables (Figure 9 and Table 21), queries (Figure 10 and Table 22), and a form-based interface. The prototype includes several queries that are invoked through the application's form interface. These queries, called "main queries" invoke other queries, called "sub-queries." Table 22 lists the main queries and sub-queries used to produce each report table or figure in the prototype. Appendix A describes these main queries and the sub-queries associated with them. The installation guide and user guide in Chapter 5 of this report includes detailed illustrations of the application's interface, structure, and functions.
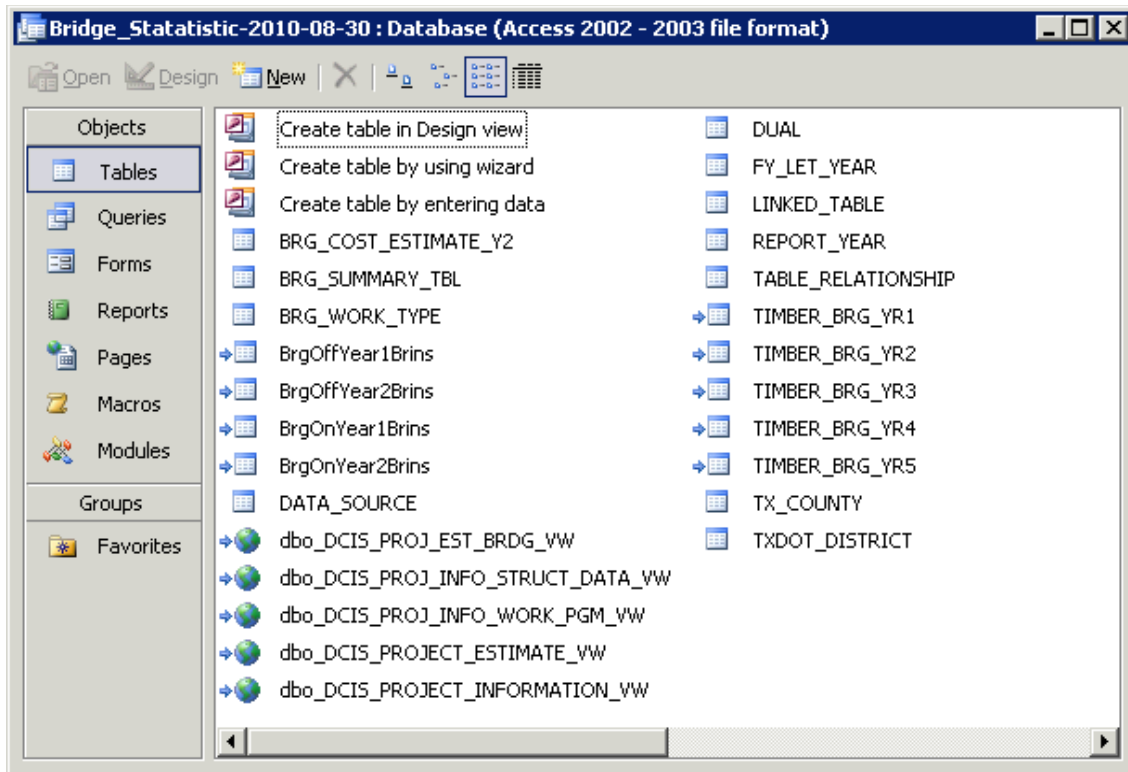
Figure 9. Tables in the Summary Bridge Statistics Prototype.

Table 21. Tables in the Summary Bridge Statistics Prototype.

| Name	Table Type	Description
BRG_COST_ESTIMATE_Y2	Native	Contains bridge project cost data. This table is produced by the Bridge Cost Estimate Prototype Application.
BRG_SUMMARY_TBL	Native	Contains a list of main queries and descriptions of the tables/figures they produce.
BRG_WORK_TYPE	Native	Contains bridge work type names and codes from Bridge Cost Information (BCI) and P3B screens of DCIS.
BrgOffYear1Brins	Linked Access Table	Contains BRINSAP data of off-system bridges for a year prior to the report year for comparison purpose. For example, to create Table 2-3 "Change in Age of Bridges from September 2006 to September 2008 in the 2008 report," this would be the BRGOF table in the fiscal year 2006 end-of-year BRINSAP snapshot database file.
BrgOffYear2Brins	Linked Access Table	Contains BRINSAP data of off-system bridges for the report year. For example, to create the 2008 report, this would be the BRGOF table in the fiscal year 2008 end-of-year BRINSAP snapshot database file.
BrgOnYear1Brins	Linked Access Table	Contains BRINSAP data of on-system bridges for the year prior to the report year. For example, to create Table 2-3 Change in Age of Bridges from September 2006 to September 2008 in the 2008 report, this would be the BRGON table in the fiscal year 2006 end-of-year BRINSAP snapshot database file.
BrgOnYear2Brins	Linked Access Table	Contains BRINSAP data of on-system bridges for the report year. For example, to create the 2008 report, this would be the BRGON table in the fiscal year 2008 end-of-year BRINSAP snapshot database file.
DATA_SOURCE	Native	Stores the data sources of the linked BRINSAP data tables for use by the Form-based interface.

Table 21. Tables in the Summary Bridge Statistics Prototype (Continued).

Name	Table Type	Description
dbo_DCIS_PROJ_EST_ BRDG_VW	Linked SQL Table	This is the linked DCIS_PROJ_EST_ BRDG_VW view from the TxDOT SQL Server database.
dbo_DCIS_PROJ_INFO_ STRUCT_DATA_VW	Linked SQL Table	This is the linked DCIS_PROJ_INFO_ STRUCT_DATA_VW from the TxDOT SQL Server database.
dbo_DCIS_PROJ_INFO_ WORK_PGM_VW	Linked SQL Table	This is the linked DCIS_PROJ_INFO_ WORK_PGM_VW from the TxDOT SQL Server database.
dbo_DCIS_PROJECT_ ESTIMATE_VW	Linked SQL Table	This is the linked DCIS_PROJECT_ ESTIMATE_VW view from the TxDOT SQL Server database.
dbo_DCIS_PROJECT_ INFORMATION_VW	Linked SQL Table	This is the linked DCIS_PROJECT_ INFORMATION_VW view from the TxDOT SQL Server database.
DUAL	Native	Empty table used by some queries (e.g., _Table_2_3_Bridge_Age_Change) to meet SQL syntax requirements when no data need to be extracted.
FY_LET_YEAR	Native	Stores a list of years from 1993–2011 for use by the Form-based interface.
HBP_PROJECT	Native	
LINKED_TABLE	Native	Stores the names of linked BRINSAP tables for use by the Form-based interface.
REPORT_YEAR	Native	Contains two records (i.e., 2006 and 2008) that are the two years used frequently on the 2008 bridge report for use by the Form-based interface.
TABLE_RELATIONSHIP	Native	Contains a list of relationships between certain queries for use by the Form-based interface. This table enables the application to identify and overwrite the fiscal years used in the listed queries according to user selections on interface.
TIMBER_BRG_YR1	Linked Access Table	Contains BRINSAP data of on-system bridges for the first fiscal year in the timber bridge analysis similar to Figure 2-3 On-System Timber Bridges by Year in the 2008 report. For example, for the 2008 report, this would be the BRGON table in the fiscal year 2002 end-of-year BRINSAP snapshot database file.
TIMBER_BRG_YR2	Linked Access Table	Contains BRINSAP data of on-system bridges for the second fiscal year in the timber bridge analysis. For example, for the 2008 report, this would be the BRGON table in the fiscal year 2003 end-of-year BRINSAP snapshot database file.
TIMBER_BRG_YR3	Linked Access Table	Contains BRINSAP data of on-system bridges for the third fiscal year in the timber bridge analysis. For example, for the 2008 report, this would be the BRGON table in the fiscal year 2004 end-of-year BRINSAP snapshot database file.
TIMBER_BRG_YR4	Linked Access Table	Contains BRINSAP data of on-system bridges for the fourth fiscal year in the timber bridge analysis. For example, for the 2008 report, this would be the BRGON table in the fiscal year 2006 end-of-year BRINSAP snapshot database file.
TIMBER_BRG_YR5	Linked Access Table	Contains BRINSAP data of on-system bridges for the last fiscal year (or the report year) in the timber bridge analysis. For example, for the 2008 report, this would be the BRGON table in the fiscal year 2008 end-of-year BRINSAP snapshot database file.
TX_COUNTY	Native	Stores the names of the Texas counties and their numbers TxDOT uses for identification purpose.
TXDOT_DISTRICT	Native	Stores the names and numbers of TxDOT districts.
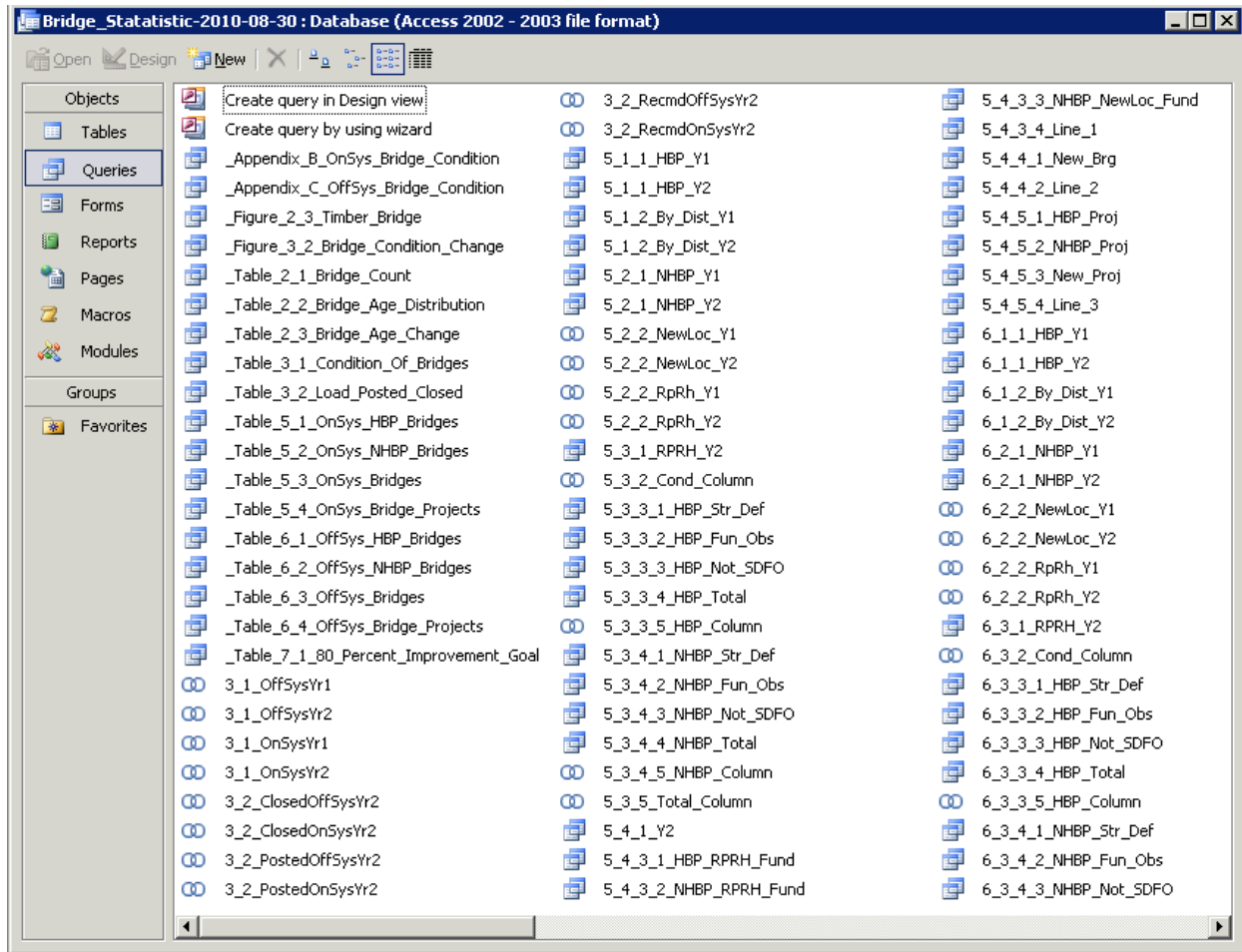
Figure 10. Queries in the Summary Bridge Statistics Prototype.
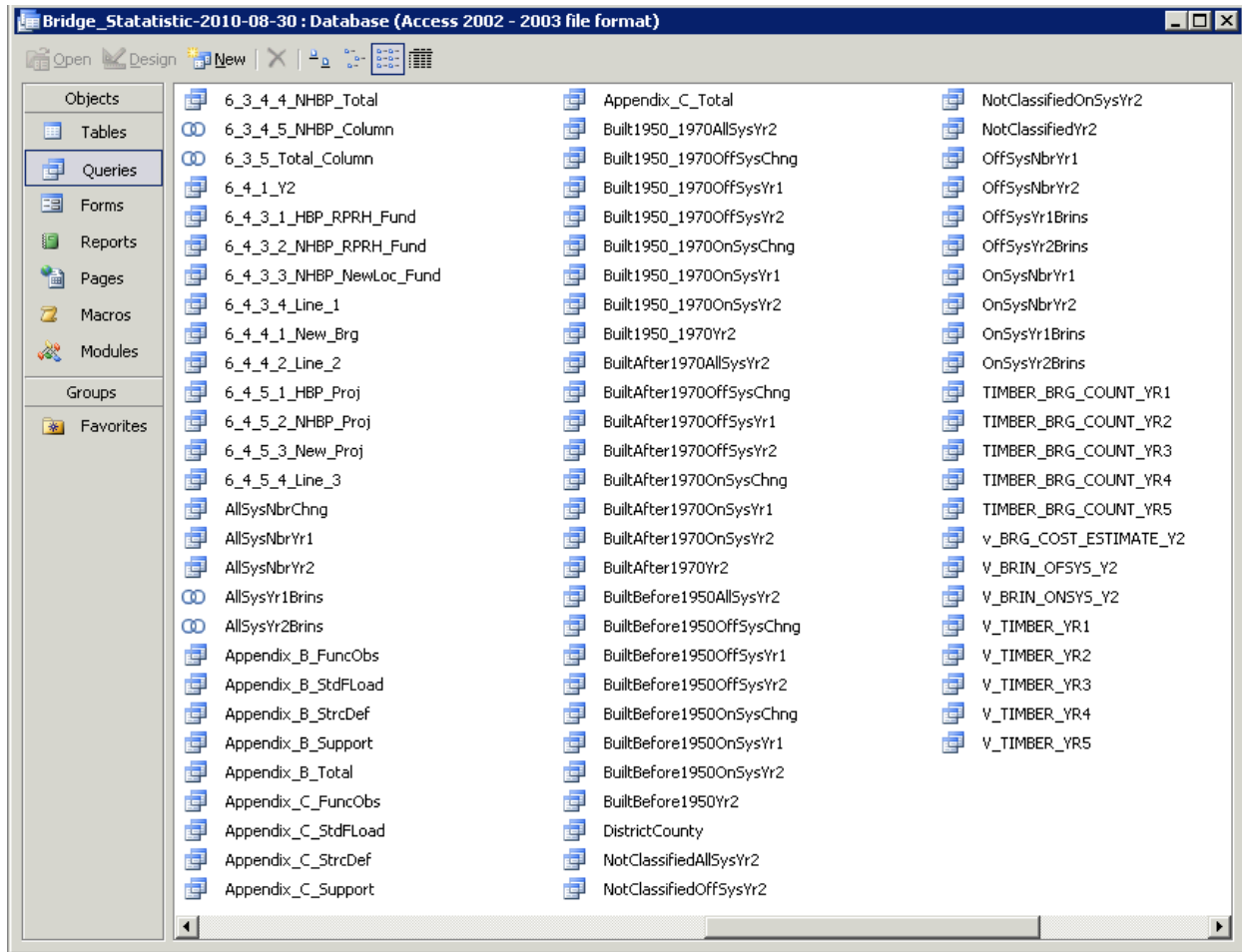
Figure 10. Queries in the Summary Bridge Statistics Prototype (Continued).

Table 22. Queries in the Summary Bridge Statistics Prototype.

Main Query Name	Table or Figure to Generate	Sub-Queries Used
_Appendix_B_OnSys_Bridge_Condition	Appendix B	Appendix_B_FuncObs Appendix_B_StdFLoad Appendix_B_StrcDef Appendix_B_Support Appendix_B_Total DistrictCounty OnSysYr2Brins
_Appendix_C_OffSys_Bridge_Condition	Appendix C	Appendix_C_FuncObs Appendix_C_StdFLoad Appendix_C_StrcDef Appendix_C_Support Appendix_C_Total DistrictCounty OffSysYr2Brins
_Figure_2_3_Timber_Bridge	Figure 2-3	V_TIMBER_YR1 V_TIMBER_YR2 V_TIMBER_YR3 V_TIMBER_YR4 V_TIMBER_YR5 TIMBER_BRG_COUNT_YR1 TIMBER_BRG_COUNT_YR2 TIMBER_BRG_COUNT_YR3 TIMBER_BRG_COUNT_YR4 TIMBER_BRG_COUNT_YR5
_Figure_3_2_Bridge_Condition_Change	Figure 3-2	3_1_OffSysYr1 3_1_OffSysYr2 3_1_OnSysYr1 3_1_OnSysYr2 OffSysNbrYr1 OffSysNbrYr2 OnSysNbrYr1 OnSysNbrYr2 OffSysYr1Brins OffSysYr2Brins OnSysYr1Brins OnSysYr2Brins
_Table_2_1_Bridge_Count	Table 2-1 Figure 2-1	AllSysNbrChng AllSysNbrYr1 AllSysNbrYr2 OffSysNbrYr1 OffSysNbrYr2 OnSysNbrYr1 OnSysNbrYr2 OffSysYr1Brins OffSysYr2Brins OnSysYr1Brins OnSysYr2Brins

Table 22. Queries in the Summary Bridge Statistics Prototype (Continued).

Main Query Name	Table or Figure to Generate	Sub-Queries Used
_Table_2_2_Bridge_Age_Distribution	Table 2-2 Figure 2-2	Built1950_1970AllSysYr2 Built1950_1970OffSysYr2 Built1950_1970OnSysYr2 Built1950_1970Yr2 BuiltAfter1970AllSysYr2 BuiltAfter1970OffSysYr2 BuiltAfter1970OnSysYr2 BuiltAfter1970Yr2 BuiltBefore1950AllSysYr2 BuiltBefore1950OffSysYr2 BuiltBefore1950OnSysYr2 BuiltBefore1950Yr2 NotClassifiedAllSysYr2 NotClassifiedOffSysYr2 NotClassifiedOnSysYr2 NotClassifiedYr2 OnSysNbrYr2 OffSysNbrYr2 AllSysYr2Brins OffSysYr2Brins OnSysYr2Brins
_Table_2_3_Bridge_Age_Change	Table 2-3	Built1950_1970OffSysChng Built1950_1970OffSysYr1 Built1950_1970OffSysYr2 Built1950_1970OnSysChng Built1950_1970OnSysYr1 Built1950_1970OnSysYr2 BuiltAfter1970OffSysChng BuiltAfter1970OffSysYr1 BuiltAfter1970OffSysYr2 BuiltAfter1970OnSysChng BuiltAfter1970OnSysYr1 BuiltAfter1970OnSysYr2 BuiltBefore1950OffSysChng BuiltBefore1950OffSysYr1 BuiltBefore1950OffSysYr2 BuiltBefore1950OnSysChng BuiltBefore1950OnSysYr1 BuiltBefore1950OnSysYr2 OffSysYr1Brins OffSysYr2Brins OnSysYr1Brins OnSysYr2Brins
_Table_3_1_Condition_Of_Bridges	Table 3-1	3_1_OffSysYr2 3_1_OnSysYr2 OffSysNbrYr2 OnSysNbrYr2 OffSysYr2Brins OnSysYr2Brins

Table 22. Queries in the Summary Bridge Statistics Prototype (Continued).

Main Query Name	Table or Figure to Generate	Sub-Queries Used
_Table_3_2_Load_Posted_Closed	Table 3-2	3_2_ClosedOffSysYr2 3_2_ClosedOnSysYr2 3_2_PostedOffSysYr2 3_2_PostedOnSysYr2 3_2_RecmdOffSysYr2 3_2_RecmdOnSysYr2 OffSysYr2Brins OnSysYr2Brins
_Table_5_1_OnSys_HBP_Bridges	Table 5-1	5_1_1_HBP_Y1 5_1_1_HBP_Y2 5_1_2_By_Dist_Y1 5_1_2_By_Dist_Y2
_Table_5_2_OnSys_NHBP_Bridges	Table 5-2	5_2_1_NHBP_Y1 5_2_1_NHBP_Y2 5_2_2_NewLoc_Y1 5_2_2_NewLoc_Y2 5_2_2_RpRh_Y1 5_2_2_RpRh_Y2
_Table_5_3_OnSys_Bridges	Table 5-3	5_3_1_RPRH_Y2 5_3_2_Cond_Column 5_3_3_1_HBP_Str_Def 5_3_3_2_HBP_Fun_Obs 5_3_3_3_HBP_Not_SDFO 5_3_3_4_HBP_Total 5_3_3_5_HBP_Column 5_3_4_1_NHBP_Str_Def 5_3_4_2_NHBP_Fun_Obs 5_3_4_3_NHBP_Not_SDFO 5_3_4_4_NHBP_Total 5_3_4_5_NHBP_Column 5_3_5_Total_Column V_BRIN_ONSYS_Y2
_Table_5_4_OnSys_Bridge_Projects	Table 5-4 Figure 5-1	5_3_1_RPRH_Y2 5_3_3_4_HBP_Total 5_3_4_4_NHBP_Total 5_4_1_Y2 5_4_3_1_HBP_RPRH_Fund 5_4_3_2_NHBP_RPRH_Fund 5_4_3_3_NHBP_NewLoc_Fund 5_4_3_4_Line_1 5_4_4_1_New_Brg 5_4_4_2_Line_2 5_4_5_1_HBP_Proj 5_4_5_2_NHBP_Proj 5_4_5_3_New_Proj 5_4_5_4_Line_3 V_BRG_COST_ESTIMATE_Y2

Table 22. Queries in the Summary Bridge Statistics Prototype (Continued).

Main Query Name	Table or Figure to Generate	Sub-Queries Used
_Table_6_1_OffSys_HBP_Bridges	Table 6-1	6_1_1_HBP_Y1 6_1_1_HBP_Y2 6_1_2_By_Dist_Y1 6_1_2_By_Dist_Y2
_Table_6_2_OnSys_NHBP_Bridges	Table 6-2	6_2_1_NHBP_Y1 6_2_1_NHBP_Y2 6_2_2_NewLoc_Y1 6_2_2_NewLoc_Y2 6_2_2_RpRh_Y1 6_2_2_RpRh_Y2
_Table_6_3_OnSys_Bridges	Table 6-3	6_3_1_RPRH_Y2 6_3_2_Cond_Column 6_3_3_1_HBP_Str_Def 6_3_3_2_HBP_Fun_Obs 6_3_3_3_HBP_Not_SDFO 6_3_3_4_HBP_Total 6_3_3_5_HBP_Column 6_3_4_1_NHBP_Str_Def 6_3_4_2_NHBP_Fun_Obs 6_3_4_3_NHBP_Not_SDFO 6_3_4_4_NHBP_Total 6_3_4_5_NHBP_Column 6_3_5_Total_Column V_BRIN_ONSYS_Y2
_Table_6_4_OnSys_Bridge_Projects	Table 6-4 Figure 6-1	6_3_1_RPRH_Y2 6_3_3_4_HBP_Total 6_3_4_4_NHBP_Total 6_4_1_Y2 6_4_3_1_HBP_RPRH_Fund 6_4_3_2_NHBP_RPRH_Fund 6_4_3_3_NHBP_NewLoc_Fund 6_4_3_4_Line_1 6_4_4_1_New_Brg 6_4_4_2_Line_2 6_4_5_1_HBP_Proj 6_4_5_2_NHBP_Proj 6_4_5_3_New_Proj 6_4_5_4_Line_3 V_BRG_COST_ESTIMATE_Y2
_Table_7_1_80_Percent_Improvement_Goal	Table 7-1	3_1_OffSysYr2 3_1_OnSysYr2 AllSysNbrYr2 OnSysNbrYr2 OffSysNbrYr2 OffSysYr2Brins OnSysYr2Brins

CHAPTER 4. PROTOTYPE DATABASE APPLICATION TO EXTRACT BRIDGE COST ESTIMATE DATA

INTRODUCTION

This chapter describes the development of the prototype database application to extract data for the production of bridge cost estimates and related quality control checks. It includes a discussion about data reporting and other requirements that guided the development effort as well as a description of the process to build the prototype database application. Chapter 5 includes the corresponding installation and user guide. Appendix B includes details on the queries and the code to produce the prototype bridge reports.

REQUIREMENTS FOR THE BRIDGE COST ESTIMATE PROTOTYPE

One of the core requirements of a BMIS is system-wide ad-hoc cost reporting at the bridge bid item level. BRINSAP and DCIS do not have ad-hoc reporting capabilities. These systems are legacy-based systems with restricted user privileges. As such, any specialized query requires TSD support. In the long term, though a customized BMIS may extract bridge cost-related data, in the short term, extraction of bridge cost-related data can be accomplished through use of replicated DCIS files.

The overall objective for this prototype database application is to develop a collection of tools to automate the reporting and extraction of bridge cost-related data at TxDOT in the short term. On a routine basis, BRG extracts, assembles, and calculates DCIS bridge cost-related attributes in a spreadsheet for further analysis. The DCIS data extraction uses several independent scripts, provided by TSD, which retrieve:
- All Category 6 (Cat 6A, 6B, RGS) projects from DCIS.
- Record Type 12 data from DCIS.
- Data from the BCI screen in DCIS.
- Data for all projects in DCIS that have been let (Actual Let Date <> 0000).
- Data for all projects that have a NBI number on the P3B screen in DCIS.
- Data for all projects in DCIS that have not been let (Actual Let Date = 0000).
- Data from the P3B screen for one letting month.
- Data from DCIS for all projects that have a NBI number on the P3B screen.

BRG staff manually assembles and combines these data sets to reduce redundancy and eliminate multiple matches. The final data set, which is used for further analysis, is assembled in a spreadsheet format (internally called the "Worktable") and contains the following attributes:
- **ACTL_LET_DT**: Actual letting date.
- **CCSJ**: Contract CSJ (project number, which may include several individual CSJs).
- **CSJ:** Control-Section-Job number.
- **DIST_NBR**: District number.
- **CNTY_NBR**: County number.
- **SYS**: On or Off System.
- **BRG_WRK_TYPE**: Bridge work type.

- **PROJ_CLS**: Functional classification of the roadway.
- **PROJ_NBR**: Project number.
- **NBI**: National Bridge Inventory structure number.
- **BRDG_TYPE**: Classified by beam type (or culvert).
- **BRG_COST_PCT**: Percentage of bridge costs associated with each bridge type if two or more bridge types exist on the same structure (e.g., a bridge with prestressed concrete I beam [GP-I] approach spans and a steel girder [GS-I] main span).
- **BRDG_DECK_AREA**: Deck area of bridge.
- **BRG_LNGTH**: Length of bridge.
- **PROJ_WIN_BID_AMT**: Winning bid (typically low bid) for the project, which includes roadways, bridges, and other items.
- **PROJ_EST_AMT**: Engineers estimate for the entire project.
- **BRG_EST_AMT**: Engineers estimate of bridge costs.
- **BRG_WIN_BID_AMT**: Winning bid (typically low bid) for bridge bid items.
- **BRG_WIN_BID_PCT**: Winning bid (typically low bid) for bid items per bridge type.
- **BRG_WIN_BID_UNIT_COST**: Winning bid (typically low bid) per bridge bid item unit.
- **BRG_EST_UNIT_COST**: Engineers estimate per bridge bid item unit.
- **CATEGORY**: Project funding category.

Specific requirements for the development of the prototype included the following:
- Replicate the Worktable.
- Use a standalone database environment (more specifically Microsoft Access 2003).
- Use generic query structures to enable the use of the prototype for any time period of interest.
- Use the live version (i.e., replicated version) of DCIS for bridge cost estimate conditions.

DEVELOPMENT OF BRIDGE COST ESTIMATE PROTOTYPE APPLICATION

Development of the prototype database application involved the following major steps, which are described in subsequent sub-sections:
- Identify the existing tables and generate lookup tables containing the data elements needed to replicate the Worktable.
- Create the reports and queries that replicate the Worktable.
- Develop a form-based interface to facilitate user-friendly report generation.

Identifying Existing Tables and Generating Lookup Tables

Much of the bridge cost estimate prototype data use DCIS data. The researchers received partial DCIS tables that facilitated the development of preliminary summary bridge statistics queries. Though helpful, these tables represent activities at a snapshot in time, where data updates are not included. The Worktable provides the status of bridge-related costs for any given time period, relies on several complete data sources, and is based on live data. Since the Worktable relies heavily on live DCIS data, TxDOT provided the researchers restricted access to live DCIS data through the TxDOT Citrix gateway, which is discussed in Chapter 3.

The researchers examined the attributes contained in the Worktable and the replicated DCIS tables found in the COMMON_DSGN schema to identify data elements and tables needed to replicate the Worktable. From this examination, the researchers used existing live tables from the COMMON_DSGN schema, created modified tables, such as associated costs for mobilization in highway construction projects, and created new lookup tables, such as data source references. Most tables in this prototype either are imported or linked tables from DCIS. Figure 11 shows a list of tables used in the Bridge Cost Estimate prototype. Descriptions of these tables are as follows:

- **dbo_DCIS-PROJECT-INFORMATION_VW.** This file contains basic data describing highway construction and maintenance projects during the planning and development phases (Table 1). This file includes projects that have already been let, those that have been approved for construction or maintenance, and projects that have not completed the approval process. The prototype application links to this DCIS replicated file view in the SQL Server COMMON_DSGN schema.

- **dbo_DCIS-WORK-PROGRAM_VW**. This file contains information about highway construction project work programs and information about the state transportation improvement program (Table 2). The prototype application links to this DCIS replicated file view in the SQL Server COMMON_DSGN schema. This file has a record for every work program and the total allocated amount approved by the Texas Transportation Commission for that work program, with allocated amounts for each district if the funds are allocated to the districts. An example of a work program is the bank balance program, which identifies areas of need such as rehabilitation, reconstruction, safety, and preventive maintenance. Work programs are also used to identify categories of work for mobility and other types of projects authorized by the commission.

- **dbo_DCIS-PROJECT-ESTIMATE_VW**. This file contains estimated cost data for individual projects, including bridges (Table 3). The prototype application links to this DCIS replicated file view in the SQL Server COMMON_DSGN schema. In this file, cost data are specified by the following record type codes:

  - 02 – Project work category.
  - 03 – Comment line.
  - 04 – Bid item or special account.
  - 05 – Unique description or special account description.
  - 06 – Fund source.
  - 07 – Bid item that has reference numbers or spec provision numbers.
  - 09 – End of bid items.
  - 10 – Bid item with a special provision number.
  - 11 – Specification list for temporary erosion item or for addendum to special provision.
  - 12 – Bridge cost estimate.

- **dbo_DCIS_PROJ_INFO_STRUCT_DATA_VW**. This file contains bridge data for highway construction and maintenance projects. This file contains fields such as NBI number, structure number, structure type, bridge work type, bridge sufficiency rating, and bridge deficiency class. In the Adabas version of DCIS, data from this file are stored in the DCIS-PROJECT-INFORMATION file as a periodic group of fields that occurs 10 times. In the replicated version of DCIS, this file is stored as a separate table in the SQL

Server COMMON_DSGN schema. The prototype application links to this table view in the SQL Server COMMON_DSGN schema.

- **dbo_DCIS_PROJ_EST_BRDG_VW**. This file contains bridge data for highway construction projects. This file contains fields such as bridge length, bridge work type, NBI, bridge type, deck area, and cost percent. In the Adabas version of DCIS, data from this file is stored in the DCIS-PROJECT-ESTIMATE file as a periodic group of fields that occurs 10 times. In the replicated version of DCIS, this file is stored as a separate table in the SQL Server COMMON_DSGN schema. The prototype application links to this table view in the SQL Server COMMON_DSGN schema.
- **DCIS_BRG_REMOVAL**. This table contains costs for removal of old structures in highway construction projects. This table contains fields such as control section, card type, bid item number, project removal cost estimate, and project removal winning cost bid. The table links to a Microsoft Access database table located on the Citrix server.
- **DCIS_PROJ_MOBIL**. This table contains bid items and associated costs for mobilization in highway construction projects. This table contains fields such as CCSJ, CSJ, bid item number, actual let date, card type, project mobilization cost estimate, and project mobilization winning cost bid. This table links to a Microsoft Access database table located on the Citrix server.
- **BRG_WORK_TYPE**. This table is a lookup table for bridge work types found in the DCIS P3B screen and BCI screen. Bridge work types include: replace, widen, maintain/repair, rehab, and remove/new. The prototype application contains this table.
- **FY_LET_YEAR**. This table contains a list of valid letting years (i.e., 1993 to 2011) for the prototype application. This table is used to define a fiscal letting year for project estimate data queries. The prototype application contains this table.
- **BIDITEM_DSCR**. This table is a lookup table for bid items used in highway construction projects. This table contains fields such as bid item number, spec book year, bid item description, and bid item unit. The prototype application links to a Microsoft Access database table located on the Citrix server.
- **LET_MONTHS**. This table is a lookup table of valid letting months (i.e., January to December) for the prototype application. This table is used to define a date range for project estimate data queries. The prototype application contains this table.
- **PROJ_REPORT_TYPE**. This table is a lookup table of report types for the prototype application. The prototype application contains this table. This table contains the following report types:
    - All Records.
    - Bridge Bid Items.
    - Bridge Cost Estimates.
    - Unmatched CSJs.
    - Total Bridge Cost Percentages not 100 percent.
    - Total Project Cost Percentages not 100 percent.

- **DATA_SOURCE**. This table is a lookup table containing a list of external database sources for the prototype application. The table has fields such as data source table name, data source type (e.g., DCIS, ACCESS), and data source location (e.g., TXDB22-COMMON_DSGN). The prototype application contains this table.
- **GLOBAL_PARAM**. This table contains data that allow permitted access to COMMON_DSGN table views. These data include user ids, passwords, server names, and database names. The prototype application contains this table.
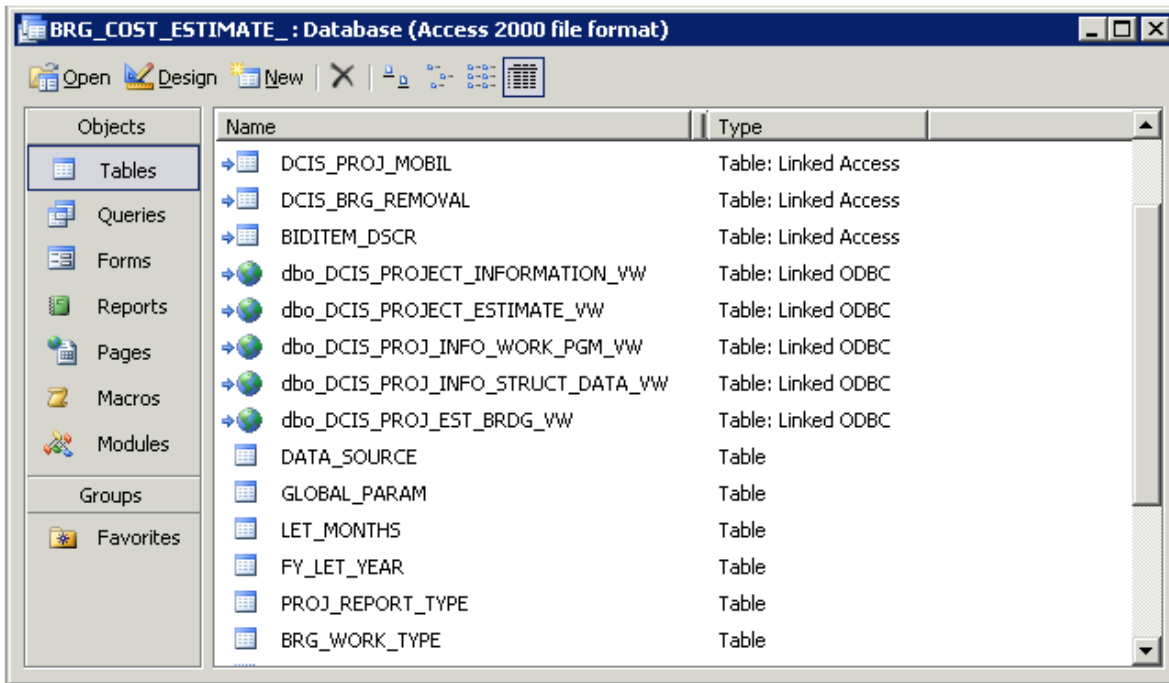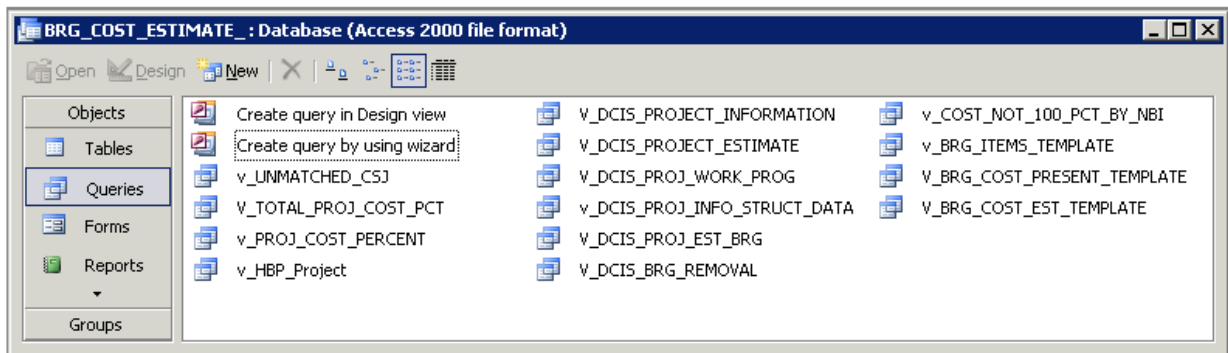

Figure 11. Tables in the Bridge Cost Estimate Prototype.

Creating Bridge Cost Estimate Prototype Queries and Reports

Concurrent with data element identification and table creation, the researchers built a set of SQL queries (Figure 12), activated through Visual Basic® (VB) code, to replicate the Worktable and generate other reports for a given fiscal year or month range. The queries and data structures used to create the reports in the Bridge Cost Estimate prototype are described in Appendix B. These reports include:
- **Project Estimate.** This report contains all records and attributes from the DCIS-PROJECT-ESTIMATE file.
- **Bridge Bid Items.** This report contains records from the DCIS-PROJECT-ESTIMATE file that have bridge-related bid items.
- **Total Bridge Cost Estimate.** This report contains total costs for individual bridges by adding the costs of all work items associated with individual bridges. This table includes one record for each bridge included in a project.

- **Disaggregated Bridge Cost Estimate (i.e., Worktable).** This report contains bridge cost data disaggregated by bridge cost percentages. This table may contain more than one record per bridge depending on the allocation of bridge cost percentages. This table uses the Total Bridge Cost Estimate table as input to the process.
- **Unmatched CSJs.** This report contains CSJs found in the DCIS-PROJECT-INFORMATION file that are not found in the Worktable.
- **Total Bridge Cost Percentages not 100 percent.** This report contains CSJs for which the total bridge cost percentages are under or over 100 percent but do not add up to 100 percent.
- **Total Project Cost Percentages not 100 percent.** This report contains CSJs for which the total project cost percentages are under or over 100 percent but do not add up to 100 percent.

Figure 12. Queries in the Bridge Cost Estimate Prototype.

Developing Bridge Cost Estimate Prototype Interface

Once the prototype tables, queries, and reports were created, the researchers developed a user-friendly GUI to help users generate bridge cost estimate reports. A specific requirement for the development of the prototype was to use a standalone database environment. Chapter 5 (Prototype Installation and User Guides) provides more information on this application and provides screen captures of the prototype interface.

The development environment for the prototype application was Microsoft Access 2003 since this software was already installed on the Citrix desktop environment. For simplicity, the prototype used multi-tabbed forms, which include:
- **Introduction.** This tab form provides brief background information on the application.
- **Bridge Reports.** This tab form creates a specific bridge report, from a list of report types, for a defined fiscal year or a range of months.
- **Report Options**. This tab form allows users to select the specific fields to include in a bridge report.
- **Export Tables.** This tab form creates a Microsoft Access file called DATA_EXPORT.mdb and exports a selected bridge report to that Access file.

On each of the tab forms are controls (e.g., list boxes, check boxes, option buttons) that set preferences, such as letting year. Also on these tab forms are command button controls. These buttons (e.g., Export Data) run VB functions and subroutines when the button is activated (i.e., clicked). The VB functions and subroutines open, run, and present the output of the bridge cost estimate SQL queries. The interface development tools (e.g., forms, controls, and the VB coding environment) for the prototype are standard in Microsoft Access; no additional software was required to develop the prototype.

CHAPTER 5. SYNTHESIS OF CURRENT BMIS DEVELOPMENT ACTIVITIES

INTRODUCTION

This chapter summarizes the findings of a nationwide survey pertaining to the use of Pontis by state and local governments. Data for the analysis included in this technical memorandum was obtained using information from *questionnaires* collected by the FHWA during several Bridge Management State Peer Exchanges (*37*). In addition, this chapter summarizes the results of the recently released NCHRP Synthesis 397 "Bridge Management Systems for Transportation Agency Decision Making" (*40*). General Accounting Office (GAO) recommendations are also summarized due to their future influence in shaping BMIS requirements and development by the states.

BACKGROUND

The FHWA Bridge Inspector's Reference Manual states, "During the bridge construction boom of the 1950s and 1960s, little emphasis was placed on safety inspection and maintenance of bridges. This changed when the 681 m (2,235-foot) Silver Bridge, at Point Pleasant, West Virginia, collapsed into the Ohio River on December 15, 1967, killing 46 people…This tragic collapse aroused national interest in the safety inspection and maintenance of bridges. The U. S. Congress was prompted to add a section to the 'Federal Highway Act of 1968,' which required the Secretary of Transportation to establish a national bridge inspection standard. The Secretary was also required to develop a program to train bridge inspectors" (*38*).

Thus, in 1971, the National Bridge Inspection Standards (NBIS) came into being. The NBIS set national policy regarding bridge inspection frequency, inspector qualification, report formats, and inspection and rating procedures.

Advances in technology and construction have greatly enhanced current bridge design. However, the emergence of previously unknown problem areas and the escalating cost of replacing older bridges make it imperative that existing bridges be evaluated properly to be kept in service and safe for the traveling public.

Much has been learned in the field of bridge inspection and data analysis. State inspection efforts along with data analysis programs are more organized and improved. The technology used to inspect and evaluate bridges has significantly improved over the years. The main Bridge Management software developed by AASHTO for the FHWA is called Pontis, which is used by several states at different levels of implementation as compilation of data in this chapter will show.

The FHWA Transportation Asset Management Case Studies for Bridge Management states, "Pontis integrates the objective of public safety and risk reduction, user convenience, and preservation of investment to produce budgetary, maintenance, and program policies. Additionally, it provides a systematic procedure for the allocation of resources to the preservation and improvement of the bridges in a network. Pontis accomplishes this by

considering both the costs and the benefits of maintenance policies versus investments in improvements or replacements" (*39*).

The FHWA document also states, "States using the Pontis Bridge Management System have found its features beneficial in terms of how it supports users in collecting bridge inventory and inspection data; in formulating network wide preservation and improvement policies for use in evaluating the needs of each bridge in a network; and in developing recommendations for identifying projects to include in an agency's capital plan for deriving the maximum benefits from limited funds. Further benefits are that Pontis integrates the objectives of public safety and risk reduction; is convenient to use; and aids in the production of budgetary, maintenance, and program policies. Most notably, it provides a systematic procedure for the allocation of resources to the preservation and improvement of the bridges in a network by considering both the costs and benefits of maintenance policies" (*39*). However, interaction between Bridge Managers and researchers showed that most of the implementation of Pontis was done at the data base level, with more sophisticated tools such as forecasting having lower levels of implementation.

PEER EXCHANGE DATA ANALYSIS

Pontis contains certain applications to support the managing of a bridge system, including:
- Storing NBI data.
- Storing element level data.
- Scheduling inspections.
- Generating inspection results.
- Identifying structures requiring maintenance.
- Identifying structures requiring rehabilitation.
- Identifying structures requiring replacement.
- Measuring performance.
- Simulating future conditions.

Most U.S. states use one or more of these applications on Pontis to manage their own bridge systems. Although Pontis can be used to maintain and predict the way a bridge will perform, only a small percentage of the states use the full system software. Table 23 contains the raw data summarizing the results of the key elements of the peer exchange survey (*37*). Summarized in Table 24 are the percentages of which state is using each application of Pontis. Of the responding states, 50+ percent are using Pontis for:
- Storing NBI data (52 percent).
- Storing element level data (56 percent).

The following applications are being used by 40+ percent of the responding states for:
- Generating inspection reports (42 percent).
- Identifying structures requiring maintenance (46 percent).
- Identifying structures requiring rehabilitation (42 percent).
- Identifying structures requiring replacement (42 percent).

Twenty-five–35 percent of the states are using Pontis for:
- Scheduling inspections (35 percent).
- Measuring performance (27 percent).
- Simulating future conditions (33 percent).

These numbers show the variability in implementation stage between the states using Pontis. In general, the more complex functions of Pontis related to measuring performance and simulating future conditions have low implementation levels. This is not surprising, considering the level of sophistication involved in these type of analyses.

From Table 25, only 11 states currently use 90–100 percent of Pontis. Following that are eight states using 80–90 percent of Pontis. The staggering result is that there are 16 states not using Pontis at all to manage their bridge systems.

California DOT (Caltrans) has pioneered the use of the bridge health index as an indicator of how the asset value of a bridge or an inventory changes over time. Florida has integrated Pontis into an existing system with its existing Citrix MetaFrame Access Suite and the Project-Level Analysis Tool (PLAT).

Table 23. Peer Exchange Data Compilation.

State	A	B	C	D	E	F	G	H	I	J	K	L	M
Alabama										x			
Alaska	x	x		x									
Arizona												x	
Arkansas	x	x	x	x	x								
California	x	x		x	x	x	x	x	x				
Colorado	x	x			x	x	x						
Connecticut										x			
Delaware	x	x	x	x	x	x	x	x	x				
District of Columbia	x				x								
Florida	x	x	x	x	x	x	x	x					
Georgia		x											
Hawaii	x	x	x	x	x	x	x	x	x				
Idaho	x	x	x	x	x	x	x						
Illinois	x	x	x	x	x	x	x	x	x				
Indiana												x	
Iowa		x											
Kansas	x	x	x	x				x	x				
Kentucky													x
Louisiana										x			
Maine	x	x	x	x	x	x	x	x	x				
Maryland												x	
Massachusetts					x	x		x	x				
Michigan		x			x	x	x	x	x				
Minnesota	x	x	x	x	x	x	x		x				
Mississippi	x	x	x	x	x	x	x						
Missouri													x
Montana	x	x		x	x	x	x		x				
Nebraska													x
Nevada	x	x	x	x	x	x	x						
New Hampshire	x	x	x	x	x								
New Jersey	x	x	x			x	x	x	x				
New Mexico	x	x	x	x									
New York												x	
North Carolina												x	
North Dakota	x	x	x	x	x	x	x						
Ohio												x	
Oklahoma	x	x			x	x	x		x				
Oregon	x	x	x	x									
Pennsylvania	x	x	x	x	x	x	x	x	x				
Puerto Rico	x	x	x	x	x	x	x	x	x	x	x	x	x
Rhode Island		x											
South Carolina	x	x	x	x	x	x	x	x	x				
South Dakota	x	x	x	x	x	x	x	x	x	x			
Tennessee		x					x		x				
Texas												x	
Utah	x	x			x	x	x						
Vermont	x	x		x	x	x	x	x	x				
Virginia		x		x	x	x	x	x	x				
Washington												x	
West Virginia													x
Wisconsin					x	x	x	x					
Wyoming	x	x			x	x	x	x	x				

Code / Description

Code	Description
A	Storing NBI data?
B	Storing element level data?
C	Scheduling inspections?
D	generating inspection reports
E	identifying structures req maint
F	identifying structures req rehabilitation
G	identifying structures req replacement
H	measuring performance
I	simulating future conditions
J	Pontis in the Future
K	Their own version of Pontis
L	Not using Pontis
M	Not using a BMS

Table 24. Percentage of Use by Application.

A	B	C	D	E	F	G	H	I	Y/N
48	44	65	58	54	58	58	73	67	N
52	56	35	42	46	42	42	27	33	Y

Table 25. Percentage of Pontis Applications Used by Each State.

State	# of Pontis Apps Used	% of Pontis used	State	# of Pontis Apps Used	% of Pontis used
Alabama	0	0	Montana	7	78
Alaska	3	33	Nebraska	0	0
Arizona	0	0	Nevada	7	78
Arkansas	5	56	New Hampshire	5	56
California	8	89	New Jersey	7	78
Colorado	5	56	New Mexico	4	44
Connecticut	0	0	New York	0	0
Delaware	9	100	North Carolina	0	0
District of Columbia	2	22	North Dakota	7	78
Florida	8	89	Ohio	0	0
Georgia	1	11	Oklahoma	6	67
Hawaii	9	100	Oregon	4	44
Idaho	7	78	Pennsylvania	9	100
Illinois	9	100	Puerto Rico	0	0
Indiana	0	0	Rhode Island	1	11
Iowa	1	11	South Carolina	9	100
Kansas	6	67	South Dakota	9	100
Kentucky	0	0	Tennessee	3	33
Louisiana	0	0	Texas	0	0
Maine	9	100	Utah	5	56
Maryland	0	0	Vermont	8	89
Massachusetts	4	44	Virginia	7	78
Michigan	6	67	Washington	0	0
Minnesota	8	89	West Virginia	0	0
Mississippi	7	78	Wisconsin	4	44
Missouri	0	0	Wyoming	7	78

NCHRP SYNTHESIS 397, BRIDGE MANAGEMENT SYSTEMS FOR TRANSPORTATION AGENCY DECISION MAKING

NCHRP recently published Synthesis 397 (*40*) on the status of BMS implementation by the States. The summary of the survey and recommendations are compatible with the results of the peer exchange data summaries reported in the previous paragraphs. Results basically confirm that higher levels of BMS implementation involving prioritization and optimization are not widespread throughout the states, and Pontis and other systems are basically being used to store and manage bridge inspection data.

The following objectives summarize the goals of NCHRP Synthesis 397 as stated in the report:

"The objective of this synthesis study has been to gather information on current practices that agency chief executive officers and senior managers use to make network-level investment and resource allocation decisions for their bridge programs, and to understand how they apply their agency's bridge management capabilities to support these decisions. The following areas of planning, programming, and performance-based decision making have been addressed:
- Condition and performance measures that are used to define policy goals and performance targets for the bridge program.
- Methods of establishing funding levels and identifying bridge needs.
- Methods and organizational responsibilities for resource allocation between the bridge program versus competing needs in other programs (pavement, safety, etc.).
- Methods of allocation among districts and selection and prioritization of projects.
- The role of automated bridge management systems (BMS) in planning, programming, resource allocation, and budgeting.
- Use of economic methods in bridge management.
- Methods to promote accountability and communication of the status of the bridge inventory and the bridge program."

Twenty U.S. and four Canadian agencies answered the survey, so the data are somehow limited to agencies that have an interest and focus on BMS implementation. NCHRP 397 also presents several charts from reference (*41*) summarizing data from a survey carried out in 2002. Data are summarized based on the survey of 34 agencies that were Pontis licensees at that time. Figures 13 and 14 summarize some of the relevant responses from reference (*41*). Figure 13 shows a weak implementation of the higher level planning capabilities of Pontis, and Figure 14 shows the degree of customization of the Pontis environment for a more complete implementation of the Pontis model.
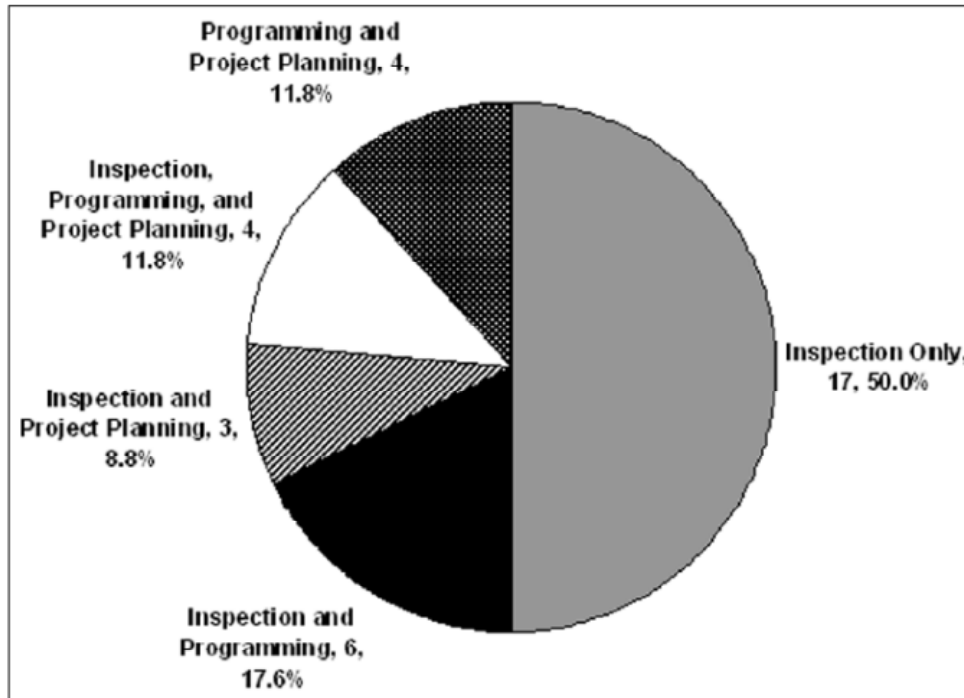
Figure 13. Pontis Functionality Used by Licensing Agencies (*41*).
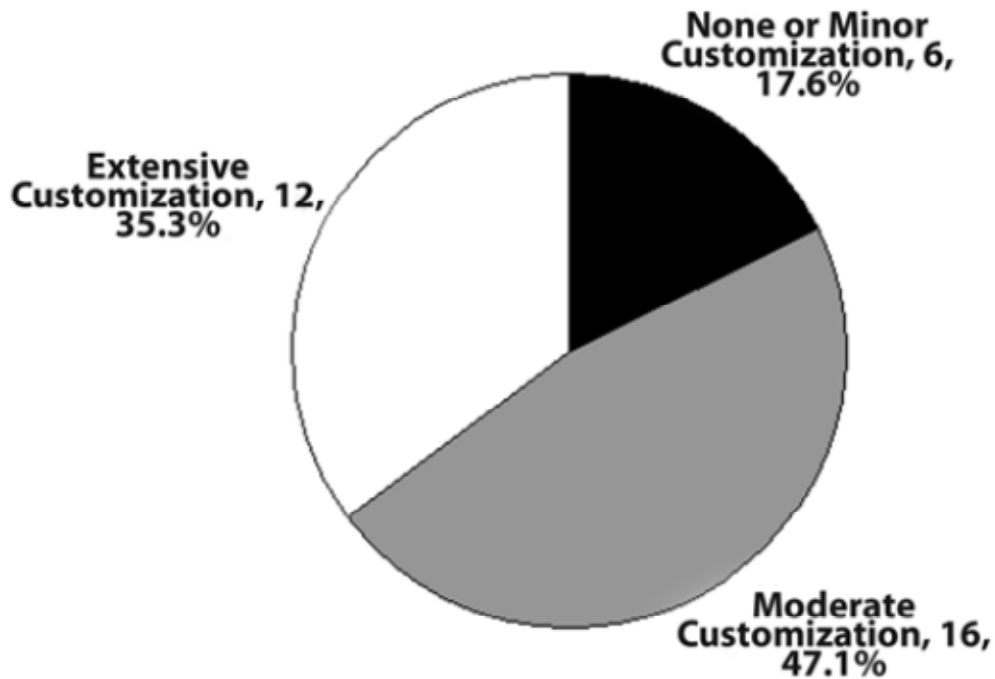
Figure 14. Degree of Pontis Customization (*41*).

NCHRP 397 carried out its own survey of the states. The planning component of the survey asked whether particular features of the agency's BMS were used to support the planning

process. A total of 17 agencies responded to this question, with the distribution of responses as shown in Figure 15. About 30 percent to 40 percent of respondents reported using their BMS for higher-level management functions, including budgeting, scenario testing, trade-off analyses, generating quantifiable parameters to provide guidance in project selection, and documenting past and planned bridge projects by political jurisdiction. Fewer than 10 percent of the respondents used their BMS for economic analyses—that is, for LCC analysis or computation of avoidable user costs as a function of alternative budget scenarios. These results show again that as the level of complexity of BMS modeling increases, such as with the use of LCC analysis, the level of implementation decreases.
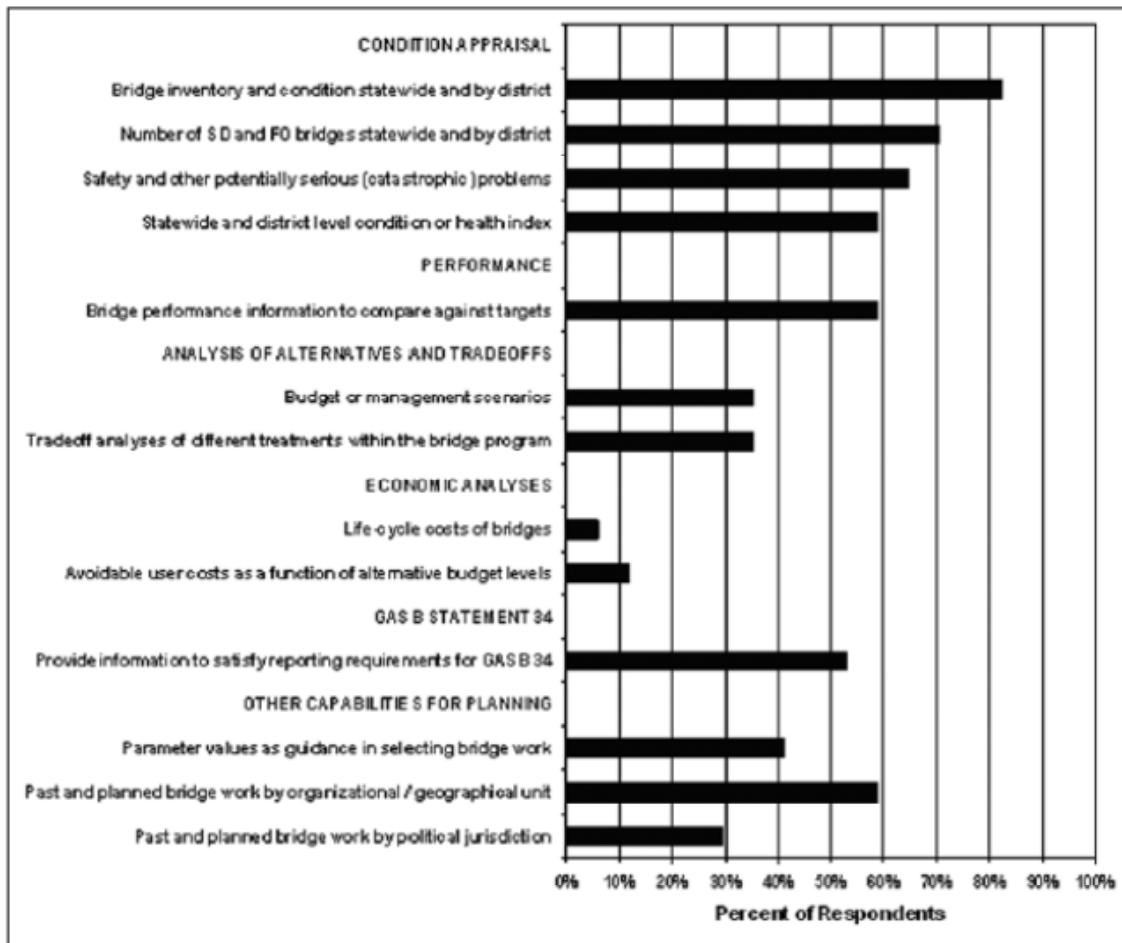
Figure 15. BMS Support of Agency Planning Processes (*40*).

Note: FO = Functional Obsolescence; GASB = Governmental Accounting Standards Board;
SD = Structural Deficiency

The following quotes from NCHRP 397 summary session deserve to be reproduced here, considering that they reinforce the results of the surveys summarized previously and show a scenario where the implementation of more complex analytical techniques in BMS is still incipient nationwide.

"More generally, however, the characteristic use of BMSs for state DOT decision making is toward more limited ends, including the following:

- Compilation and display of current and near-term information rather than long-term analyses.
- A focus on technical results such as bridge condition and performance rather than also considering economic comparisons of benefits and costs.
- A preference for straightforward calculations and analyses, including database management and computations of bridge ratings and indexes, rather than more sophisticated modeling such as forecasting, scenario analyses, trade-off analyses, and optimization."

Several survey respondents in NCHRP 397 pointed to ways of strengthening business processes in the implementation of BMS. These are quoted as follows:

- "Coordination of the bridge program with other programs and projects (e.g., roadways) across a broader set of policy objectives (e.g., preservation versus capacity).
- An ability to explore choices and trade-offs and to calculate LCCs of each alternative.
- Long-term effects (benefits and other impacts) of proposed expenditures on bridges.
- Comparisons of performance measures versus target values and outcomes for alternative scenarios.
- Total project costs, not just those related to work on the bridge structure proper. Additional items include, for example, the costs of right-of-way, detours, utilities, roadway approaches and embankments, and so forth.
- Socioeconomic and political considerations related to bridge projects.
- A more complete bridge management package, able to help evaluate achievement of performance targets, to generate alternative scenarios subject to budget constraints, to explore choices and trade-offs, and to calculate resulting road-user costs, which would be beneficial from a budgeting perspective.
- Information on key parameters (e.g., regarding condition, performance, and budget) that would facilitate delegating to lower-level managers the responsibility for selecting what work to do on specific bridges on the network.
- BMS predictions of the funding levels needed to maintain structural condition, described by the respondent as a derivative of alternative scenario generation subject to budget constraints. Just as important would be BMS estimates of bridge investments and their timing to be able to identify bridge network maintenance at the lowest LCC. [Author note: This is a current concern in Texas with the limited availability of funding and is being addressed by the "Texas 2030 Committee" that is modeling scenarios of bridge condition in the future under restricted budgets.]
- Strengthened BMS algorithms in the calculation of LCCs, scope of bridge performance analysis, and treatment selection. (These comments related to Pontis specifically.)"

GOVERNMENT ACCOUNTABILITY OFFICE RECOMMENDATIONS

The Government Accountability Office (GAO) recently released a report summarizing recommendations for the Federal Highway Bridge Program (HBP) (*42*). These recommendations will have a strong influence in shaping legislation affecting the Federal HBP:

- Define the specific national goals of, and federal interests served by, the HBP.
- Develop performance measures that respond to, and reflect progress toward, these federal goals and interests.
- Identify best-practice methods and tools that can be incorporated within the HBP, drawing on existing approaches such as BMSs and leading-edge techniques applied by state DOTs.
- Review and evaluate mechanisms that can align HBP funding with performance to achieve a focused, sustainable federal bridge program.

CHAPTER 6. IDENTIFICATION OF USER AND DATA NEEDS

INTRODUCTION

Chapter 2 documented sources of data available to develop a BMIS. Once available data sources and systems have been identified, the next step in building a framework for a BMIS is to identify the needs of existing and anticipated users of bridge-related data. In general, certain tools in information systems are used more than others. Additionally, tools may not exist in current information systems and require user-built alternatives (i.e., workarounds). To effectively implement a useable and robust BMIS, the needs of all users must be considered.

Once user needs are identified, the next step in building the BMIS framework is to identify the data needs, data attributes, and relationships required for each user need. Data attributes contained in existing bridge-related systems (e.g., BRINSAP, PonTex, and the FTW Bridge Inspection Application) can be mapped to user needs to identify gaps in data and in relationships between tables and systems.

This chapter describes the identification of user and data needs for a comprehensive BMIS. Specifics on the physical structures and implementation specifications to meet user needs are not in the scope of this research

IDENTIFICATION OF USER NEEDS

Presentations to TxDOT Personnel

To identify user needs, researchers presented proposed features for a BMIS to TxDOT personnel that are involved in bridge inspection, design, construction, maintenance, and project programming activities. Researchers made presentations to and obtained feedback from personnel in the Bridge Division, San Antonio District, Houston District, Brownwood District, San Angelo District, Fort Worth District, and Wichita Falls District. One major goal of this effort was develop a high level of BMIS system requirements based on user needs and other constraints such as schedule, cost, and rollout.

The presentation documents distributed to TxDOT personnel is in Appendix A. The appendix also includes a document prepared by Taylor Buckner (Bridge Inspection Engineer in the Fort Worth District) that lists the current features and additional features desired in that district's Bridge Inspection Reports System. The researchers also reviewed that document with TxDOT personnel. The following is a summary of the presentation.

The researchers proposed that the TxDOT BMIS should include the following:

- An inventory system with elemental descriptions in graphical form (i.e, using a bridge diagram, click on particular elements and obtain inspection and cost information).
- A way for the districts to interact with the system (possibly a revision to PonTex). The system will allow the districts to update cost and inspection information.

- A prioritization system that is easy to understand and is easy for TxDOT to incorporate.
- A budget forecasting system.

For a network level graphical interface, the researchers suggested using an interface similar to the TxDOT Load Restricted Bridge Application and modifying it as required. This interface can be used to identify bridge locations; review bridge inspection data in tabular format (including load posting, rated as structurally deficient or functionally obsolete, vertical and horizontal clearances, etc.); and review bridge programming information (i.e., scheduled for rehab or replacement). The researchers also suggested using the Harris County web-based viewer as a template for displaying bridge inspection related data. Appendix A shows screenshots from both the application and viewer.

For a project level graphical interface, the researchers suggested starting with graphics from bridge layout sheets and intelligently link elemental data, photos, and other data to the sheets. The system should have the ability to store "intelligent" drawings that connect with the pertinent data (dynamic link between the drawings, graphics, and data). A link between inspections and rehab or maintenance costs is desirable (i.e., click on a structural element and look at the inspection data).

For bridge inventory and inspection records, the researchers suggested starting with a system similar to what the Fort Worth District has developed and is what is currently being developed for PonTex (i.e., a "virtual office" where all of the bridge inspection data are stored in a PC database). The researchers also recommended considering incorporating elemental data and video taken by inspectors in this system. Appendix A also shows screenshots from the Fort Worth system.

The researchers also recommended the following:
- TxDOT should establish a data collection protocols or procedures for:
  - Inventory.
  - Inspection (including audits).
  - Collecting data for tracking deterioration (using elemental data as a possible basis).
  - Obtaining descriptions, dates, and costs of maintenance or rehabilitation activities.
  - Coding maintenance activities (these data may be stored in MMIS/MMS).
  - Requirements for obtaining photos or videos.
- TxDOT should establish state-level and district-level modules, considering the needs for Division and district level users. An approach for the state and an approach for the district need to be developed (both research and business approaches). The business strategy will be a consequence of this effort.
- TxDOT should establish more effective definitions for bridge quality levels. Currently a loose definition exists for an inadequate bridge.
- After quality levels are defined, TxDOT needs to establish effective forecasting procedures.

After the presentation, the researchers and TxDOT personnel reviewed the document prepared by Taylor Buckner. TxDOT personnel agreed with what the researchers presented in general and provided feedback that is documented in the next section.

Development of User Needs

From the feedback, the researchers assembled a list of user needs and requirements that existing TxDOT systems such as BRINSAP, PonTex, and the FTW Bridge Inspection application do not meet. These systems are described earlier in this report and in the report for Product 0-6389-P1. The list of user needs in this chapter identifies gaps in existing systems and desired features of a BMIS. TxDOT anticipates implementing the next release of Pontis; however, the research team is not familiar with this release. Therefore the research team cannot assess whether the latest version of Pontis would be able to address these user needs.

At the highest level, users indicated that comprehensive bridge data management at TxDOT would include the following features:
- Inventory system with elemental descriptions in graphical format (i.e., using a bridge diagram, click on particular elements and obtain inspection and cost information).
- Mechanisms for districts to interact with the system (possibly a revision to PonTex). The system would allow districts to update cost information.
- Bridge project prioritization scheme that is easy to understand and is easy for TxDOT to incorporate.
- Budget forecasting system.
- Additional database attributes and multimedia capabilities.
- Additional functions to store, enter, query, report, and track attributes and multimedia from these databases.
- More effective coordination and integration between information systems.
- Mechanisms to streamline production of reports.
- Coordination with bridge owners and entities responsible for maintenance.

At a finer level of disaggregation, based on feedback provided by users, user needs could be organized by priority as follows:

High Priority User Needs:

- Expand appraisal working documents to include additional attributes such as clearances and ratings.
- Coordinate with bridge owners or entities responsible for maintenance.
- Generate automatic updates of history and inspection follow-up documents when corrective actions in bridge inspection records are noted.

Medium Priority User Needs:

- Generate a database to manage elemental data.
- Generate a database to manage load posting data.
- Generate a database to manage vertical clearance, sign, and horizontal data.

Low Priority User Needs:

- Generate a NBI Data Report using data from mainframe databases.
- Manage traffic control data involving the bridge structure.
- Generate a database to manage data not included in the NBI database.

- Provide a mapping component that generates spatial locations of bridges and bridge-related infrastructure assets, such as load posting signs, and allows report generation.
- Build the functionality for electronic signatures on required reports and documents.
- Create a portable version of BMIS that could work on a laptop in the field and on-site.
- Generate automatic updates of related documents when sign material data are updated.

Other needs, which were not given a priority but were highlighted by users, include the following:

- Update the Bridge Incident Tracking system (which is used for tracking events when bridges have impact and/or high load damages) and improve coordination with stakeholders.
- Develop a bridge *project* prioritization system that is easy to understand and is easy for TxDOT to incorporate.
- Develop a user-friendly bridge *maintenance* prioritization system using elemental data to help TxDOT personnel effectively plan maintenance projects.
- Include linkages to related TxDOT information systems and references.
- Include a budget forecasting system that optimizes the use of funds and allows for the possibility of allocating funds by district.
- Follow systems analysis and design standards for BMIS implementation.
- Develop an inventory system with elemental descriptions in graphical format.
- Develop functionality to predict the remaining useful life of a structure.
- Develop user-defined tools and interfaces.
- Include user-defined ad-hoc tracking capabilities with results provided in tabular or graphical form
- Include quality control checks.

IDENTIFICATION OF DATA NEEDS

Once user needs are identified, the next step in building the BMIS framework is to identify the data needs, data attributes, and relationships required for each user need. During the meetings with stakeholders, users provided specific details of their needs and data requirements to address those needs. Tables 26 through 50 identify the user need, the specifics of the user need, and associated missing data attributes to meet that need.

User Need 1. Expand appraisal working documents to include additional attributes such as clearances and ratings.

Table 26. Data Needs in Connection with User Need 1.

Data Need	Description
A	Include the following attributes in the Bridge Appraisal Worksheet: • AADT • Roadway Width • Designated Level of Service • Functional Classification • Vertical Clearance • Minimum Vertical Clearance • Underpass Right Lateral Clearance • Underpass Left Lateral Clearance • Inventory Rating • Operating Rating • Bridge Posting • Waterway Adequacy • Approach Roadway Alignment

User Need 2. Coordinate with bridge owners or entities responsible for maintenance.

Table 27. Data Needs in Connection with User Need 2.

Data Need	Description
A	Obtain contact information for bridge owners or entities responsible for maintenance. Include contact information for the following stakeholders: • County Judges • County Commissioners • City Managers • Mayors • City Engineers • Public Works Director • Community Development Director • TxDOT Area Engineers • TxDOT Maintenance Section Supervisors • Regional River Authorities • Regional Water Districts • Army Corps of Engineers • FEMA
B	Provide data structures to associate bridges with contact information.
C	Provide triggers in the BMIS application to notify bridge owners through appropriate correspondence when activities are to occur on specific bridges they own.
D	Add a feedback feature on the Bridge Inspection Follow-up Action Worksheet for bridge owners or entities responsible for maintenance to respond when Follow-up Actions occur.
E	Provide mechanisms to update contact information of bridge owners or responsible agencies.

User Need 3. Generate automatic updates of history and inspection follow-up documents when corrective actions in bridge inspection records are noted.

Table 28. Data Needs in Connection with User Need 3.

Data Need	Description
A	Modify the Bridge Inspection Record form and its associated database to include the following attributes: • Corrective Action. • Corrective Action Date. • Corrective Action Recorded By.
B	Modify the Bridge History Sheet form and its associated query structures to retrieve data from the Corrective Action attributes to populate the History of Corrective Actions section of the form.
C	Modify the Bridge Inspection Follow-up Action Worksheet form and its associated query structures to retrieve data from the Corrective Action attributes to populate the Follow-up Actions Taken section of the form.

User Need 4. Generate a database to manage elemental data.

Table 29. Data Needs in Connection with User Need 4.

Data Need	Description
A	**Include elemental data attributes from PonTex in a database that is linked to BRINSAP.**
B	**Include with the database functions for data entry, data query and report generation.**
C	**Include mechanisms in the database to synchronize data with bridge inspection safety data.**
D	**Link or embed related scanned and electronic documents, CAD files, and image files in the database.**

User Need 5. Generate a database to manage load posting data.

Table 30. Data Needs in Connection with User Need 5.

Data Need	Description
A	**Include load posting data attributes in a database that is linked to BRINSAP.**
B	**Include with the database functions for data entry, data query, and report generation.**
C	**Include mechanisms in the database to synchronize data with bridge inspection safety data.**
D	**Link or embed related scanned and electronic documents, CAD files, and image files in the database.**

User Need 6. Generate a database to manage vertical clearance, sign, and horizontal data.

Table 31. Data Needs in Connection with User Need 6.

Data Need	Description
A	Create a database containing vertical clearance and horizontal data that is linked to BRINSAP.
B	Include the following attributes in the vertical clearance database: • Posted VC • Measured VC • Difference between posted VC and measured VC • Flag where difference is less than or equal to two inches • Flag where difference is less than or equal to four inches • Flag where difference is zero
C	Include with the vertical clearance database functions for data entry, data query and report generation.
D	Create a database containing vertical clearance signs that is linked to BRINSAP.
E	Include the following attributes in the vertical clearance signs database: • Sign location (e.g., at structure, before structure) • Sign status (e.g., missing, improper sign reflectivity material) • Vertical clearance value posted on sign
F	Include with the sign database functions for data entry, data query and report generation.
G	Include with the sign database a query to track existing vertical clearance signs that need maintenance.
H	Include with the sign database relationships that permit queries that span multiple databases (e.g., select signs with improper vertical curve values).
I	Include mechanisms in the vertical clearance and sign databases for the exchange and coordination of data with the TxDOT Motor Carrier Division Oversize/Overweight Permits Office.
J	Include vertical and lateral clearances with bridge inspection data.

User Need 7. Generate a NBI Data Report using data from mainframe databases.

Table 32. Data Needs in Connection with User Need 7.

Data Need	Description
A	Create an import function that retrieves NBI attribute values from BRINSAP.
B	Create a report form template and create a function to print NBI attribute values using the template.

User Need 8. Manage traffic control data involving the bridge structure.

Table 33. Data Needs in Connection with User Need 8.

Data Need	Description
A	Incorporate traffic control attributes and associated metadata, such as contact information, in the data collection, data storage, and reporting of fracture critical inspections.
B	Incorporate traffic control attributes and associated metadata, such as contact information, in the data collection, data storage, and reporting of routine safety inspections.
C	Incorporate traffic control attributes and associated metadata, such as contact information, in the data collection, data storage, and reporting of special inspections.
D	Incorporate traffic control attributes and associated metadata, such as contact information, when performing inspections over or under a railroad.
E	Include the following attributes when performing inspections over or under a railroad: • DOT railroad crossing number or railroad location number • Time duration required for inspection over or under railroad
F	Coordinate data collection and data values with railroad stakeholders for inspections over or under a railroad.
G	Incorporate traffic control attributes and associated metadata, such as contact information, when checking vertical and horizontal clearances.
H	Develop a sequence of required steps for incorporating traffic control attributes into inspections.
I	Link traffic control data provided through inspections to BRINSAP.

User Need 9. Generate a database to manage data not included in the NBI database.

Table 34. Data Needs in Connection with User Need 9.

Data Need	Description
A	Create a database containing additional attributes (e.g., bearings, joints, scour histories, and temporary repairs) not included in NBI that is linked to BRINSAP.
B	Include the attributes listed in Table in the database.
C	Include historical bridge inspection data and the historic bridge evaluation for National Register (NR) eligibility listing in the database.
D	Include with the database functions for data entry, data query, and report generation.
E	Link or embed related scanned and electronic documents, CAD files, and image files in the database.

User Need 10. Provide a mapping component that generates spatial locations of bridges and bridge-related infrastructure assets, such as load posting signs, and allows report generation.

Table 35. Data Needs in Connection with User Need 10.

Data Need	Description
A	**Identify and implement the optimum hardware/software environment for mapping of bridge locations. The mapping of bridge locations at TxDOT can use existing hardware/software components or use a new environment within the TxDOT core architecture. Existing hardware/software components for graphical framework in a BMIS include:** • **TxDOT's Main Street Texas** • **TxDOT's Load Restricted Bridges web application** • **Harris County Asset Management viewer** **Potential mapping environments include:** • **Client/server** • **Desktop GIS** • **Spatial database management systems (Spatial DBMS)** • **Server GIS** • **WebGIS Clients** • **Mobile GIS** • **WebMap Servers**
B	**Identify and implement the mechanism to create spatial bridge points from latitudes and longitudes in the NBI database, import the points into the mapping component and edit those points based on existing spatial layers (e.g., highways, imagery).**
C	**Identify and implement the mechanism to create and store spatial points for bridge-based load posting signs, as well as import the points into the mapping component. The load posting sign database should include:** • **Status and year rebuilt, rehabilitated, or replaced.** • **A mechanism to check if signs are removed once a bridge is fixed or replaced.**
D	**Identify the integration and functionality of the mapping component, for example:** • **The mapping component could be in a multi-tab form, or as an application option.** • **Clicking on a bridge in the mapping component could result in a list of associated documents and multimedia, such as bridge inspection data (e.g., load posting, structurally deficient, functionally obsolete, vertical and horizontal clearances), and bridge programming information (i.e., scheduled for rehabilitation or replacement).**

	• Based on user input, standard and ad-hoc reports and maps can be generated, such as:

	o District and County level maps showing bridge locations
	    o Separate on system and off system bridge locations
	    o Bridges with a sufficiency level under a certain value
	    o All railroad bridges
	    o All bridges over water
	    o Bridges over 300 feet long

User Need 11. Build the functionality for electronic signatures on required reports and documents.

Table 36. Data Needs in Connection with User Need 11.

Data Need	Description
A	Review methods for electronic signatures as defined by the Texas Engineering Practice Act and Rules Concerning the Practice of Engineering and Professional Engineering Licensure, Title 22, Part 6, Chapter 133, Subchapter B, Rule §137.37 Electronic Seals and Electronic Signatures, authored by the Texas Board of Professional Engineers. Two methods are allowed: Electronically copying original hard copy work that bears a seal, original signature, and date and transmit this work in a secure electronic format. Creating an electronic seal and electronic signature for use in transmitting electronically formatted engineering work, regardless of whether the work was originally in hard copy or electronic format.
B	Identify a set of standard procedures for the use of electronic signatures.
C	Identify and configure the required hardware (e.g., scanners) and software (e.g., software encryption) to implement standard procedures for electronic signatures.

User Need 12. Create a portable version of BMIS to work on a laptop in the field and on-site.

Table 37. Data Needs in Connection with User Need 12.

Data Need	Description
A	With involvement from users, build the BMIS application and underlying system architecture to optimize the application's usage on-site. The choice between creating a standalone version of BMIS, a web-enabled version, or providing access to the application through an internet gateway on a laptop, cellular phone, or tablet PC requires a formal systems analysis.

User Need 13. Generate automatic updates of related documents when sign material data are updated.

Table 38. Data Needs in Connection with User Need 13.

Data Need	Description
A	Modify the Summary of Needed Load Posting Materials spreadsheet and its associated query structures to retrieve sign summary items from the Materials Needed section of the Bridge Summary Sheet report. These items include: • R12-2Tb • W12-5 • R12-2Tc • Posts • R12-4Tb • Hardware Sets • R12-4Tc • Decals

User Need 14. Update the Bridge Incident Tracking system (which is used for tracking events when bridges have impact and/or high load damages) and improve coordination with stakeholders.

Table 39. Data Needs in Connection with User Need 14.

Data Need	Description
A	Identify the criteria for bridge impact/high load damage and the bridge of interest.
B	Obtain road life to identify previous work on bridge.
C	Provide a link to Plans Online to obtain electronic bridge plans to make impact aftermath decisions.
D	Identify bridge owners or responsible entities using the Bridge Incident Tracking System (BITS). Populate the BITS database for the incident.
E	Coordinate subsequent activities with bridge owners.

User Need 15. Develop a bridge *project* prioritization system that is easy to understand and is easy for TxDOT to incorporate.

Table 40. Data Needs in Connection with User Need 15.

Data Need	Description
A	Incorporate the current TxDOT bridge section priority, which is: • Priority 1: Structurally Deficient On System Bridges • Priority 2: Structurally Deficient Off System Bridges • Priority 3: Functionally Obsolete On System Bridges • Priority 4: Functionally Obsolete Off System Bridges
B	Provide functionality for multiple priority criteria, such as: • Preventing multiple projects being planned on the same bridge • Replacing bad bridges • Reducing the number of less than adequate bridges • Programming bridges for preventive maintenance and rehabilitation before their condition becomes serious

User Need 16. Develop a user-friendly bridge *maintenance* prioritization system using elemental data to help TxDOT personnel effectively plan maintenance projects.

Table 41. Data Needs in Connection with User Need 16.

Data Need	Description
A	**Provide functionality for multiple priority criteria, such as:** • **When feasible** • **Immediate** • **Serious** • **Within a month** • **Within the next calendar year** • **When funding is available**
B	**Link TxDOT's routine maintenance contract system with BMIS.**
C	**Generate a list of maintenance items with priorities.**
D	**Integrate maintenance activity coding with element level inspections.**
E	**Use element level inspection data to guide the maintenance program.**

User Need 17. Include linkages to related TxDOT information systems and references.

Table 42. Data Needs in Connection with User Need 17.

Data Need	Description
A	**Link bridges to electronic bridge plans from the TxDOT Plans Online database.**
B	**Provide links to the TxDOT bridge inspection manual, the elements coding manual, and other related references.**

User Need 18. Include a budget forecasting system that optimizes the use of funds and allows for the possibility of allocating funds by District.

Table 43. Data Needs in Connection with User Need 18.

Data Need	Description
A	Develop estimates for preventive maintenance projects, such as the amount of joint sealant needing replacement.
B	Calculate the depreciated asset value of the structure based on the initial construction cost and a depreciation factor using the bridge's current age and type of construction.

User Need 19. Follow systems analysis and design standards for BMIS implementation.

Table 44. Data Needs in Connection with User Need 19.

Data Need	Description
A	Identify core TxDOT business processes for a BMIS and then fit BMIS needs to these processes.
B	The BMIS should enhance work, be a positive experience, and be user-friendly.
C	Include factors of speed, and security in the development of the BMIS.
D	Develop functionality, interfaces, access, and level of access based on type of user (e.g., novice, expert) and user responsibilities (e.g., inspection, maintenance).
E	Standardize terminology (e.g., underclearance, bridge width) and ensure uniformity in the inspection process.
F	Focus BMIS implementation first on system bridges given that data collection for off system bridges will be problematic.
G	Evaluate the use of the Fort Worth District Bridge Inspection Reports System as a framework for implementation of a BMIS.
H	Provide mechanisms for Districts to interact with the BMIS to update cost and inspection information.
I	Provide mechanisms for TxDOT personnel to obtain and analyze data at one computer or workstation, instead of going to Districts or other BRG sections to obtain data.
J	Provide the functionality to merge data from various sources into appropriate report templates (i.e., merge comments and ratings into one form, such as the Bridge Inspection Record, Form 1085).
K	Design the BMIS to allow for new technologies (e.g., select a form element and automatically post updates into the form using iPads or iPhones.
L	Build intelligence into data retrieval and processing functions to recognize alternate file formats (e.g., DGN or PDF).

User Need 20. Develop an inventory system with elemental descriptions in graphical format.

Table 45. Data Needs in Connection with User Need 20.

Data Need	Description
A	Hyperlink bridge diagrams, bridge layouts and elements on those diagrams and layouts, to photos, videos, other diagrams, as well as inspection and cost data.

User Need 21. Develop functionality to predict the remaining useful life of a structure.

Table 46. Data Needs in Connection with User Need 21.

Data Need	Description
A	Incorporate a deterioration model into the BMIS that could predict remaining useful life for a structure based on attributes such as: • Current structural condition • Type of construction • Environmental conditions based on geographical location.
B	Calculate and determine if rehabilitation or replacement of a structure is a better option.

User Need 22. Develop user-defined tools and interfaces.

Table 47. Data Needs in Connection with User Need 22.

Data Need	Description
A	**Identify and implement dynamic tools and interfaces that users can customize. For example, the system should allow the user to type in an NBI number and optionally display the latest bridge inspection reports, with photographs, download current and previous bridge plans from the Plans Online database, and display the satellite view of the bridge site from Google Earth.**
B	**Identify and implement a set of core structured tools, such as determining the condition of a bridge, by either entering the NBI number, selecting from a list, or selecting from a map.**

User Need 23. Include user-defined ad-hoc tracking capabilities with results provided in tabular or graphical form.

Table 48. Data Needs in Connection with User Need 23.

Data Need	Description
A	**Identify core attributes and documents that should be tracked such as:** • **Changes in site conditions or surrounding development** • **Pending projects for the bridge** • **Participation waived projects** • **Maintenance interventions** • **Embankment erosion, channel erosion, and debris**
B	**Modify data structures, forms, and interfaces to store date information with core attributes and documents.**
C	**Design, implement, and customize user-interfaces for tracking of core attributes and documents based on the type of data (e.g., use a mapping environment to display changes in site conditions or surrounding development).**
D	**Identify and implement mechanisms to notify stakeholders of certain conditions (e.g., inform maintenance about embankment erosion, channel erosion, and debris).**

User Need 24. Include quality control checks.

Table 49. Data Needs in Connection with User Need 24.

Data Need	Description
A	Check that maintenance work is being conducted according to the follow-up action worksheet.
B	Identify if a bridge is part of a currently funded project (or not).
C	Ensure CSJs for bridge related projects can be found and that they are linked with a NBI number.

Table 50. List of Desired Attributes Not Found in Existing TxDOT Information Systems.

Attribute Name	
Bridge Element Attributes	
Multi-Bridge	
Relative Position (North, South, East, West, Center)	On School Bus Route Flag
Bridge Wearing Surface Type	ISD Name
Bridge Wearing Surface Thickness	ISD Primary Contact Name
No Plans Available Flag	ISD Primary Contact Address
Maintained By	ISD Primary Contact Telephone Number
Pedestrian Crossing Flag	Maximum Gross Weight Of Bus On Route
On Heavy Truck Route Flag	Bus Route Map
Fracture Critical Cap Type (Box Or Plate)	History Of Debris Problem Flag
Crown Span Value	Debris Problem
Temporary Structure Flag	History Of Debris Accumulation
Load Posting Not Required Flag	Channel Direction Not Aligned With Bridge Opening (Skew Angle) Flag
Improper Load Posted Flag	History Of Scour Problem Flag
Weight Limit Revised Flag	Scour Structure Type (Piles, Spread Footings, Drilled Shafts, Pile Cap On Piles, Trestles, Frames, Single Columns, Tie Beams, Embankments)
Weight Limit Revised Value	Scour Problem Type (Exposure, Undermining, Leaning, Embankment Material Loss, Embankment Protection Failure)
Missing Signs Flag	Scour Problem Date
Missing Signs Value	Scour Unknown Foundation Flag
Road Closed To Traffic Flag	Scour Steep Embankment Flag
No Crash Wall (Single Column Bent) Flag	Scour Lateral Stream Migration Flag
Two-Column Bent Protection Flag	Scour Erodible Channel Material Flag
Cap Problems	Scour Vertical Degradation Flag
Joint Problems	Load Guidance Requested Flag
Bearing Problems	Load Guidance Requested Date
Beam End Problems	Load Factor Method Requested Flag
Cracked Riprap Flag	Load Factor Method Requested Date
Riprap Joint Problems	Load Factor- Entity To Perform Structural Analysis
Cracked Box Beams Flag	Load Factor-Structural Analysis Estimated Completion Date
Lateral Movement Flag	Load Factor-Structural Analysis Method
Channel Migration	Load Factor-Inventory Rating (IR) & Operating Rating (OR) Results
Spread Footing With Undermining	Impact/High Load Damage Flag
Spread Footing Exposed Without Undermining	Impact/High Load Damage Date
Two Girder	Impact/High Load Damage Cumulative Cost
Timber Pile Abutments Flag	Impact/High Load Damage Type
Skew Angle	Impact/High Load Damage Condition

Attribute Name	
Delineation Present Flag	Impact/High Load Damage Affected Elements
Delineation Type	ASR/DEF Bent Cap Damage Flag
Deck – Top	
Material Type	Deck Thickness
Construction Type	Reinforced Flag
Forms Left In Place	ACP Overlay Thickness
Deck – Underside	
Material Type	Deck Thickness
Construction Type	Reinforced Flag
Forms Left In Place	ACP Overlay Thickness
Joints	
Type	Ease Of Repair
Repair Methods Required	Repair Cost
Bearings	
Type	Ease Of Repair
Repair Methods Required	Repair Cost
Drainage System	
Type	Piping
Functioning Flag	Pipe Supports
Below Deck	Outlet
Channel	
Cross Section Measurements	Data Collection Date
Crossing Profiles	Channel Name/Id
Entire Bridge Structure	
Costs Greater Than $500k Flag	Land Locked Flag
Resides In Airport Area Flag	Historical Bridge Flag
Navigation Lighting Flag	Outdated Bridge Railing Flag
Navigation Lighting Schedule Flag	Last Date Category 6 Funds Were Spent
Inspection Attributes	
Waterway Inspection Equipment Checklist - Small Boat	
Deep Cycle Battery	SHIFLO (Depth Finder)
Hip/Chest Waders	Throw Cushion (Throwable PFD)
Paddles	Trolling Motor
Personal Flotation Devices (PFD)	Weighted Drop Line
Waterway Inspection Equipment Checklist - Large Boat	
Air Horn	SHIFLO (Depth Finder)
Hip/Chest Waders	Throw Cushion (Throwable PFD)
Paddles	Weighted Drop Line
Personal Flotation Devices (PFD)	Working Lights – Front & Back
Registration Card (Attached To Keys)	
Flooded Waterway Inspection	

Attribute Name	
Inspection Date	Relative Amount Of Floating Debris
High Water Mark	Channel Cross Section Measurements From Weighted Drop Line Or SHIFLO
Approximate Water Velocity	Photos/Video
Bridge Deck or Approach Roadway Overtopped Flag	General Comments
Winter Season Inspection	
Inspection Date	Examination Of Exposed Trestle Piles
Examination Of Exposed/Undermined Spread Footing	Vegetation Level
Examination Of Exposed Piling	Lowest Observed Channel Elevation
Examination Of Exposed Drilled Shaft	Relative Measureable Feature Condition
Examination Of Exposed Pile Cap	General Comments
Dry Season Inspection	
Inspection Date	Examination Of Exposed Trestle Piles
Examination Of Exposed/Undermined Spread Footing	Lowest Observed Channel Elevation
Examination Of Exposed Piling	Relative Measureable Feature Condition
Examination Of Exposed Drilled Shaft	General Comments
Examination Of Exposed Pile Cap	
Unknown Foundation Investigation	
Structure Type (Piles, Spread Footings, Drilled Shafts, Pile Cap On Piles, Trestles, Frames, Single Columns, Tie Beams)	Debris Description
Embankment Slope	Priority Level For Investigation
Slope Protection Type	Entity To Perform Investigation
Erodible Channel Material	Contract Number
Degradation Flag	Contract Cost
Lateral Channel Migration	Estimated Date Of Completion
Bridge Snooper Inspection Checklist	
Generator	Traffic Counter
Welder	SHIFLO (Depth Finder On Ski boat)
Oxy-Acetylene Torch	Weighted Drop Line
Air Compressor	2-Way Radios
Hydraulic Wrench	Chain Drag Equipment
Electric Drill	Air Monitor
Electric Impact Wrench	Fracture Critical Tools
Cordless Drill	Dye Penetrant Kit
Chain Saw	Bridge Snooper Working Position (Top Of Bridge Deck, Below Bridge Deck)
Portable Generator	
Maintenance Attributes	
Repairs-Temporary	

Attribute Name	
Date Of Repair	Project CSJ
Description Of Repair	Required Work To Make Repair Permanent
Repair-Permanent	
Date Of Repair	Project CSJ
Description Of Repair	
Programmed Bridgework Attributes	
Replacement	
Project CSJ	Estimated Completion Of PS&E
Entity Preparing PS&E	Estimated Letting Date
Approximate Cost Of Project	Contract CSJ
Initial Construction Cost	Reason For Bridgework
Rehabilitation	
Project CSJ	Estimated Completion Of PS&E
Entity Preparing PS&E	Estimated Letting Date
Approximate Cost Of Project	Contract CSJ
Initial Construction Cost	Reason For Bridgework
Equivalent-Match Project - EMP	
Project CSJ	Date Agreement Signed
Associated With PWP Number	Deadline Date For Completion Of Work
Contract CSJ	Initial Construction Cost
Reason For Bridgework	
Participation-Waived Project – PWP	
Project CSJ	Date Contract Begins
Associated With Employee Number (If Any)	Date Final PS&E Due
Date Agreement Signed	Estimated Letting Date
Design Consultant	Contract CSJ
Initial Construction Cost	Reason For Bridgework
Preventative Maintenance	
Project CSJ	Estimated Completion Of PS&E
Entity Preparing PS&E	Estimated Letting Date
Approximate Cost Of Project	Contract CSJ
Initial Construction Cost	Reason For Bridgework

CHAPTER 7. POSSIBLE BMIS INTERFACE APPROACHES

INTRODUCTION

This chapter documents the recommendations for the development of a District Level BMIS module. These recommendations are based on several district interviews carried out around the state that indicated two main concerns that District Bridge Engineers have:

- The ability to retrieve bridge information electronically encompassing BRINSAP, Scour Reports, Plans, Historical Inspection data, and others.
- The ability to display and link information in a geo-referenced basis by interacting with a map.

With the results of these interviews in mind, this chapter summarizes the in-house developed Fort Worth District Bridge Inspections Reports System and uses its existing data structure to build a prototype web based system that could be used as a blueprint for implementation at other TxDOT districts.

This chapter also illustrates the use of the TxDOT MapZapper database application and ArcMap^{TM} to generate maps displaying bridge inspection related data, both on a district level and statewide level.

THE FORT WORTH SYSTEM

Figure 16 depicts the opening screen for the Fort Worth District Bridge Inspections Reports System. From this screen the user is presented with several options. To understand the flow of information of the Fort Worth system and in support of the web-based prototype District Level BMIS, the following paragraphs will summarize the data structure for the Fort Worth System. This data structure is included in the prototype web-based system proposed by this project.

To summarize this data structure, assume that the user clicked on the Existing Inspections button in Figure 16. After this action, the user would be presented with the screen depicted in Figure 17 where it is possible to retrieve the information for a specific bridge by using the Bridge Navigation Panel, the appropriate County filter to expedite the search and using the drop-down menu in the Bridge Navigation Panel. The user may also input a DCCSS number directly into the box to retrieve the information for a specific bridge. After the target bridge is located, the user may generate several reports and gain access to supporting documents and inspection pictures of details of the bridge. When clicking on the buttons depicted in Figure 17, the user is in fact building queries to existing databases or directly retrieving information stored in a data drive. For example, the user may click on the View Pictures button on Figure 17 and be presented by the screen depicted by Figure 18, which includes one of the pictures from a recent inspection.

The action carried out by the View Pictures button clicked in Figure 17 consists in actually pointing the Fort Worth BMIS system to a specific sub-directory in a data storage device. Figure 19 depicts the file structure of the Fort Worth system. All files for the selected Structure ID (02-073-0079-05-039) are stored inside a sub-directory in a specific path in a connected mass data storage device—in this case P:\Brisapp\InspFiles\073\On\MS_05\0079-05-039. Where 073

corresponds to the county number, MS_05 corresponds to the maintenance section, and 0079-05-039 are the remaining digits in the Structure ID identification number.

Other reports may be also generated using other buttons in the main screen of the Fort Worth system depicted in Figure 16. The Fort Worth system is a very powerful management tool to help decisions and access bridge data at the district level. However, it lacks the powerful resources available with associating the bridge data with geo-referenced information. The prototype developed by this research project is a step in this direction and may serve as a basis for a District Level Bridge Management tool to be implemented at the districts. This prototype is described in the following paragraphs.
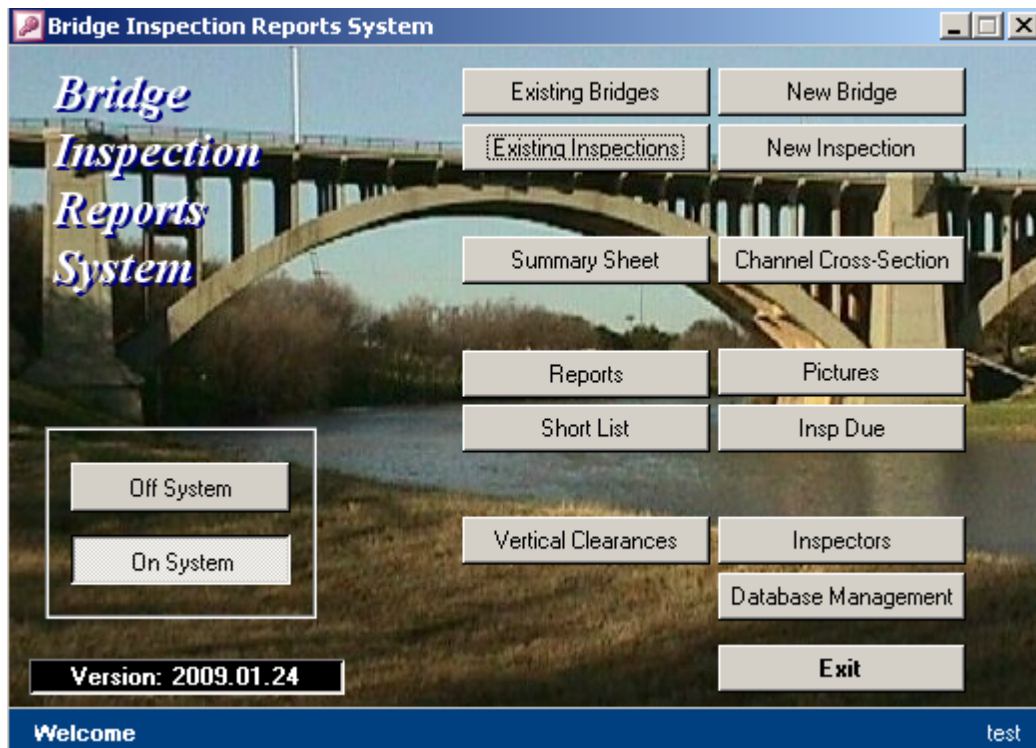
Figure 16. Fort Worth District Bridge Inspection Report System.

Figure 17. Bridge Navigation Panel.
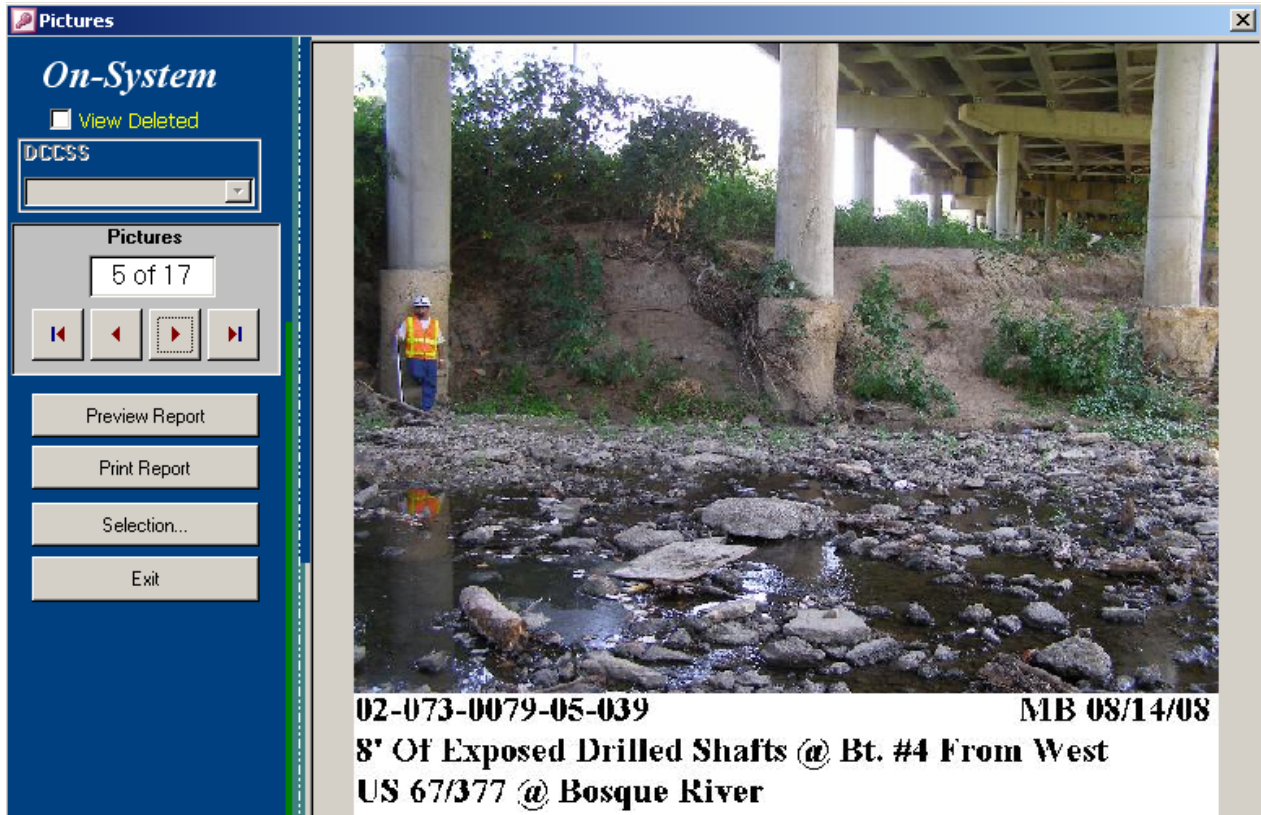
Figure 18. Picture Browsing Using the FW District System.
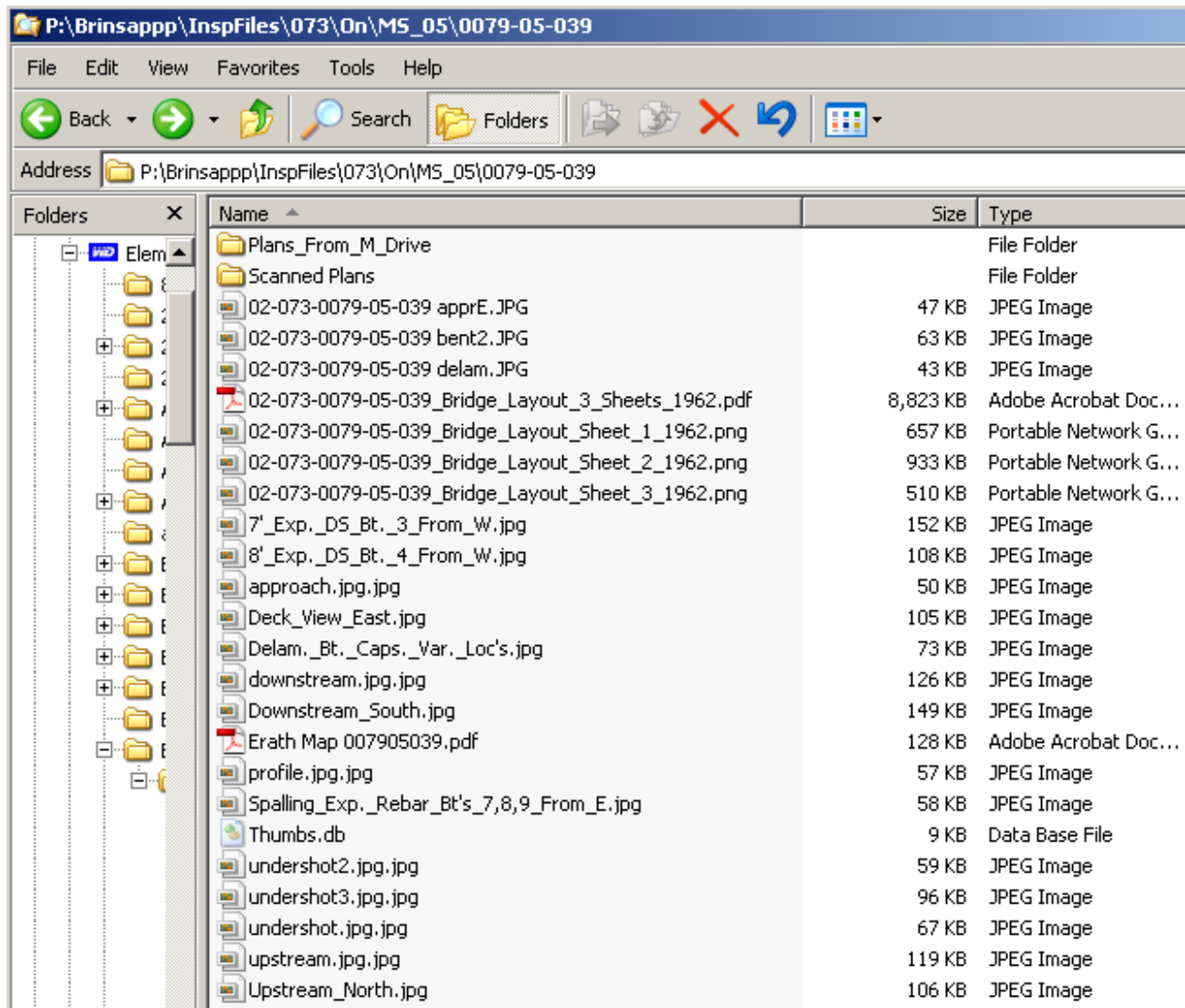
Figure 19. File System for the Fort Worth System.

DISTRICT LEVEL PROTOTYPE WEB-BASED SYSTEM

In the past few years, geo-referenced information has become widespread through the internet, with several providers offering base-map capabilities to private and public entities. Several providers of web-based mapping services come to mind with the most popular ones being Google Maps, Yahoo Maps, and Bing Maps. TxDOT currently has a corporate license of Bing Maps and already has several Bing Maps based websites to publish TxDOT data to the public. A TxDOT bridge related example is the Load Restricted Bridge Map available at http://apps.dot.state.tx.us/apps/gis/lrbm/. Figure 20 depicts a screen capture of this website. Bing maps-based websites offer an array of options to the user that have the potential to vastly improve the decision making based on bridge data at the district level. The existing data structure of the Fort Worth Bridge Inspection Reports System offers and excellent opportunity for addition of geo-referenced information.

For the purpose of this project, a web server was established at the University of Texas at San Antonio (UTSA) to mesh-up bridge information with Bing maps information. A key component of this mesh-up of geo-referenced information is the establishment of a GeoRSS file for which a sample segment is presented in Figure 21. Details for the GeoRSS file structure are available from http://www.georss.org/Main_Page. This GeoRSS file should reside in the web server and contains two key pieces of information:

- The geo-referenced information for each bridge.
- The location of the supporting inspection files in the web server.

Key lines in this GeoRSS file are the ones marked <link> and <georss:point>. The <link> line points to the directory in the web server's mass storage device that contains specific bridge information such as inspection results, pictures and plans and the <georss: point> line contains the point location for a specific bridge in terms of latitude and longitude.

The GeoRSS file segment depicted in Figure 2 describes the GeoRSS information for Structure ID 022200000804408. It also establishes the location of the supporting files for this bridge as http://bridgedata.coe.utsa.edu/0008-04-408, which is the server where the web-based district module was developed and tested. Finally, it provides the location of this specific bridge as being 32.72045058,-97.51101646 for latitude and longitude, respectively.

For the prototype website presented in this report, data were input manually in the GeoRSS file. However, it would be fairly straightforward to write SAS code to query the BRINSAP data and generate the GeoRSS file for a massive number of bridges in a specific TxDOT district.
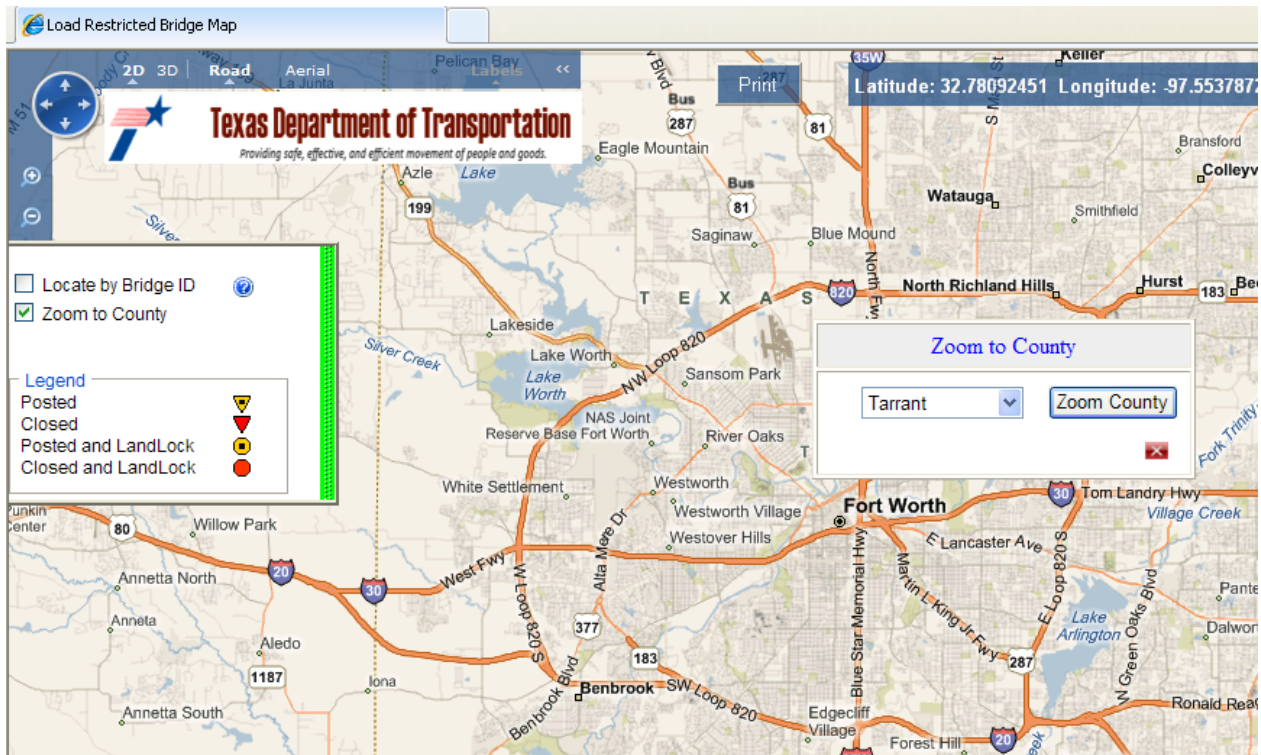
Figure 20. TxDOT Load Restricted Website.

```
<?xml version="1.0" encoding="UTF-8" ?>
 <rss xmlns:georss="http://www.georss.org/georss" xmlns:geo="http:/
<channel>
   <title>Tarrant County Bridges</title>
   <link>http://bridgedata.coe.utsa.edu/</link>
   <description>English</description>
   <language>en-us</language>
   <pubDate>2010-06-17T17:41:49Z</pubDate>
   <generator>BridgeMap http://bridgedata.coe.utsa.edu/</generator>

<item>
   <title>022200000804408</title>
   <link>http://bridgedata.coe.utsa.edu/0008-04-408</link>
   <description>Bridge Information</description>
   <pubDate>2010-06-17</pubDate>
   <georss:point>32.72045058,-97.51101646</georss:point>
   </item>

<item>
   <title>022200000804409</title>
   <link>http://bridgedata.coe.utsa.edu/0008-04-409</link>
```

Figure 21. GeoRSS Sile Structure.

Figure 22 presents the overview screen for the District Level BMIS web-based module developed for this project. A few bridges in the Forth Worth District have their location depicted in Figure 22, and if the user does a "mouse over" the bridge with Structure ID (02-073-0079-05-039)—the same bridge used to illustrate the Fort Worth District existing Bridge Inspections Reports System discussed earlier—the user would see the box depicted in Figure 22, with a hyperlink for the bridge information. In addition, all the capabilities of the Bing Maps environment are available to the user to display regular road maps as well as satellite imagery and a "bird's-eye view" at several zoom levels. Figure 23 illustrates the capabilities of the Bing Maps environment by displaying a "bird's-eye view" of the selected bridge.

Additional information for the bridge may be also obtained by clicking on the hyperlink on the box labeled "Bridge Information." By clicking on this hyperlink, the user is presented with the screen depicted in Figure 24, which actually encompasses all the files available for this specific bridge following the same file structure depicted in Figure 19.

To compare the capabilities of the web-based system with the existing Fort Worth system, the same bridge inspection picture depicted in Figure 18 is retrieved by clicking on the appropriate file and the result is depicted by Figure 25. In summary, any information on a specific bridge, stored in the appropriate sub-directory in the web server mass storage device may be retrieved by locating the bridge in the web-based prototype District BMIS system and clicking on the hyperlink labeled "Bridge Information." The file structure is identical to the Fort Worth existing system.

The web-based prototype District BMIS system can handle almost any file type, provided that the client computer accessing the web-based system has the proper application installed. This includes a vast variety of file types that are frequently used to store bridge information, including MicroStation files. Figure 26 depicts a bridge plan sheet that was stored in the system using a pdf format. The ability to read MicroStation files also opens the possibility to use "smart" drawings to link to bridge information such as inspection results.
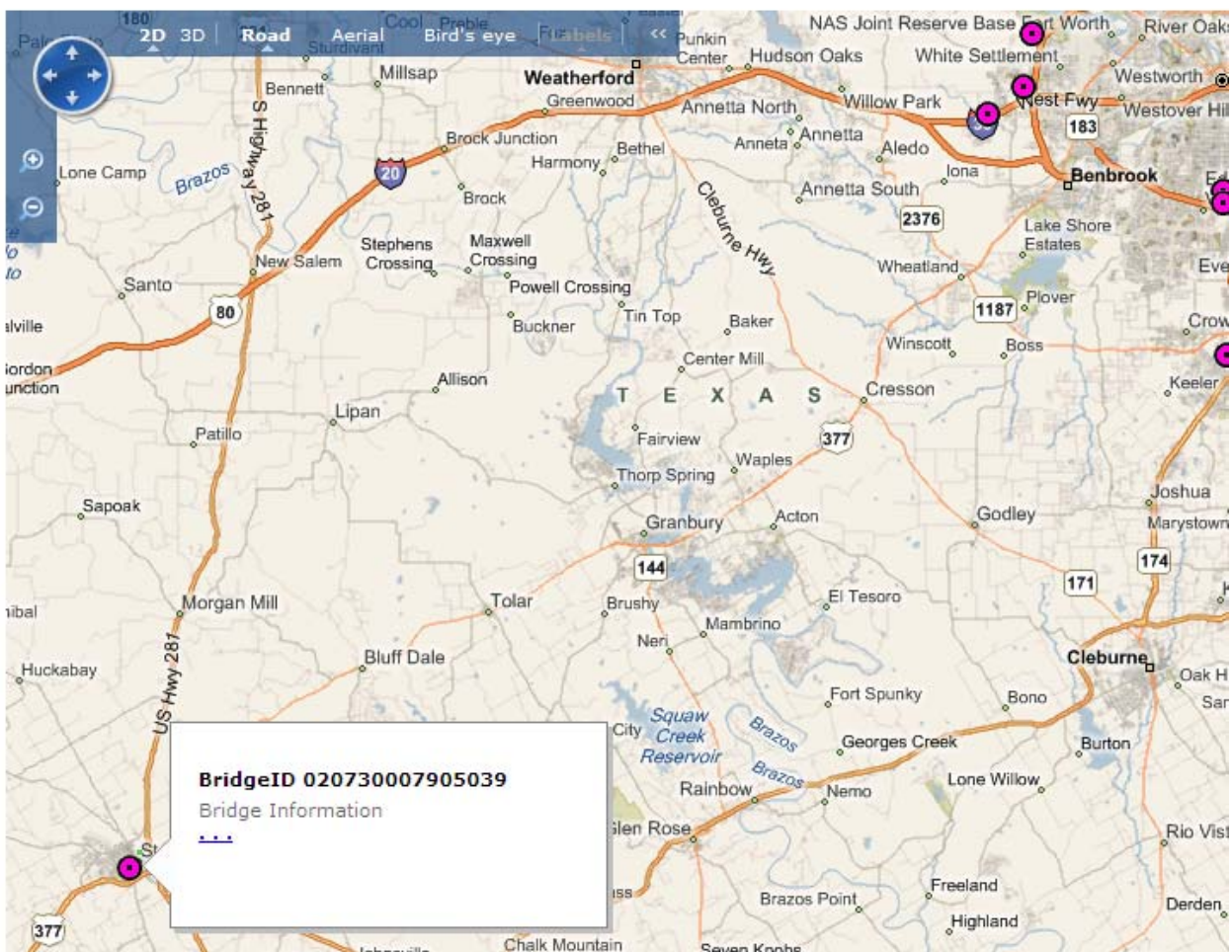
Figure 22. Overview Screen for the Prototype Web-Based District BMIS Module.
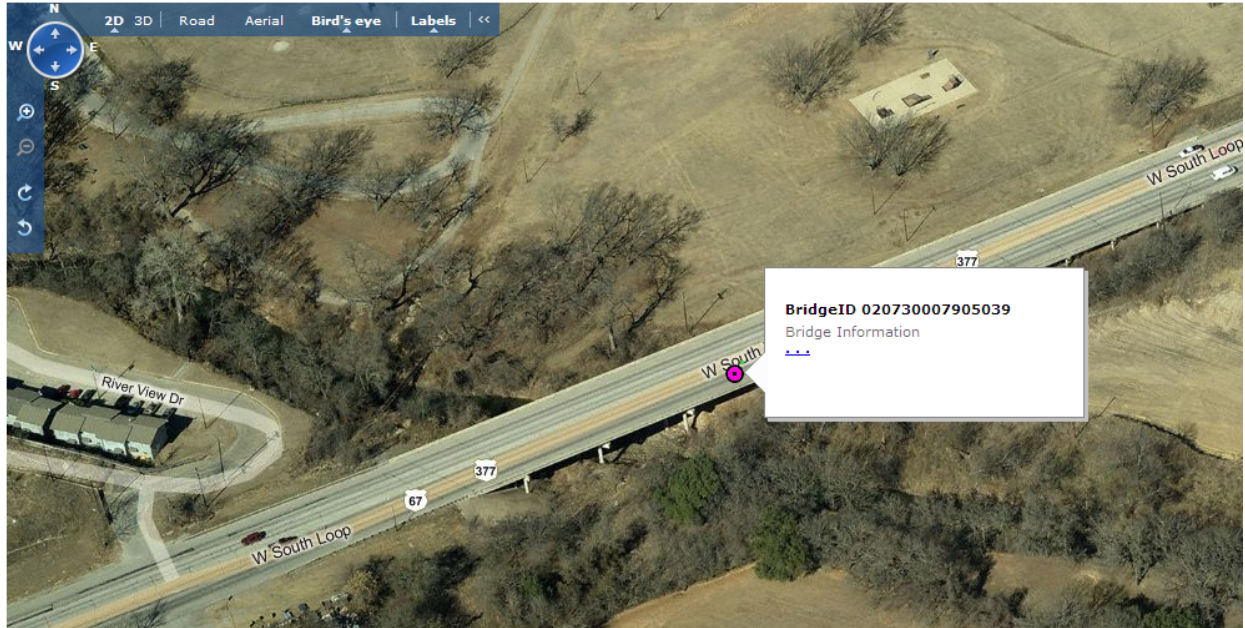
Figure 23. Bird's-Eye View of a Specific Bridge in the Fort Worth District.
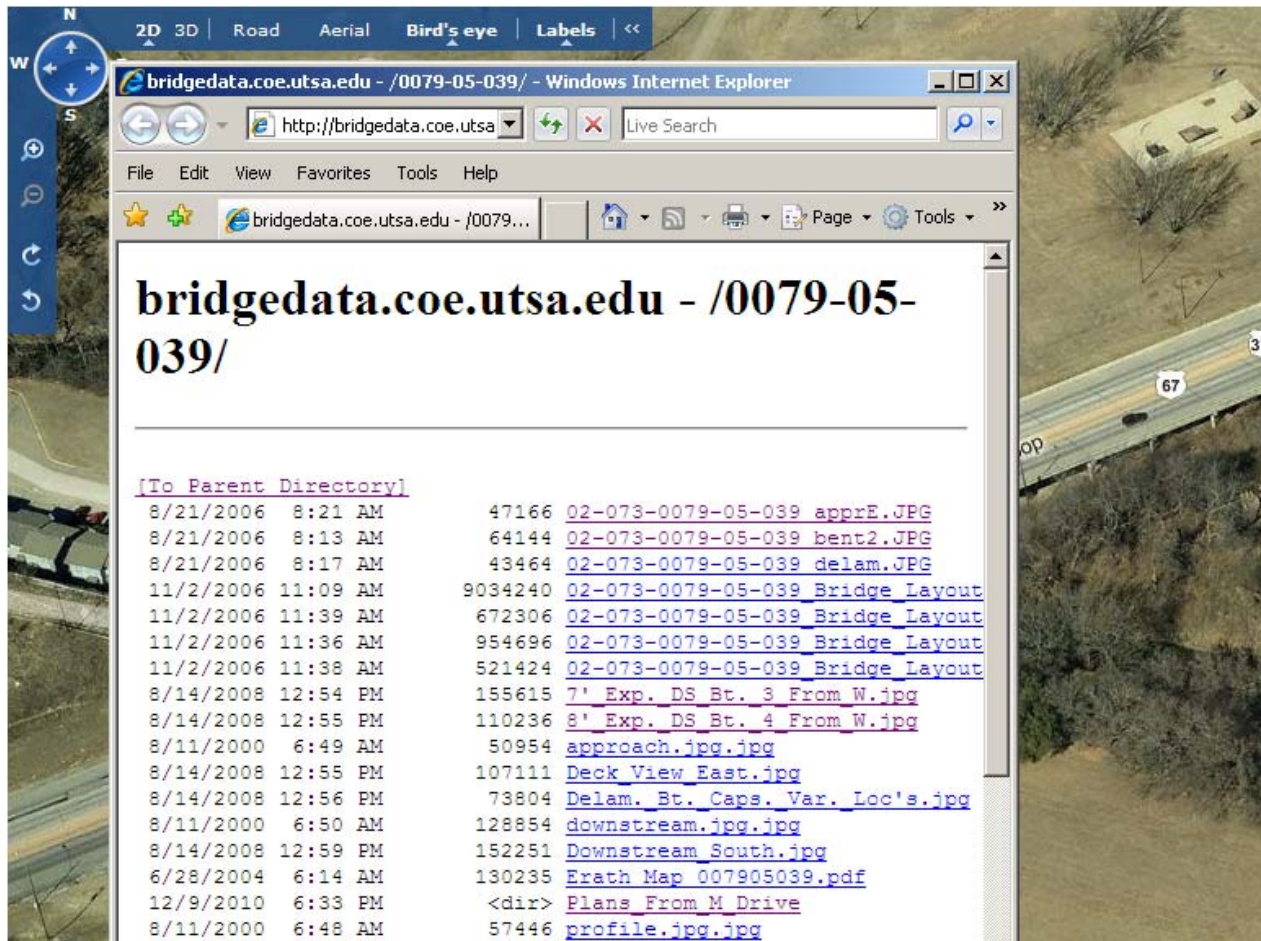
Figure 24. Data Files Available for a Specific Bridge in the Web-Based District BMIS System.
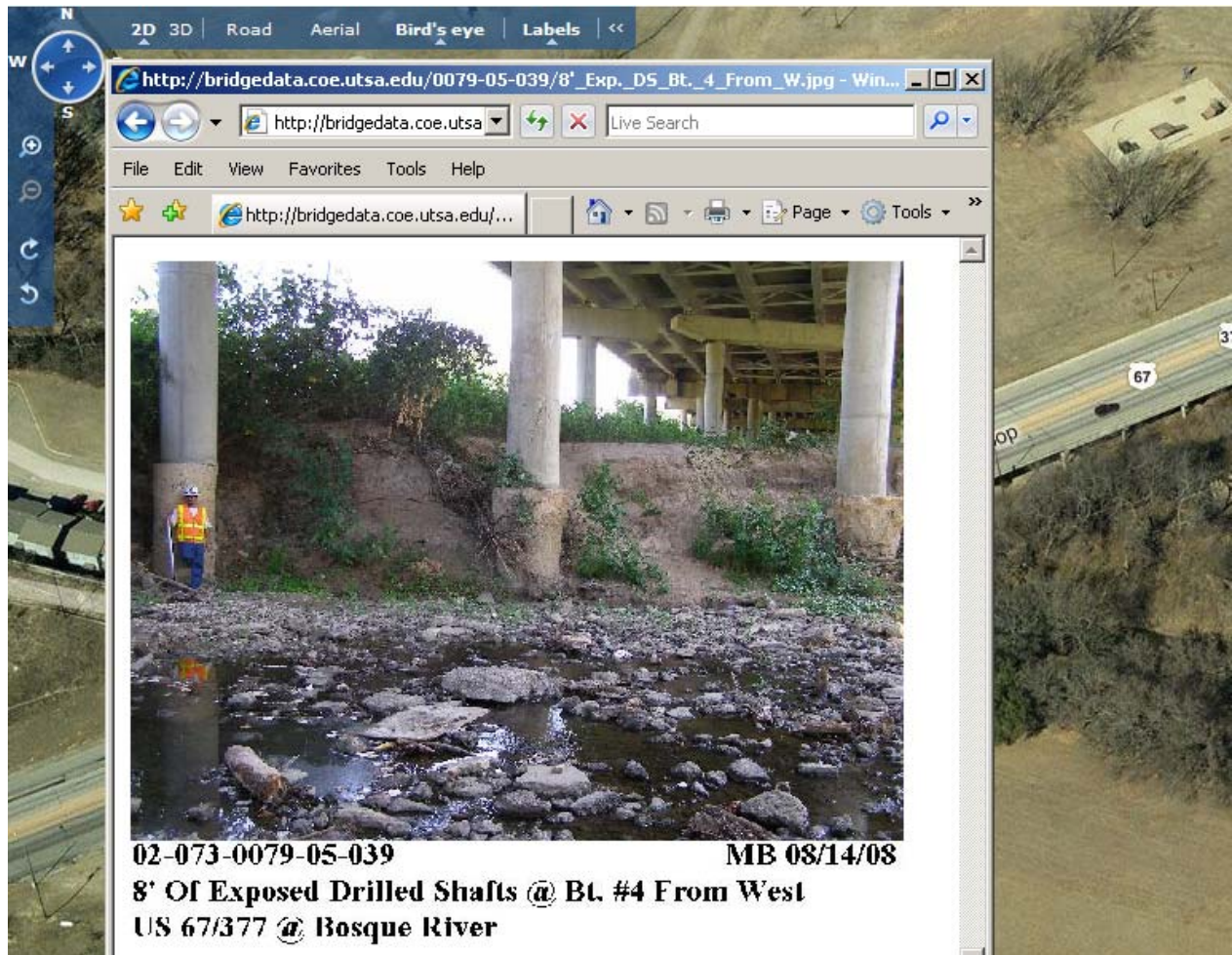
Figure 25. Picture of Inspection on a Bridge in the Fort Worth District as Retrieved by the Web-Based System.
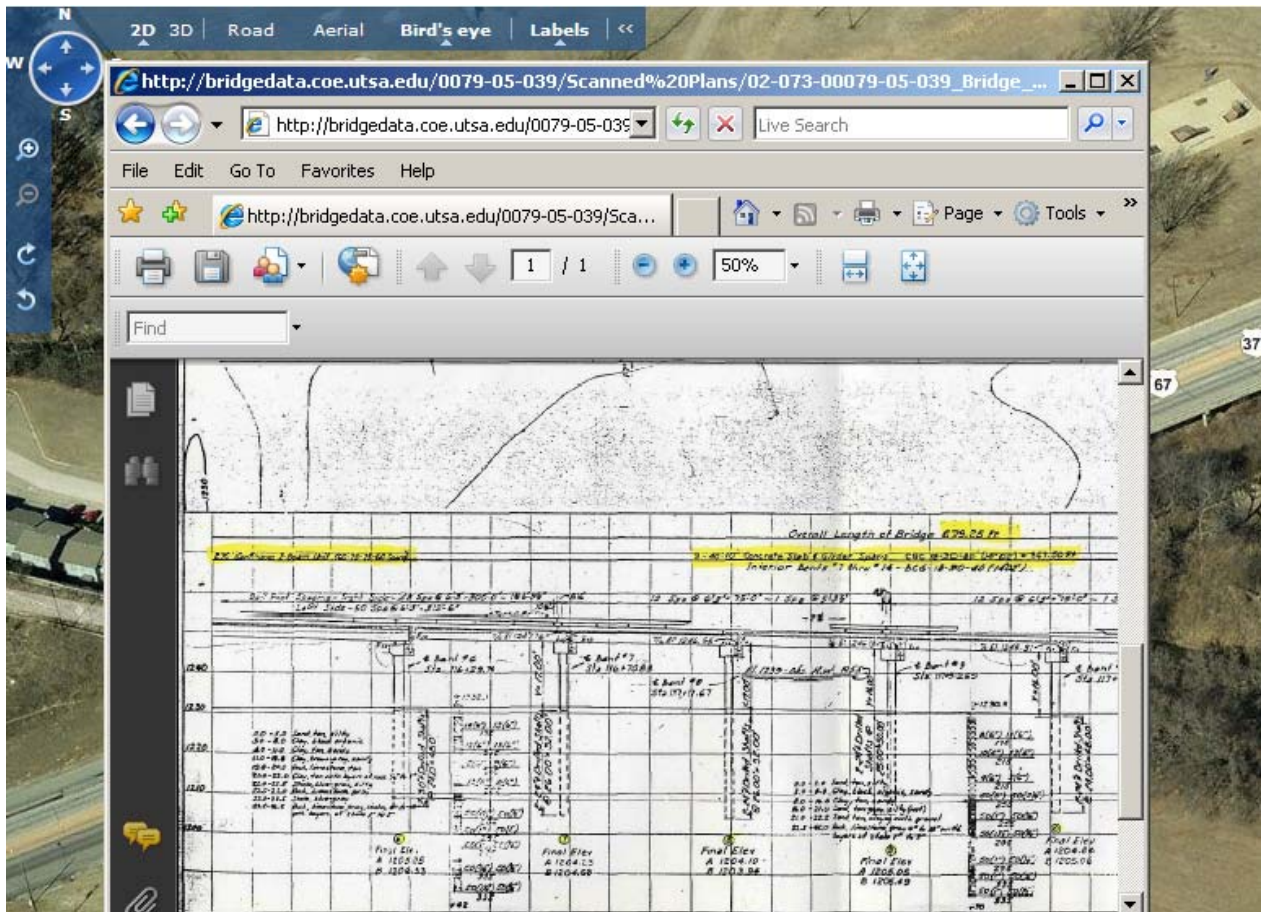
Figure 26. Plans for a Bridge in the Fort Worth District as Retrieved by the Web-Based System.

Microstation Interactive Drawings

The latest versions of Microstation software have the capability of building dynamic links to information stored in a SQL database. With this capability in mind, the researchers for this project developed prototype Microstation files for a specific bridge to illustrate these capabilities and evaluate the potential for implementation at TxDOT. Figure 27 illustrates this dynamic link concept for a specific element in a given bridge. By clicking on the element 109 link on Figure 27 the user is presented with the inspection information for that element depicted on Figure 28. For this specific bridge, element 109—Prestressed Concrete Girder—has 4,997 ft in condition 1 and 8 ft in condition 2. The user could also add maintenance recommendations for specific elements that compose the bridge and any other information that is pertinent to bridge management using an appropriate data structure for the linked SQL database. Figure 29 depicts the table in the SQL database that contains the inspection information pertinent to this specific element 109 in this specific bridge.
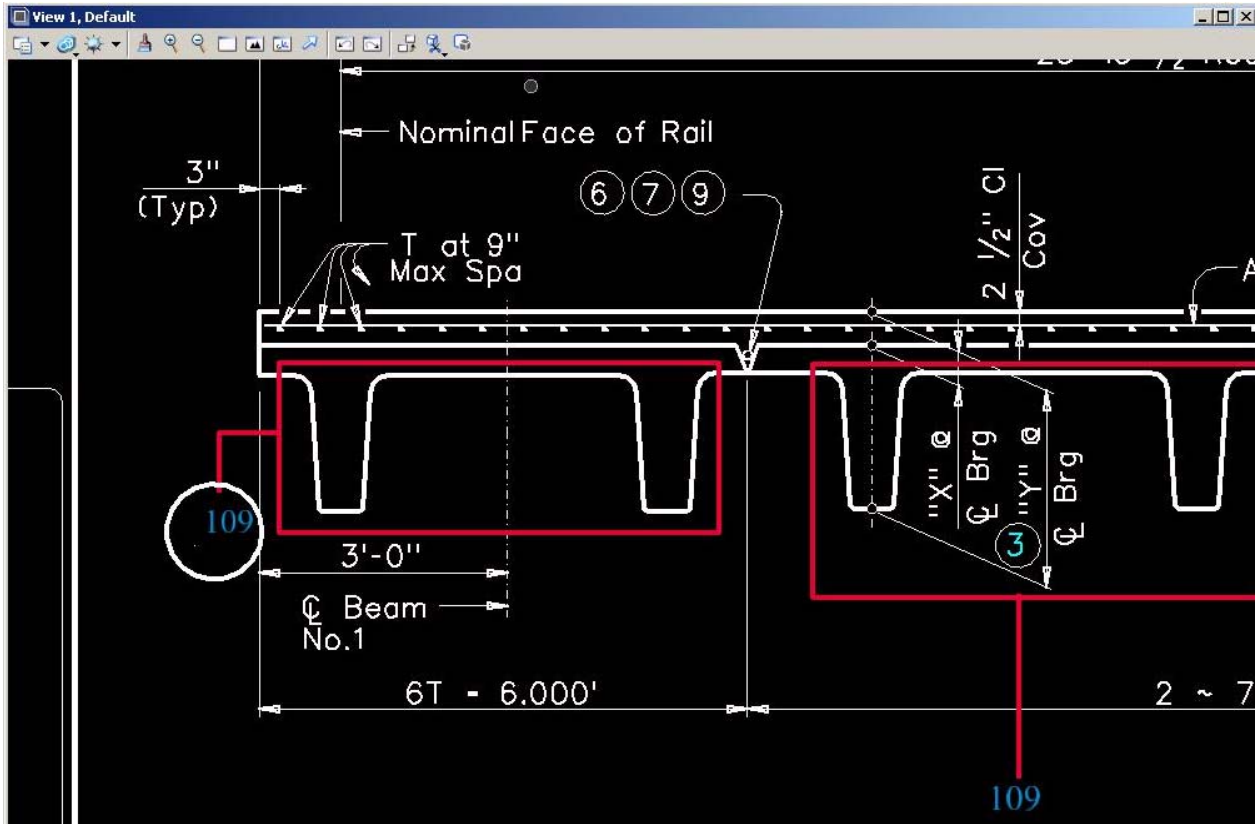
Figure 27. Microstation Drawing with "Smart" Link Embedded for Element 109.
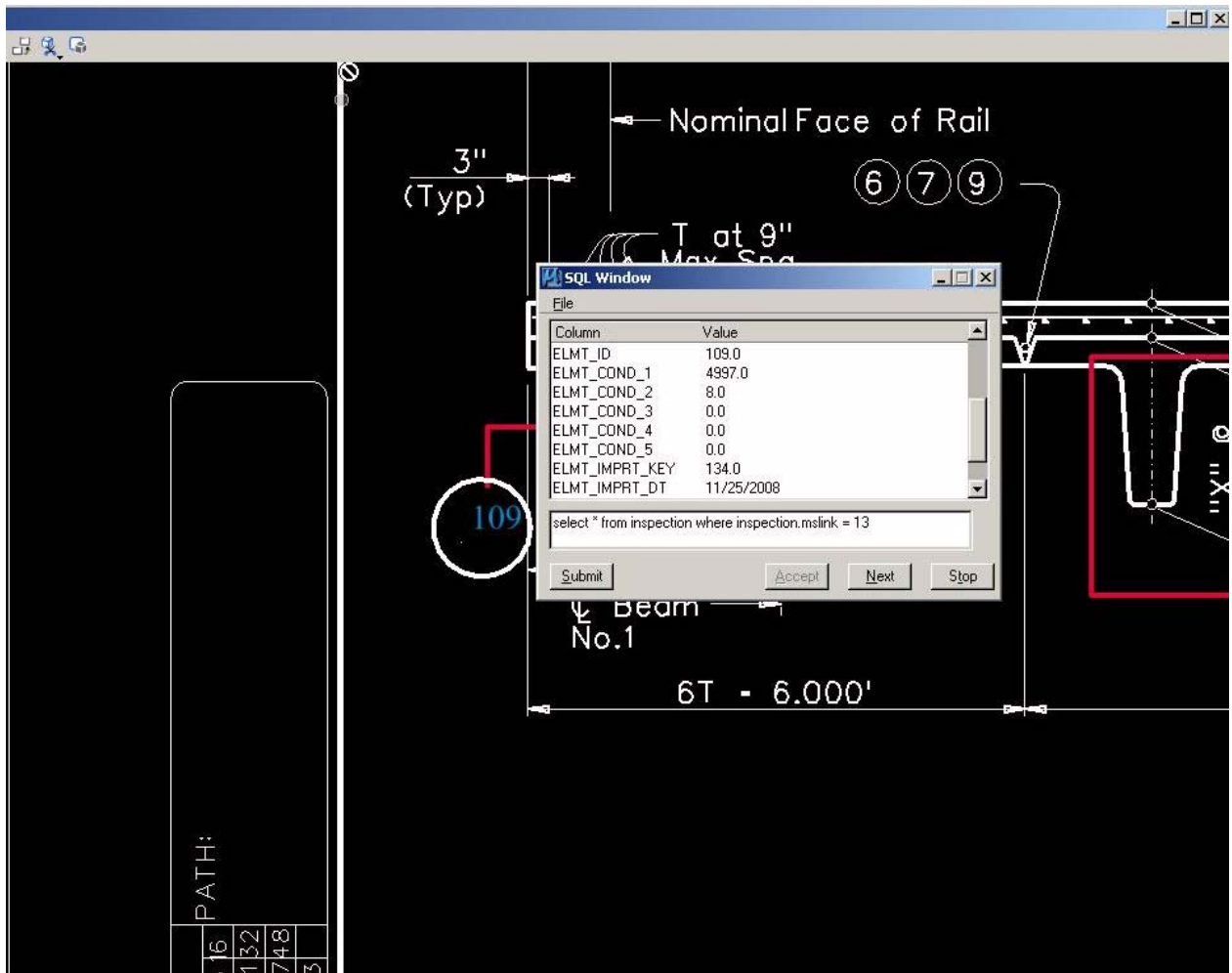
Figure 28. Inspection Information Viewed by Using a Dynamic Link to a Database.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	STRUCTURE_ID	INSPECTION_DATE	INSPKEY	INSP_TYPE	SEQ_NUM	VERSION	CMPNT_KEY	ELMT_ID	ELMT_COND_1	ELMT_COND_2	ELMT_COND_3	ELMT_COND_4	ELMT_COND_5
2	160040018003072	8/1/2006	1	RT	1	0	1	12	1	0	0	0	
3	160040018003072	8/1/2006	1	RT	1	0	1	301	115	0	115	0	
4	160040018003072	8/1/2006	1	RT	1	0	1	331	1430	0	0	0	
5	160040018003072	8/1/2006	1	RT	1	0	1	345	500	0	0	0	
6	160040018003072	8/1/2006	1	RT	1	0	1	0	1	0	0	0	
7	160040018003072	8/1/2006	1	RT	1	0	1	109	4997	8	0	0	
8	160040018003072	8/1/2006	1	RT	1	0	1	310	364	0	0	0	
9	160040018003072	8/1/2006	1	RT	1	0	1	215	92	0	0	0	
10	160040018003072	8/1/2006	1	RT	1	0	1	270	4	0	0	0	
11	160040018003072	8/1/2006	1	RT	1	0	1	234	550	2	0	0	
12	160040018003072	8/1/2006	1	RT	1	0	1	204	50	10	0	0	
13	160040018003072	8/1/2006	1	RT	1	0	1	272	1	1	0	0	
14													
15													
16													

Figure 29. Inspection Information Database with Information Retrievable by the Microstation Drawing.

GENERATING BRIDGE INSPECTION DATA MAPS USING MAPZAPPER AND ARCMAP

TxDOT's Materials and Pavements Section in the Construction Division developed a MS Access 2003® database application known as MapZapper. This application allows users to generate maps displaying Pavement Management Information System (PMIS) data such as condition scores and distress scores, traffic information such as ADT and percent trucks, and other related information. The application uses ESRI ArcMap^{TM} to generate the maps. Figure 30 shows the MapZapper main menu. Figure 31 shows the mapping options in MapZapper. Figure 32 shows an ArcMap^{TM} Window displaying a map of the Fort Worth District with pavement condition score ranges. Figure 33 is a map displayed in ArcMap^{TM} that is formatted to display the district name, the pavement condition score range legend, the map distance scale, and other information.
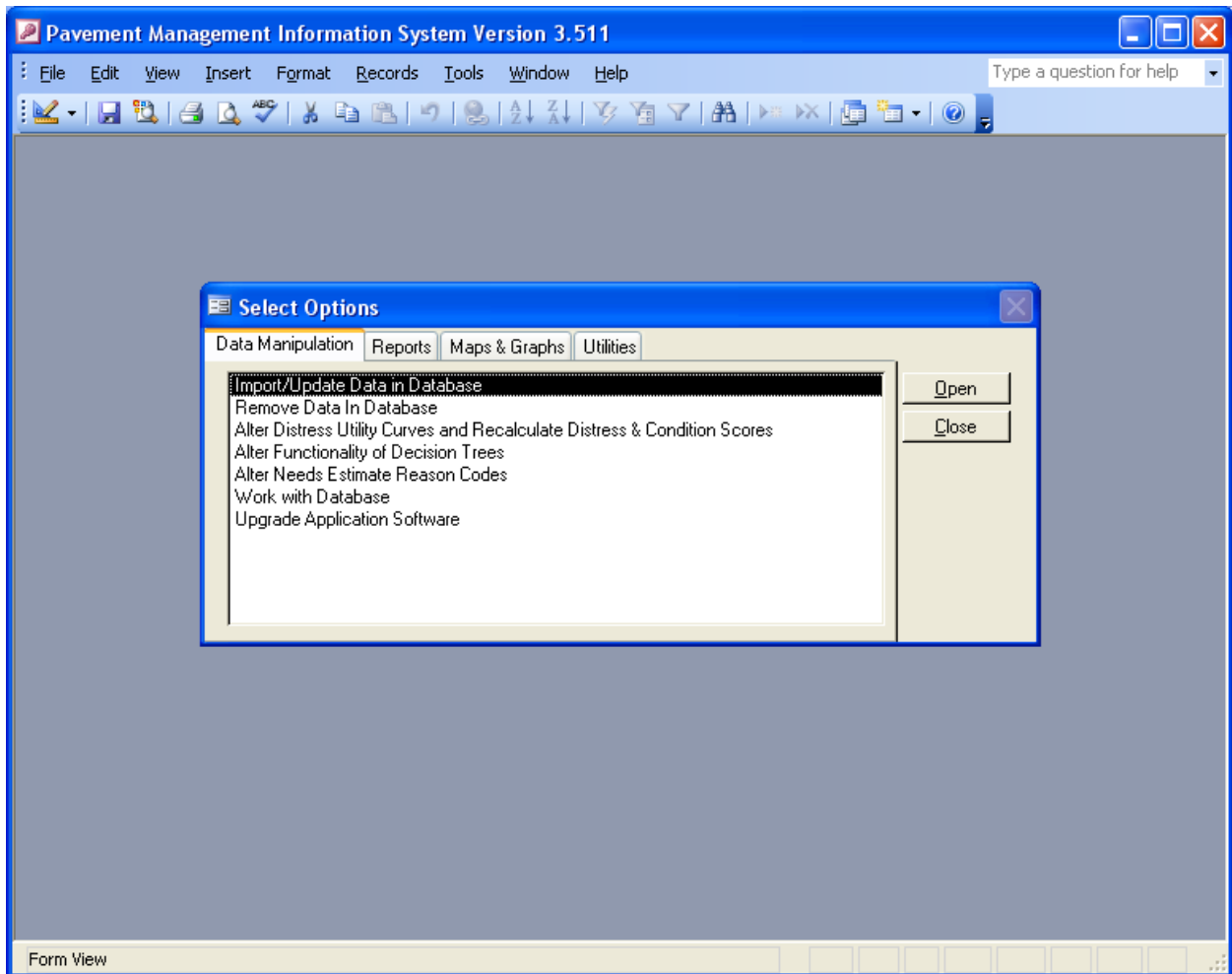
Figure 30. MapZapper Main Menu.
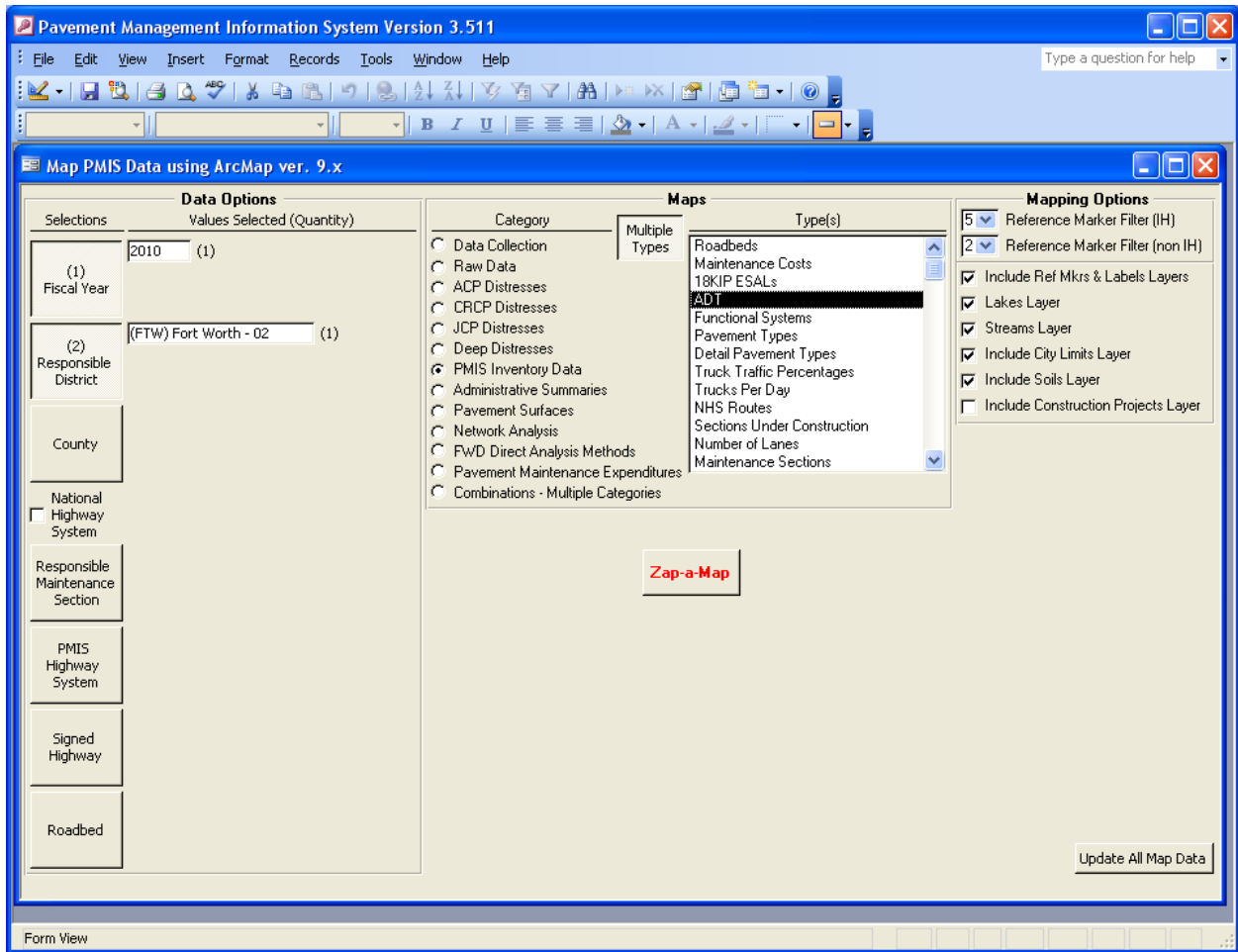
Figure 31. Mapping Options in MapZapper.
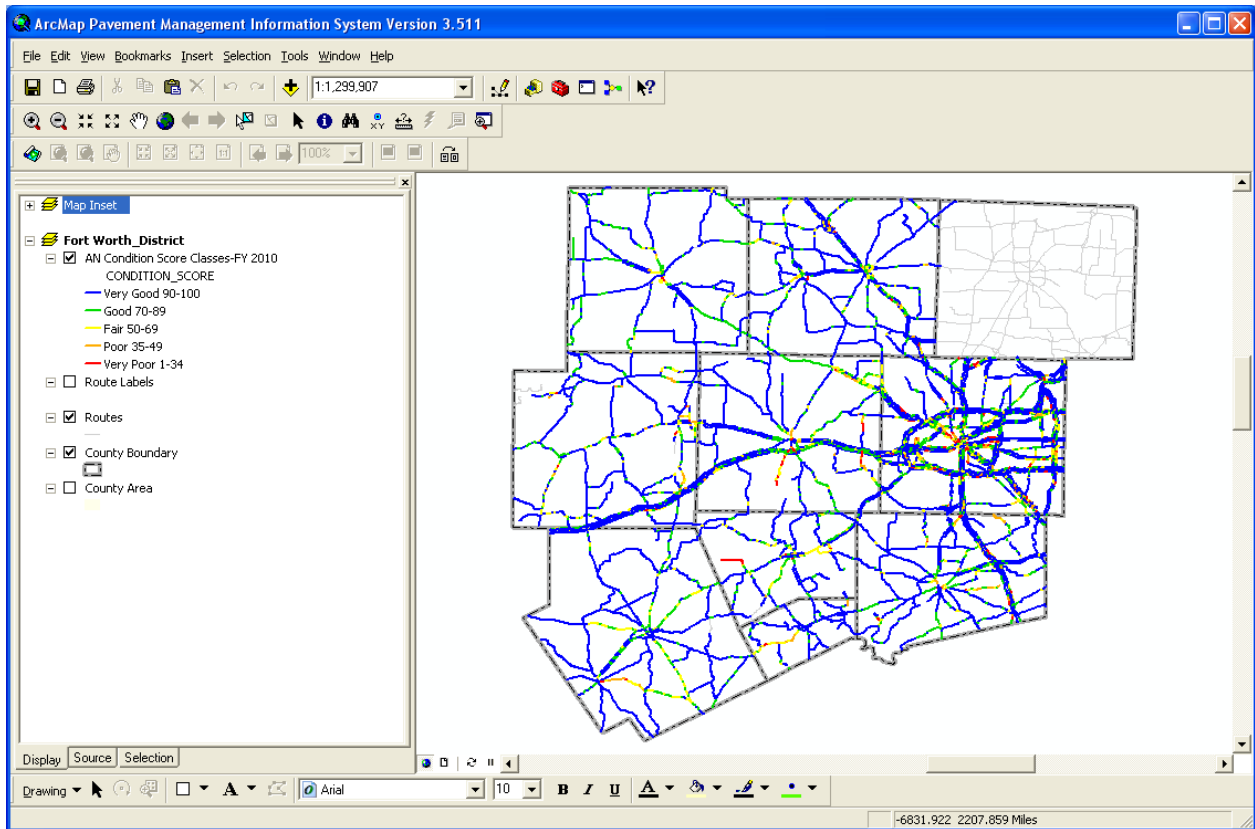
Figure 32. ArcMap[TM] Window Showing a Pavement Condition Score Map.
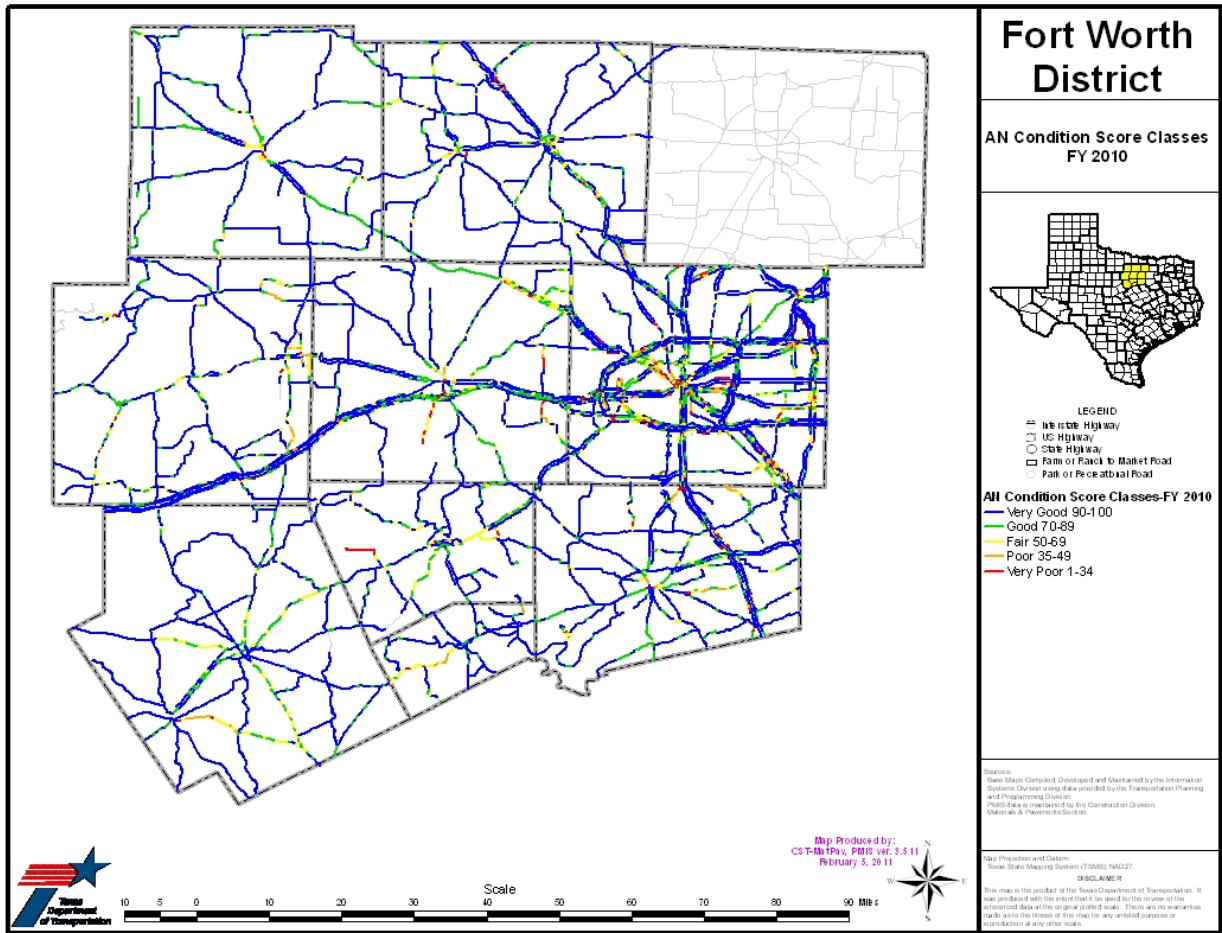
Figure 33. Pavement Condition Score Map Generated from ArcMap^{TM}.

This application can also be used to generate maps to display bridge inspection related information. Using the procedure outlined in Appendix B that uses MapZapper, ArcMap, and bridge inspection information in Dbase 4™ format, researchers generated the maps such as the one in Figure 34, which shows bridge locations where the superstructure rating was less than five. Figure 35 is another map showing the locations of all on system truss bridges.
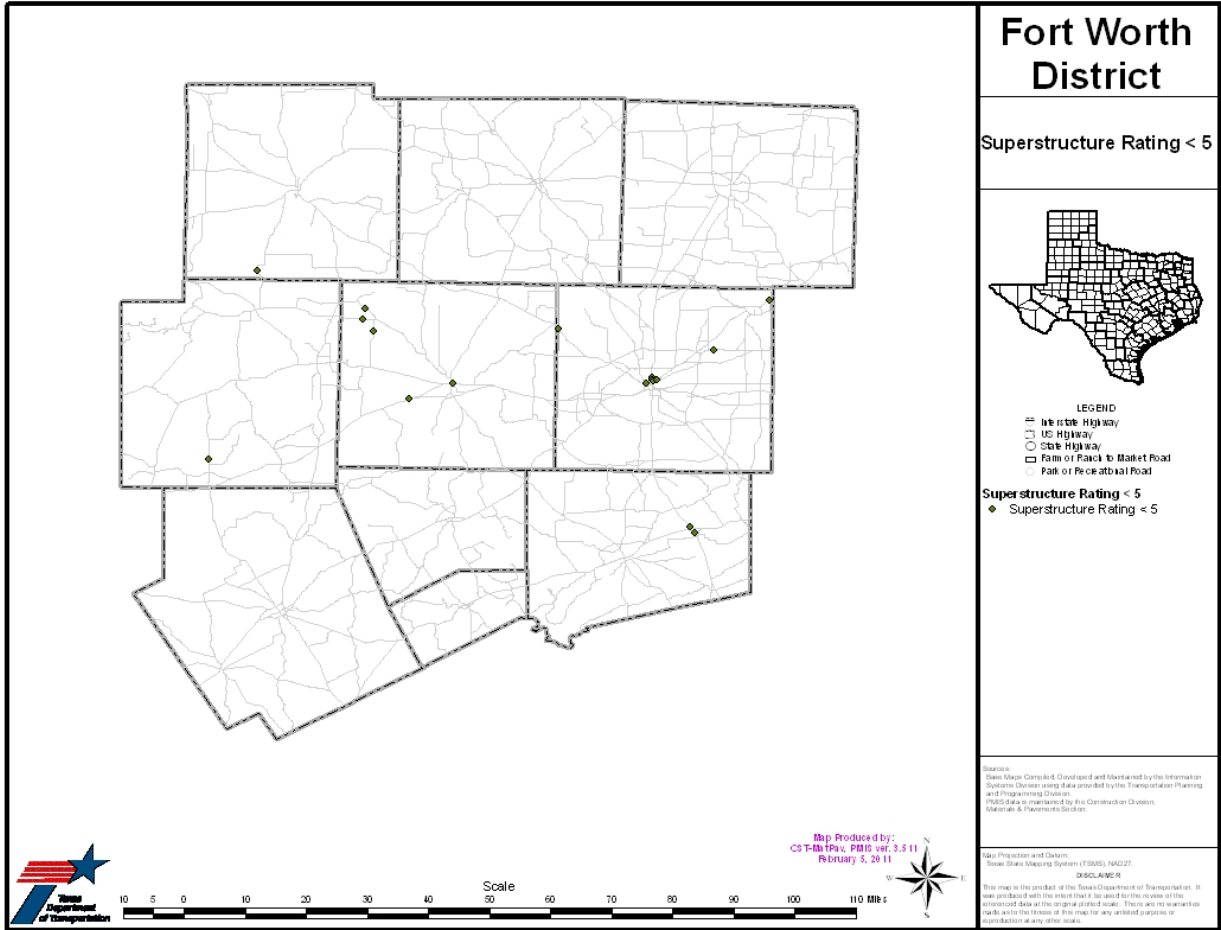
Figure 34. Map of Bridge Superstructure Rating Less than Five Generated from ArcMap^{TM} .
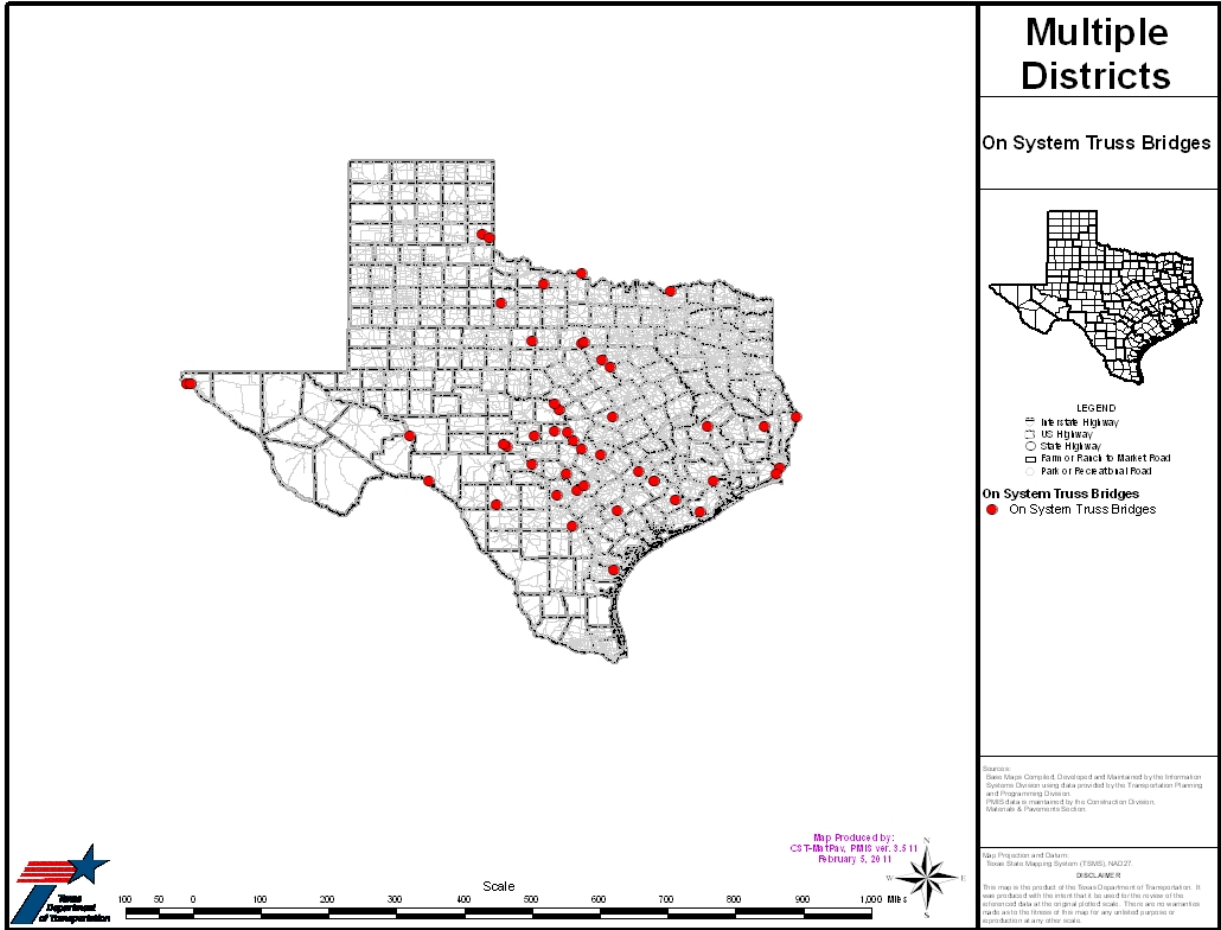
Figure 35. Map Showing Location of On System Truss Bridges.

ArcMap can also display a table of bridge inspection data for a particular bridge by clicking on a bridge location. Figure 36 shows one such example.
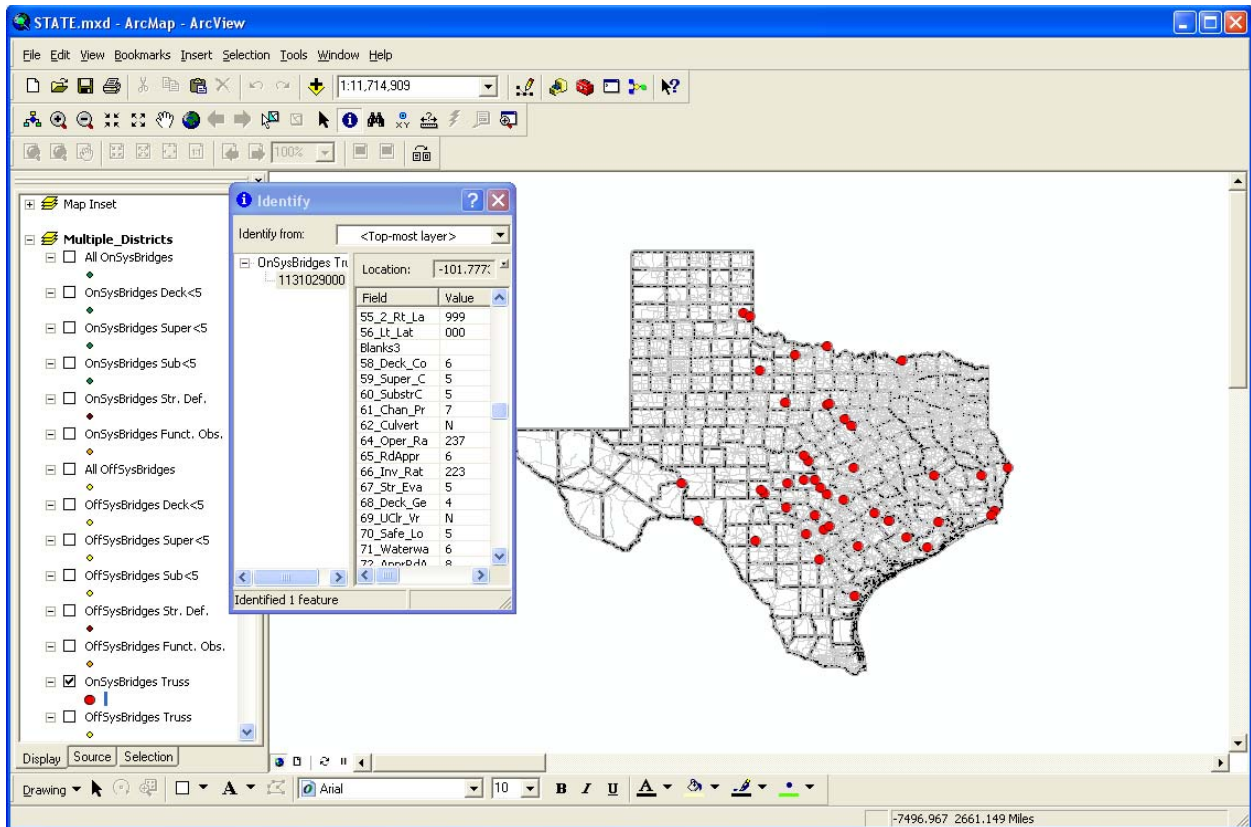
Figure 36. ArcMap™ Window Showing a Map of On System Truss Bridges and a Table of Bridge Inspection Data for One Bridge.

The researchers found that generating such maps using MapZapper and ArcMap was relatively easy to do. The mapping of bridge-related data could be incorporated into MapZapper; TxDOT personnel from the Bridge and Construction Divisions will need to discuss this possibility. However, TxDOT personnel can generate such maps now with current software.

RECOMMENDATIONS

- A customized web interface needs to be added to allow the user to search for specific bridge or bridges through different criteria such as: Structure ID, County, and other search criteria selected by the user. This feature will be particularly useful for TxDOT districts that have a high number of bridges making it difficult to locate specific bridges in the interactive map.

- All new bridges should be required to have MicroStation plans available that add information about elemental breakdown of the structure with dynamic database links to inspection history. These "smart" drawings would be particularly powerful in managing required maintenance and inspection information.

- Since it may take some time to implement the next release of Pontis, TxDOT personnel should consider using the TxDOT Mapzapper database application and ArcMap to display bridge inspection data and generate maps using these data.

CHAPTER 8. MODEL DEVELOPMENT AND RECOMMENDATIONS

INTRODUCTION

This chapter summarizes recommendations and recent developments in bridge management concepts and recommends BMIS modules for future development by TxDOT. A key NCHRP report summarizes theoretical concepts that will be implemented in future versions of Pontis. NCHRP Report 590 "Multi-Objective Optimization for Bridge Management Systems" (*43*) sets the stage for the implementation of multi-attribute decision making theory to the prioritization and optimization of bridge MR&R activities. The current routines embedded in the Pontis software are directed to a more complex analysis that involves optimization over a planning horizon.

The current Pontis optimization approach has come under criticism by Pontis users due to its implementation hurdles and data intensiveness coupled with a disconnection from day to day operations of bridge managers nationwide. This fact is documented in Chapter 5 of this report that points to a lack of implementation of Pontis for use in more sophisticated analysis such as optimization and prioritization. NCHRP Report 590 proposes a more simplified approach geared toward a single period analysis (current conditions) and suggests an approach to optimize the overall utility—a multi-attribute decision theory term discussed later in more detail in this chapter—for a single annual planning cycle.

TxDOT has pioneered multi-attribute decision theory implementation for bridge prioritization many years ago with the use of TEBSS (Texas Eligible Bridge Selection System) (*44*) that calculated a score based on the multi-attribute decision theory. The TxDOT and the NCHRP procedures will be compared and discussed during the chapter development. In addition, results from the analysis of historical elemental inspections are used to potentially support budget forecasting over multiple periods for the Texas bridge network. Recommendations for implementation of the several theoretical models presented are included at the end of the chapter.

MULTI-CRITERIA DECISION THEORY APPLIED TO BMS

Traditionally, decision makers in BMS have considered single criteria within their framework of analysis in order to solve prioritization problems. Recently, however, there has been a renewed awareness of the need to consider several criteria simultaneously when evaluating alternative bridge Maintenance Rehabilitation and Replacement (MR&R) projects as documented in NCHRP Report 590. A problem when selecting bridge projects for maintenance, rehabilitation, and replacement is the treatment of several criteria associated with each project. Furthermore the process is discrete in nature, since individual projects must be ranked. The decision maker concerned with the bridge project selection can find some useful analytical techniques in the field of multi-objective decision analysis. These techniques treat the bridge project selection process as a choice among a finite number of discrete project alternatives, which are evaluated using a common set of multiple criteria.

The solution described in this chapter and previously by references (*43, 44*) is to treat the problem through a weighted average technique (*45, 46*), applied whenever ranking of the

potential projects is needed. The weighted average technique calculates a priority index, with user-defined weights applied over several criteria for each potential project. The result of this weighted average technique is a score in a 0 to 100 scale, for each project, that measures the utility of the project for funding. A score of 100 means a high priority for funding and zero low priority. Equation 7.1 defines this weighted average technique, and is basically the same as equation 2-7 in NCHRP Report 590:

$$U_j \quad = \quad \sum_{i=1}^{n} w_i \, r_{ij} \tag{7.1}$$

Where:

$w_i =$ weight for the ith attribute,

$U_j =$ Utility or score for the jth project,

$r_{ij} =$ value of the ith attribute for the jth project, and

$n \ =$ number of attributes.

An issue when using a weighted average technique to evaluate utilities of competing projects centers on how to value the attributes—which are a numerical representation of the criteria—involved in the decision process, and the solution involves determining r_{ij} in Equation 1 for the different attributes involved in the decision process. Another issue is associated with estimating the weights, w_i, that summarize the relative importance of the attributes to the decision maker.

To apply the proposed weighted average technique, the attributes have to be scaled. The ideal way to perform this operation is to elicit the individual utility function for each attribute directly from the decision makers, as these are used in the management process. These utility functions reflect the decision maker's preference structure when choosing between different alternatives characterized by attributes. However, the numerical range of the attributes, combined with the number of projects involved in the decision process, makes this task cumbersome to accomplish in a consistent manner. Therefore, reference (*44*) proposed a modification to this basic technique which is termed attribute percentile scaling.

Percentile scaling is a statistically based methodology that scales the attributes involved in the decision-making process. As a simple example of this technique, the selection criteria is assumed to be based on one attribute, Average Daily Traffic (ADT), and applied to a data set comprising 200 projects. Table 51 shows a frequency distribution for the ADT attribute for this hypothetical bridge population. Percentile scaling, in the recommended approach, corresponds to the cumulative frequency of the attribute. This means that by choosing a project with an ADT of 9,000, this project is better than, or equal to, 80 percent of all projects in the ADT set. The percentile scaling numeric value is therefore a function of the numeric value of a particular attribute that measures the position of a project, as a better candidate for funding, relative to the rest of the projects in the set. In terms of multi-attribute decision theory, this assumes a linear

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value function based on the cumulative frequency of ADT. This approach can be extended to any other attributes involved in the decision process. In the implementation of this concept in bridge MR&R prioritization, the percentile scaling curve for the attribute ADT would look more like Figure 37. Figure 37 was generated using BRINSAP data and serves as a good surrogate for the attribute ADT utility function discussed in NCHRP Report 590 without going through the sometimes hard to implement elicitation process.

Table 51. Frequency Distribution for a Bridge Population Using the ADT Attribute.

ADT	Number of Projects	Cumulative Number of Projects	Frequency (Percent)	Cumulative Frequency (Percent)
800	60	60	30	30
2,500	40	100	20	50
5,500	40	140	20	70
9,000	20	160	10	80
14,000	20	180	10	90
50,000	20	200	10	100
Totals	200			100
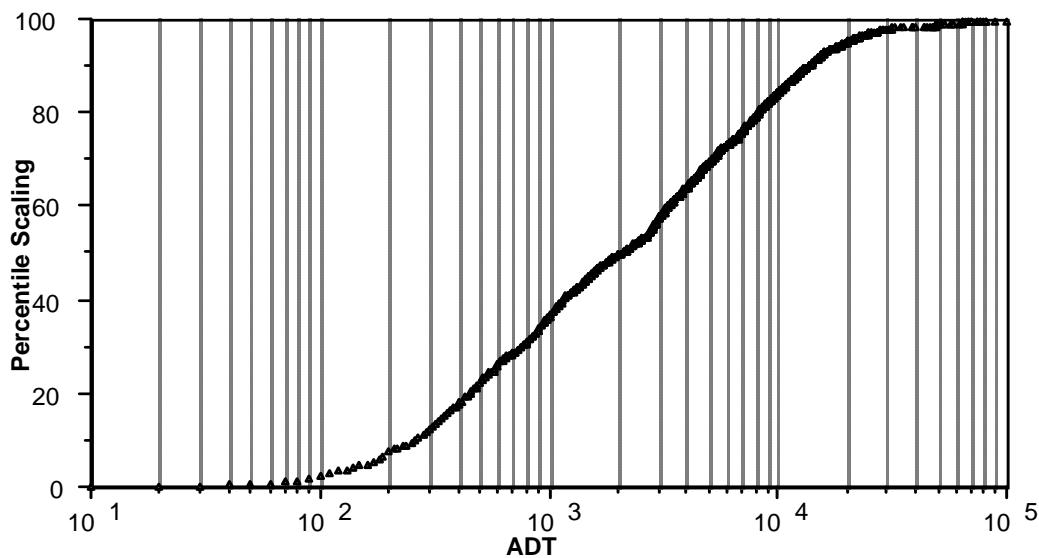
Figure 37. Percentile Scaling Curve for ADT.

Several methods are documented in the multi-objective decision theory literature to evaluate the weights in Equation 7.1. "Direct Weighting" is the simplest one, the one adopted by TEBSS, and also documented by NCHRP 590. In the direct weighting method, the decision maker assigns numerical values to weights in a direct manner. Examples of direct methods include the following:

- Ranking: Rank all the criteria in the order of decreasing importance.
- Categorization: Assign criteria to different categories of importance, each carrying a different weight.
- Point allocation: Allocate 100 points among criteria in proportion to their importance.

Examples of attributes used in the TEBSS system are:

- **ADT**. Average Daily Traffic over the structure. This measure rates the importance of the bridge relative to service provided to the vehicle users. If the bridge is posted or closed, users suffer immediate economic impacts leading to higher travel costs. Such impacts could include detouring, translating into longer travel time, and higher fuel and vehicle maintenance expenditures.
- **CPV.** Cost Per Vehicle, defined as the cost of the proposed project divided by the average daily traffic levels. This provides a measure of the cost effectiveness of the project.
- **DSS.** This attribute comprises a minimum of the Deck, Substructure, or Superstructure condition ratings. These ratings are zero to nine integer values, where zero represents a critical condition and nine represents a new condition.
- **SR.** The Sufficiency Rating index was created by FHWA staff and uses a zero to 100 scale, which reflects the ability of a structure to remain in service in its present condition.
- **BWR.** This is a Bridge Width Ratio, defined as the ratio between the existing roadway width and the standardized width. This attribute measures the geometric safety of the bridge.

NCHRP 590 lists several other attributes that could be used to rank and optimize BMS decisions. Tables 52 and 53 summarize the relative weights for the attributes listed in NCHRP 590. Table 52 lists the attributes for overall goals, and Table 53 details these attributes even further as Individual Performance Measures. Values for these weights and the identification of attributes were elicited during a two day work session with panel members for the project and are to be considered preliminary. During the same working session with the NCHRP panel, the researchers of NCHRP 590 also elicited utility functions that are documented in the report.

Table 52. Recommended Relative Weights: Overall Goals (*43*).

Overall Goal	Relative Weight
Bridge Preservation	0.360
Safety	0.205
Protection from Extreme Events	0.150
Agency Cost	0.175
User Cost	0.110
TOTAL	**1.000**

Table 53. Recommended Relative Weights: Individual Performance Measures (*43*).

Overall Goal	Performance Measure	Relative Weight	Total
Condition Preservation	NBI Ratings	0.271	
	Health Index	0.507	1.000
	Sufficiency Rating	0.222	
NBI Ratings	Deck	0.330	
	Superstructure	0.340	1.000
	Substructure	0.330	
Traffic Safety	Geometric Rating	0.570	1.000
	Inventory Rating	0.430	
Protection from Extreme Events	Scour	0.385	
	Fatigue	0.265	1.000
	Earthquake	0.205	
	Other	0.145	

Optimization in NCHRP 590

Optimization in NCHRP 90 is handled in a simpler way than in the current version of Pontis. The mathematical formulation is presented by Equation 7.2 for the single objective approach of optimizing MR&R activities under a single constraint like an annual budget. This is the case when the decision maker's objective is to determine the best possible candidate projects to be implemented to maximize the bridge network utility in terms of various performance measures and subject to a budget constraint. This network-level optimization problem can be formulated as the following integer programming problem:

$$\max \sum_{k=1}^{n} \sum_{j \in L_k} U_{jk} X_{jk}$$

$$s.t. \quad \sum_{k=1}^{n} \sum_{j \in L_k} AC_{jk} X_{jk} \leq B$$

$$\sum_{j \in L_k} X_{jk} = 1, \quad k = 1, 2, \dots . n$$

$$X_{jk} \in \{0, 1\} \quad k = 1, 2, \dots ., n, \; j \in L_k \qquad (7.2)$$

Where:

U_{jk} is the utility as calculated by equation 7.1 for the jth bridge in the network for intervention type k (interventions could range from do nothing to replacement of the bridge). X_{jk} is and integer variable that can assume zero or one values. If the optimization routine sets it to one, it means that intervention k is selected for bridge j to maximize the objective function.

The heuristic solution documented in NCHRP 590 treats the problem as a simple prioritization approach as was well documented in reference (*44*). This simplified solution treats the problem as an Incremental Utility-Cost (IUC) Ratio Heuristic simplifying the problem by using the mathematical formulation described in Equation 7.1 and treating the problem as a prioritization of the IUC of the alternatives with a cut-off list established by a set budget.

In TxDOT's case, it is recommended that this optimization/ranking approach be implemented two different ways at the state and district levels. At the state level, interventions should be limited to do nothing, rehabilitate and replace, and be applied to bridges eligible under the federal Highway Bridge Program (HBP). At the district level, the optimization routine should be implemented to prioritize regular maintenance activities as defined by established decision trees.

DECISION TREES

Decision trees are well documented in the Pontis/CoRe documentation. Figure 38 presents an example of decision tree for element 300—strip seal expansion. Figure 39 has another Pontis decision tree for Element. TSR stands for Total System Replacement and MR&R stands for Maintenance, Rehabilitation, or Replacement.

As may be observed in these figures, each element and condition state in the AASHTO CoRe Element Guide has a set of feasible MR&R actions defined for it. These same actions and their preservation models can be used, with the proper adaptation, in Texas. Decision trees are key elements in the development of analytical optimization/prioritization models at TxDOT.

The CoRe elements have a large number of defined MR&R actions, which is important for distinguishing the costs and effectiveness of actions. However, this can greatly complicate the use of a bridge-level decision-support tool by an engineer working at this level of detail where a

single intervention may contain 20–30 actions selected from 50–80 possibilities. To make the future implementation at TxDOT more user friendly, similar types of actions should be grouped together over multiple condition states and elements. This grouping will be essential for the feasible implementation of the CoRe/Pontis decision trees at the district level as part of the optimization/prioritization procedures described previously.

Element 300 - Strip Seal Expansion Joint			
State	Action	MRR Action Type	TSR Action Type
1	0 - Do nothing	Do nothing	
2	0 - Do nothing	Do nothing	
2	1 - Patch, reset, and clean	MRR expansion joints	
3	0 - Do nothing	Do nothing	
3	1 - Replace gland and/or patch	MRR expansion joints	
3	2 - Replace joint	MRR expansion joints	Bridge replacement Superstructure replacement Deck structure replacement Expansion joint replacement

Figure 38. CoRe/Pontis Decision Tree for Element 300 – Strip Seal Expansion Joint.

Element 107 - Painted Steel Girder			
State	Action	MRR Action Type	TSR Action Type
1	0 - Do nothing	Do nothing	
1	1 - Surface clean	Routine maintenance	
2	0 - Do nothing	Do nothing	
2	1 - Surface clean	MRR steel coating	
2	2- Clean and paint	MRR steel coating	
3	0 - Do nothing	Do nothing	
3	1 - Spot blast, clean and paint	MRR steel coating	
4	0 - Do nothing	Do nothing	
4	1 - Spot blast, clean and paint	MRR steel coating	
4	2 - Replace paint system	MRR steel coating	Steel coating replacement
5	0 - Do nothing	Do nothing	
5	1 - Rehab unit	MRR steel elements	
5	2 - Replace unit	MRR steel elements	Bridge replacement Superstructure replacement

Figure 39. CoRe/Pontis Decision Tree for Element 107 – Painted Steel Girder.

DETERIORATION MODELS BASED ON ELEMENT INSPECTIONS

TxDOT's Element Inspection and Coding Manual subdivides bridges into elements according to bridge element features and characteristics. The purpose of subdividing a bridge into elements is to be able to implement inspection results in a more streamlined manner supporting:
- Forecasts of bridge deterioration.
- Forecasts of costs for repair, rehabilitation, or replacement.

- Identification of alternative programs based on level of service or other criteria.
- Optimization of expenditure based on user and agency costs.
- Budget forecasts.
- Development of improvement programs.

A key element on accomplishing the listed objectives for the use of Elemental Bridge Inspections is the development of forecasts of bridge deterioration rates by element. Environmental factors, such as temperature, humidity, and traffic, affect the rate of deterioration of bridge elements and data analysis would need to be segmented to address these factors.

Previous studies focused on the prediction of bridge performance using overall inspection values specified by the NBI coding guide, which provides global ratings for items as deck, superstructure, and substructure. In this chapter, we propose methodologies for modeling the deterioration of individual elements of a bridge. These individual element deterioration curves will be key elements in the development of future BMIS modules that forecast bridge condition and optimize limited funding. Individual element deterioration curves will also be a key element in the prediction of overall bridge network condition as summarized by the Bridge Health Index (BHI).

The bridge health index is a single numerical rating of 0 (worst possible condition) to 100 (best condition) that reflects element inspection data in relation to the asset value of a bridge or network of bridges. The formulas for computation of the bridge health index are as follows (*49*):

$$\text{Health Index (HI)} = (\textstyle\sum \text{CEV} \div \sum \text{TEV}) \times 100 \qquad\qquad (7.4)$$

Where:
- Total Element Value (TEV) = Total element quantity × Failure cost of element (FC)
- Current Element Value (CEV) = $(\sum$ [Quantity in condition state i × WF(i)]) × FC

The condition state weighting factor (WF) is given by:
(WF) = 1 − [(Condition State# − 1) ÷ (State Count − 1)]

The BHI is a possible strong candidate to report performance goals and performance compliance for the Texas bridge network. This Index is a potential substitute for the "good or better approach" that TxDOT currently used to report bridge performance and compliance with set goals to the Texas Legislature and the public in general.

The BHI relies strongly on elemental inspection data and the ability to forecast future element conditions. A key element on any BMIS development is the establishment of element deterioration models to forecast bridge condition.

MARKOVIAN TRANSITION MATRICES

The current condition matrix for a given element can be represented by Equation 7.1, and the Markovian transition matrix for a specific element may be represented by Equation 7.5. Condition at any point in time is calculated using Equation (7.6):

S=[c1 c2 c3 c4]   (7.5)

Where:
  S: Current condition matrix.
  c1: Percentage of bridge element in condition 1.
  c2:Percentage of bridge element in condition 2.
  c3: Percentage of bridge element in condition 3.
  c4: Percentage of bridge element in condition 4.

  $P(i)=S*[p]^{i-1}$ (7.6)

Where:
  P(i): The age condition prediction, i is the age.
  [p]: The Transition matrix.

$$[p] = \begin{bmatrix} \rho1 & 1-\rho1 & 0 & 0 \\ 0 & \rho2 & 1-\rho2 & 0 \\ 0 & 0 & \rho3 & 1-\rho3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Each row represents the condition transition from one condition state to the other. The $\rho1$, $\rho2$, $\rho3$, and $\rho4$ are the transitional probability of each condition representing elements that would stay in the same condition from one period to the next. Consequently, 1-$\rho1$, 1-$\rho2$, 1-$\rho3$, and 1-$\rho4$ are the transition probabilities to the next condition state.

In the analysis process, we will use this method to forecast the future conditions by applying the transition matrix [p] to the first year conditions. In the process of estimating an appropriate transition matrix for the historical TxDOT data, we calculated the transitional probabilities manually using Excel and the Wolfram Mathematica package for each Makovian transition matrix for the sample elements presented later in this chapter.

A numerical example for a given hypothetical element is supplied as an example of the mechanics of the Markovian process.

If a bridge has 500 ft of a given element at age zero (new condition), and the Makovian transition matrix is:

Matrix p	Condition 1	Condition 2	Condition 3	Condition 4
Condition 1	9.940E-01	6.000E-03	0.000E+00	0.000E+00
Condition 2	0.000E+00	9.930E-01	7.000E-03	0.000E+00
Condition 3	0.000E+00	0.000E+00	9.760E-01	2.400E-02
Condition 4	0.000E+00	0.000E+00	0.000E+00	1.000E+00

At the beginning of the first year of deterioration the condition state would be P(i)=S*[p]

Where S is the initial condition (new no deterioration) represented by the following matrix:

Condition 1	Condition 2	Condition 3	Condition 4
1	0	0	0

The multiplication would result in the following forecast for the element condition after the first year:

Condition 1	Condition 2	Condition 3	Condition 4
0.99	0.01	0	0

Meaning that 1 percent of the element would have transitioned to Condition State 2 after one year. If the approach is extended to forecast the condition after 10 years by multiplying the transition matrix p the appropriate number of times, the resulting $[p]^{i-1}$ matrix would be:

Matrix p^{10}	Condition 1	Condition 2	Condition 3	Condition 4
Condition 1	0.94159435	0.056580061	0.001712208	0.00011338
Condition 2	0	0.93216434	0.060873447	0.006962213
Condition 3	0	0	0.784328826	0.215671174
Condition 4	0	0	0	1

And the resulting condition state after 10 years would be obtained by multiplying the S matrix (initial condition, new) by the last matrix p^{10} resulting in the following condition matrix P at age ten:

Condition 1	Condition 2	Condition 3	Condition 4
0.942	0.056	0.002	0

Meaning that at age 10, 94.2 percent of the element or 471 ft will be in condition state one, 5.6 percent of the element or 28 ft will be in condition two and 0.2 percent of the element or 1 ft will be in condition three.

Figure 40 presents graphically the plots of the predicted percentages in each condition state for this element. For any given age, as expected, the percentages add to 100 percent.
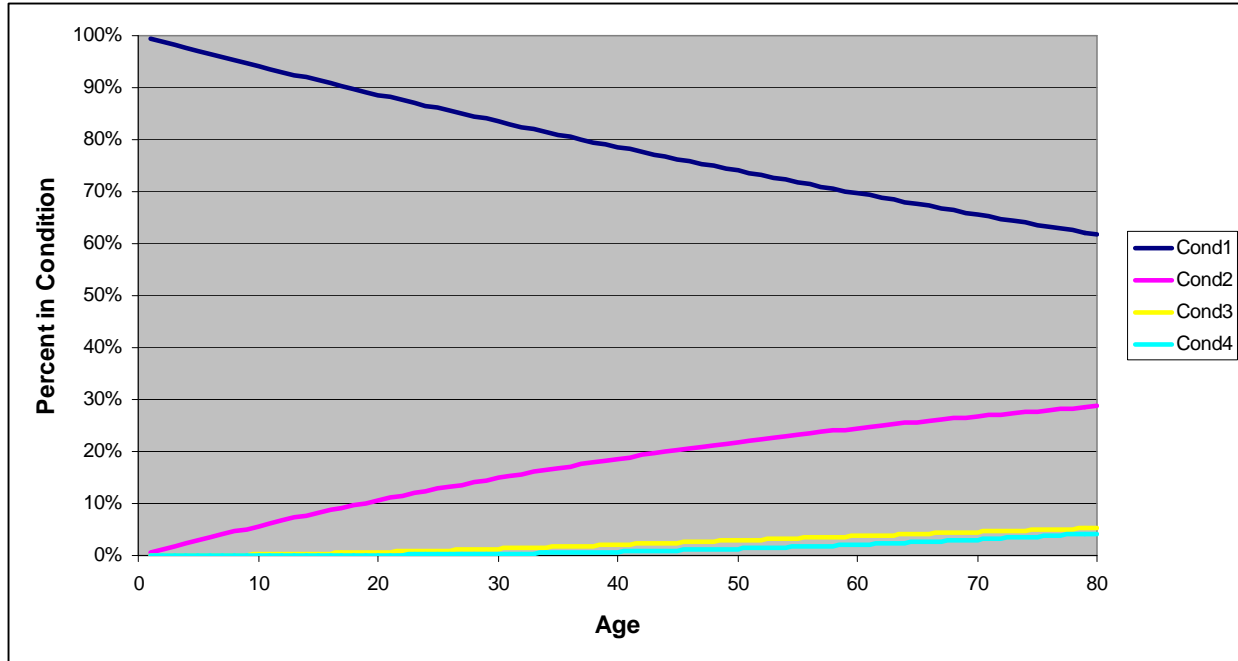
Figure 40. Example of Deterioration Curves Using Transition Probabilities Matrix.

TXDOT HISTORICAL ELEMENT INSPECTION DATA

Historical data for this effort were combined in an SAS data set to support the analysis. This data set encompasses data spanning from the year 2000 to 2009 and containing close to one million observations. This data set was assembled by merging historical element inspection data and BRINSAP data available at TxDOT. The first step in assembling the analysis data set was to incorporate the inventory information from BRINSAP in order to be able to calculate the bridge age. The next step was to calculate the total inventoried amount for a given bridge element in linear feet or square feet. The final step was then to calculate percentages of a given element that were in different condition states.

A sample of this data set is depicted by Figure 41. This sample includes the available historical data for Structure ID 150150007308260 with results of elemental inspections for years 2000, 2002, 2005, and 2006. Several elements were used to describe this specific structure and Figure 41 depicts the historical results of these inspections for elements 109, 164, 205, and 215, which are described in the element coding guide as Open Girder - Prestressed Concrete, Secondary Members - Painted Steel, Column or Pile Extension - Reinforced Concrete and Abutment - Reinforced Concrete, respectively. This specific bridge has not deteriorated based on the historical data available. This bridge may have possibly undergone some maintenance showing a reverse trend for element 205. Conditions remained at a condition one state for all elements. The data were treated further to calculate bridge age at the time of the inspection and also reduce the quantities measured to a percentage deteriorated variable as it may observed in Figure 41. Element 109 (Prestress Concrete Girder) has a total of 2,450 linear feet for this bridge. As may be observed for lines 508,332 through 508,335 of the data set sample depicted in Figure 41, the percentage in condition one, the pcond1 variable, remains at 100 percent for the

available historical data for this bridge, with 0 percent transitioning to the other four states. Element 205 (Column or Pile Extension - Reinforced Concrete) measured as a count (each) had 10 columns in condition one and two columns in condition two in inspection years 2000 and 2002. Unexpectedly, the condition for the columns improved in inspection years 2005 and 2006 with two columns that were in condition state two in 2000 and 2002 going back to a better condition of one. This could be explained by maintenance interventions or simple variability between inspectors and is expected in a massive inspection effort that deals with thousands of inspections on a yearly basis.

	brid	elemnum	cond1	cond2	cond3	cond4	cond5	yearinspec
508332	150150007308260	109	2450	0	0	0	0	2000
508333	150150007308260	109	2450	0	0	0	0	2002
508334	150150007308260	109	2450	0	0	0	0	2005
508335	150150007308260	109	2450	0	0	0	0	2006
508336	150150007308260	164	51	0	0	0	0	2000
508337	150150007308260	164	51	0	0	0	0	2002
508338	150150007308260	164	51	0	0	0	0	2005
508339	150150007308260	164	51	0	0	0	0	2006
508340	150150007308260	205	10	2	0	0	0	2000
508341	150150007308260	205	10	2	0	0	0	2002
508342	150150007308260	205	12	0	0	0	0	2005
508343	150150007308260	205	12	0	0	0	0	2006
508344	150150007308260	215	56	0	0	0	0	2000
508345	150150007308260	215	56	0	0	0	0	2002
508346	150150007308260	215	56	0	0	0	0	2005
508347	150150007308260	215	56	0	0	0	0	2006

	27 Yr Built	16 1 GPSLatitude	17 1 GPSLongitude	age	total	pcond1	pcond2	pcond3	pcond4	pcond5
508332	1983	2952454651	09848189716	17	2450	100	0	0	0	0
508333	1983	2952454651	09848189716	19	2450	100	0	0	0	0
508334	1983	2952454651	09848189716	22	2450	100	0	0	0	0
508335	1983	2952454651	09848189716	23	2450	100	0	0	0	0
508336	1983	2952454651	09848189716	17	51	100	0	0	0	0
508337	1983	2952454651	09848189716	19	51	100	0	0	0	0
508338	1983	2952454651	09848189716	22	51	100	0	0	0	0
508339	1983	2952454651	09848189716	23	51	100	0	0	0	0
508340	1983	2952454651	09848189716	17	12	83	17	0	0	0
508341	1983	2952454651	09848189716	19	12	83	17	0	0	0
508342	1983	2952454651	09848189716	22	12	100	0	0	0	0
508343	1983	2952454651	09848189716	23	12	100	0	0	0	0
508344	1983	2952454651	09848189716	17	56	100	0	0	0	0
508345	1983	2952454651	09848189716	19	56	100	0	0	0	0
508346	1983	2952454651	09848189716	22	56	100	0	0	0	0
508347	1983	2952454651	09848189716	23	56	100	0	0	0	0

Figure 41. Sample Historical Element Inspection Data.

EXAMPLE OF DEVELOPMENT OF MARKOVIAN TRANSITION MATRIX FOR ELEMENT 107 STEEL GIRDER, RIVETED OR ROLLED BEAM - PAINTED STEEL

The data for element 107 was extracted from the historical data set described previously; resulting in 8,395 observations distributed over different ages and condition states. Information was aggregated by age by adding the amount of linear feet in each of the condition states for a given age. The percentage in each condition state was then calculated.

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A sample of the resulting data set is presented in Figure 42. At age 7, the data set for Element 107 has 22 bridges amounting to 145,216 linear feet of steel girders. From this overall quantity, 145,164 ft are in condition state one leading to an expectation that a bridge with steel girders at age seven should present 99.96 percent of its girders in condition state one. Using the same rationale, the remaining linear feet of steel girders in the remaining condition states should add up to 0.04 percent. The historical values using this process for Element 107 are charted and presented in Figure 43 for the evolution of condition state one. Similar charts can be plotted for condition states two, three, four, and five. However, as the revised CoRe Bridge Inspection Manual had addressed, elements almost never get to condition five without intervention by agencies responsible for bridge maintenance and the revised manual only recognizes condition states up to four (*5*). Figure 43 shows that the trend for the percentage of a steel girder bridge in Texas that remains in condition one is what would be expected for the behavior of this type of structure. However, there are some fluctuations throughout the span of 80 years (Figure 43) that may be caused by maintenance and varied environmental conditions throughout the state of Texas. These fluctuations suggest that any future implementation of these concepts in a comprehensive BMIS for Texas should address climatic and other factors by segmenting the data for analysis accordingly. Similar charts may be plotted for condition states two through five using the same approach described previously.

age	COUNT	totals	cond1s	cond2s	cond3s	cond4s	cond5s	pcond1	pcond2	pcond3	pcond4	pcond5
7	22	145,216	145,164	50	2	0	0	0.99964	0.00034	0.00001	0	0
8	36	153,990	150,073	959	2,958	0	0	0.97456	0.00623	0.01921	0	0
9	13	28,532	28,153	379	-	0	0	0.98672	0.01328	0	0	0
10	37	119,098	115,415	2,032	1,651	0	0	0.96908	0.01706	0.01386	0	0
11	19	74,724	68,855	3,128	2,741	0	0	0.92146	0.04186	0.03668	0	0
12	33	132,380	125,047	6,751	582	0	0	0.94461	0.051	0.0044	0	0
13	31	101,021	94,055	5,996	970	0	0	0.93104	0.05935	0.0096	0	0
14	26	85,274	73,502	11,058	562	0	152	0.86195	0.12968	0.00659	0	0.001782
15	33	75,341	61,345	13,480	516	0	0	0.81423	0.17892	0.00685	0	0
16	19	70,098	58,357	10,868	721	0	152	0.83251	0.15504	0.01029	0	0.002168

Figure 42. Resulting Data Set Sample for Historical Condition State Data for Element 109.

The next step was to adjust a Markovian transition matrix for element 107. Several authors in areas unrelated to bridge management have published routines to fit Markovian transition matrices to observed data (*48*). For this application of Markovian processes, the adjustment of the transition probabilities was performed manually. Future implementation of this approach needs to be automated, but this is outside of the scope of this research project.

Manual adjustment of the Markovian transition matrix was done interactively using the software package Wolfram Mathematica, which has strong support for matrix operations such as power and multiplication of matrices. After several manual iterations, an acceptable transition matrix for element 107 was identified and is presented in Table 54.
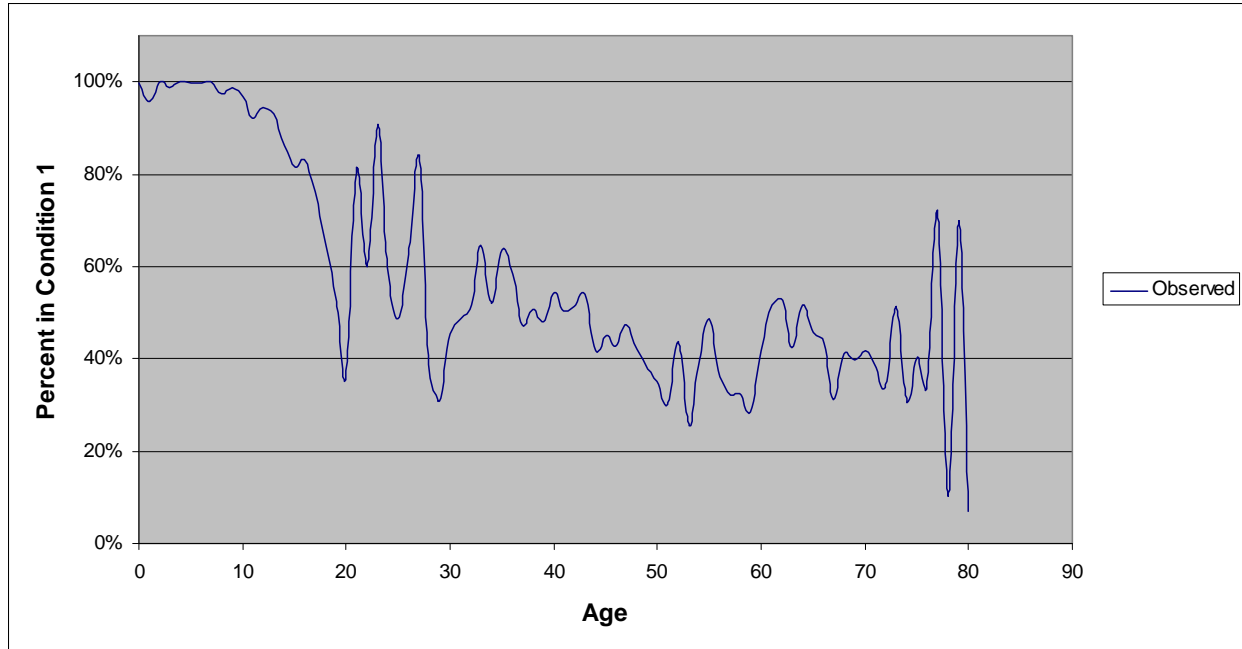
Figure 43. Evolution of Percentage of Element in Condition 1 for Element 107.

Table 54. Markov Transition Probability Matrix for Element 107.

	Condition 1	Condition 2	Condition 3	Condition 4
Condition 1	0.98	0.02	0	0
Condition 2	0	0.98	0.02	0
Condition 3	0	0	0.997	0.003
Condition 4	0	0	0	1

The results of the Markovian modeling approach and the observed data for element 107 are presented in Figures 44, 45, 46, and 47 for the transitions of condition one through four, respectively. Considering the variability observed in the actual data, the effectiveness of the Markovian model to represent the condition states at a given age for element 107 seems defensible. As an example of use of these curves, the fitted model states that at age 60 years, 41.7 percent of a bridge steel girder will be in condition one, with the remaining 58.3 percent having transitioned to conditions two, three, and four. In addition, the 58.3 percent are broken down in 36.4 percent in condition two, 21.7 percent in condition three, and 0.2 percent in condition four.

A similar analysis was carried out for element 109 (Open Girder - Prestressed Concrete) and shows that these type of elements present almost negligible deterioration with almost no migration from condition state one to the other condition states as shown by the data plotted in Figure 48.
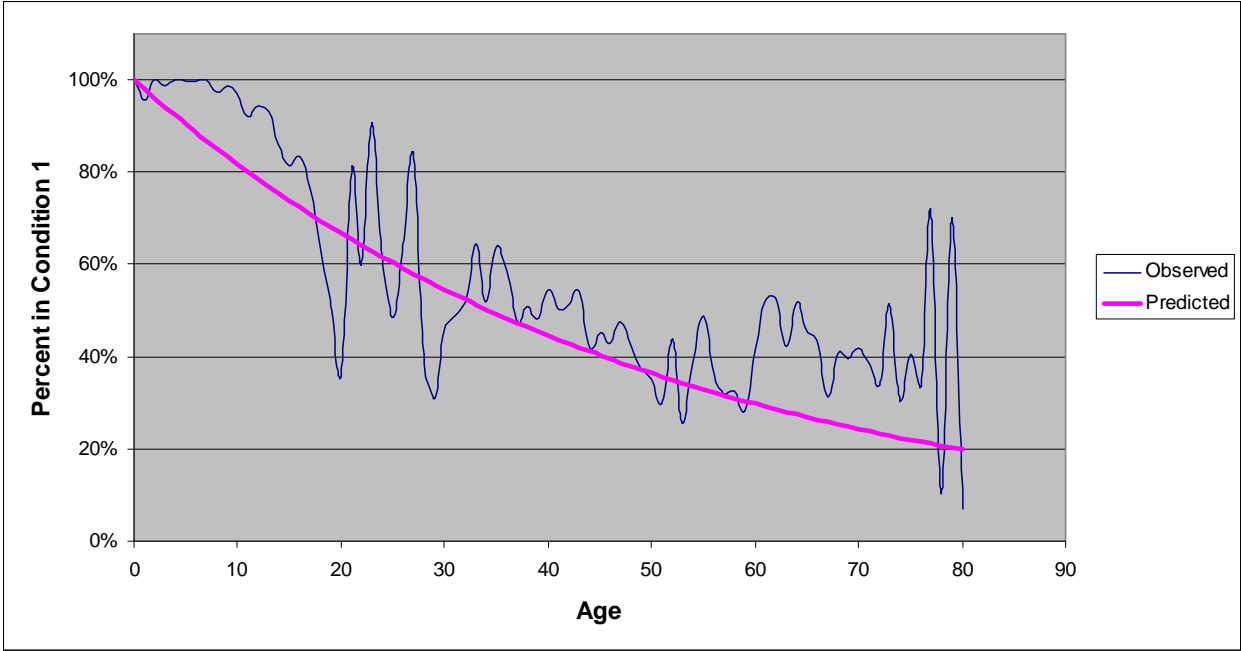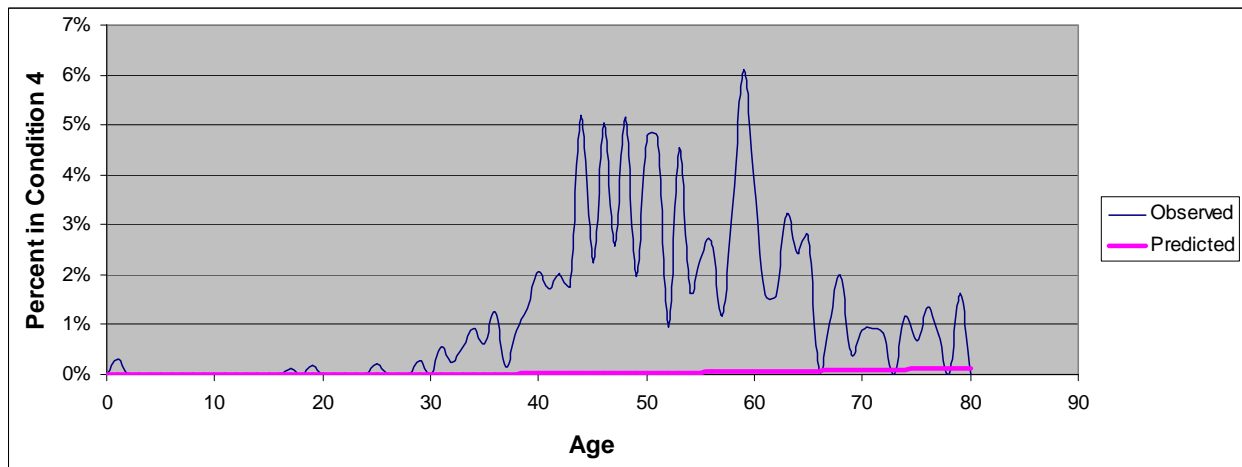
Figure 44. Markovian Deterioration Curve for Condition One for Element 107.
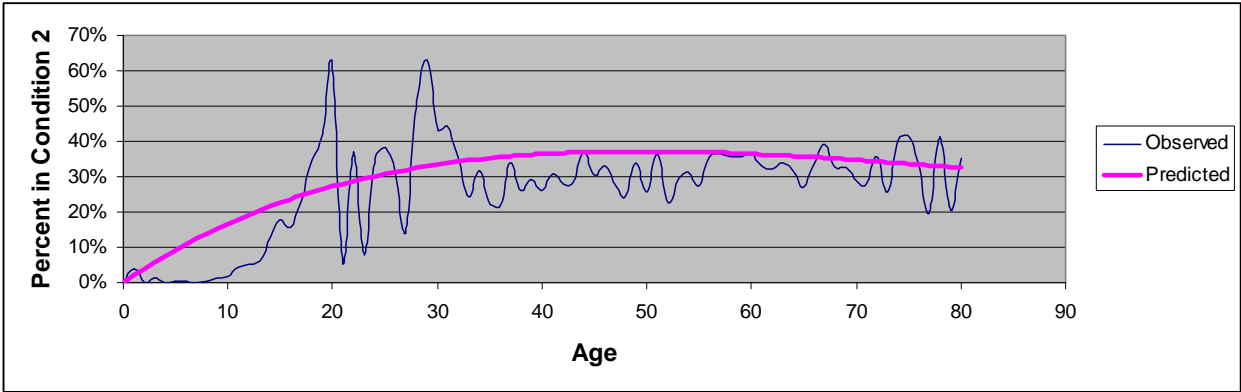
Figure 45. Markovian Deterioration Curve for Condition Two for Element 107.
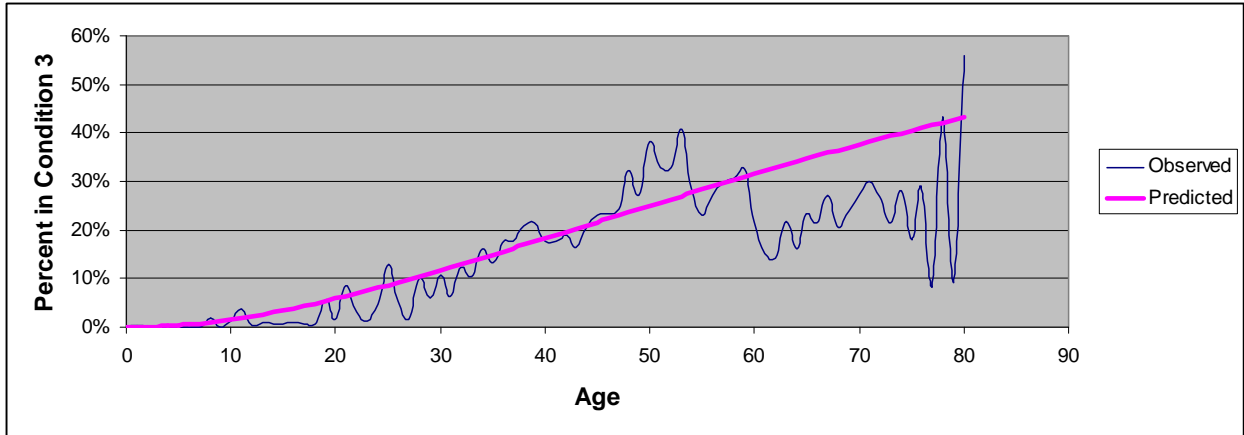
Figure 46. Markovian Deterioration Curve for Condition One for Element 107.
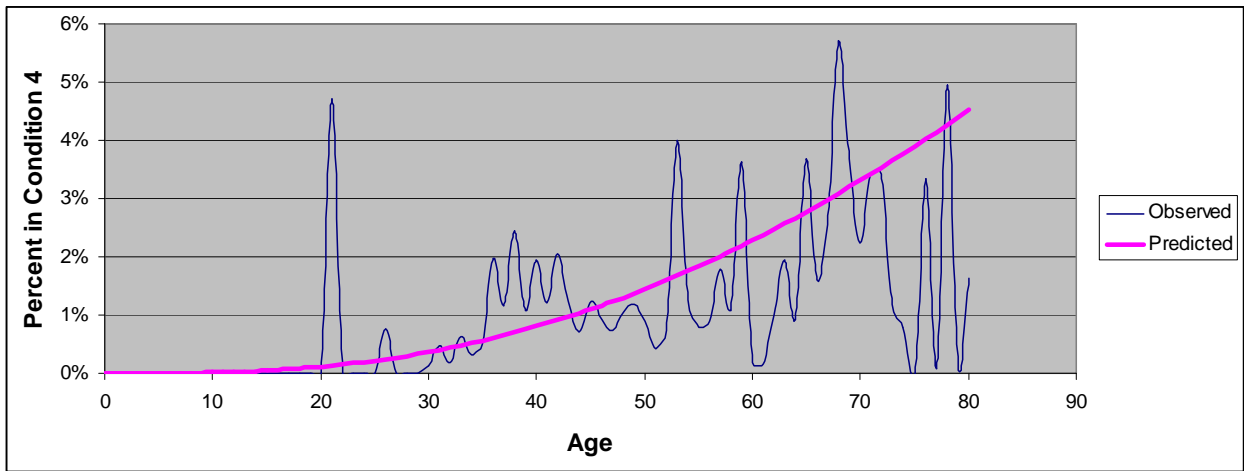
Figure 47. Markovian Deterioration Curve for Condition One for Element 107.
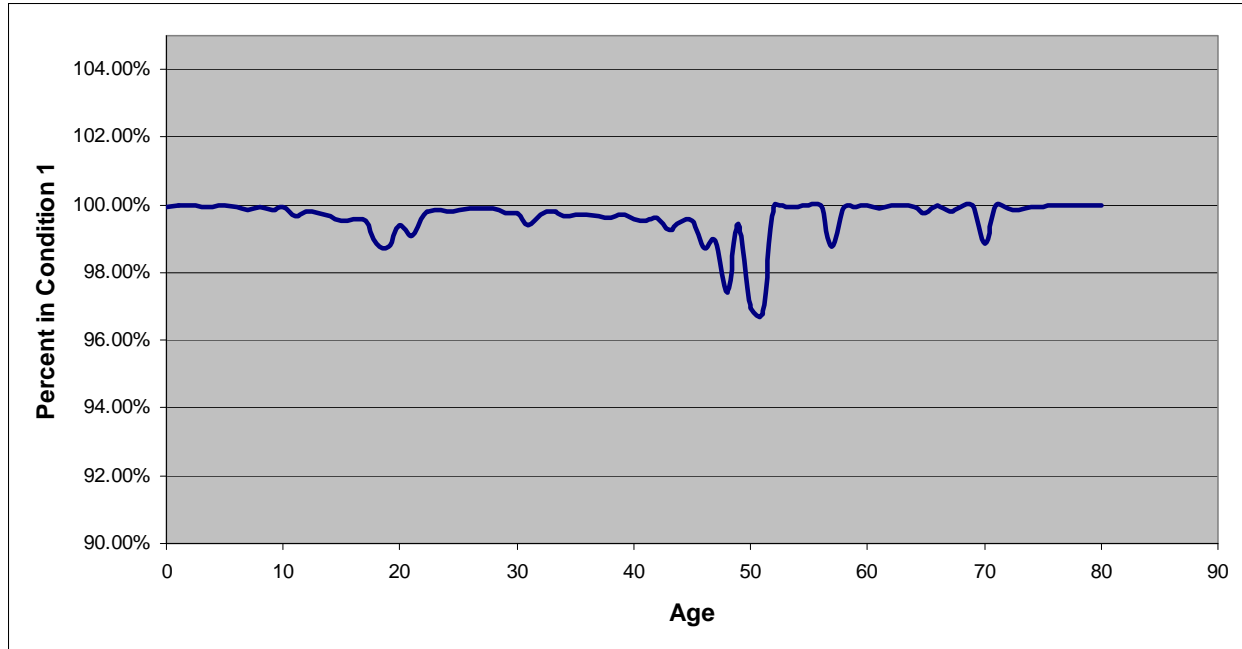
Figure 48. Deterioration Curve for Condition One for Element 109.

EXAMPLE OF DEVELOPMENT OF MARKOVIAN TRANSITION MATRIX FOR ELEMENT 12 REINFORCED CONCRETE DECK

Following a similar methodology as for element 107 and after several manual iterations, an acceptable transition matrix for element 12 was identified and is presented in Table 55. The calculations are different than the ones carried out for element 107, since conditions for element 12 (Reinforced Concrete Deck) are reported in count instead of linear feet and results may be only extended to support statements of condition state for the whole network as a function of bridge age and not for individual bridges. Figures 49 through 52 summarize the analysis carried out for element 12.

The following statement clarifies the type of analysis supported by this type of models. At age 60 years, for the whole network of bridges, 54.7 percent of the decks would be in condition state one, 43.8 of the decks would be in condition state two, 1.4 percent of the decks would be in condition state three, and 0.1 percent would be in condition state four. These models would be useful to forecast deck condition at the network level to forecast deck MR&R funds.

The analysis could be further improved by adjusting a Markovian transition matrix based on deck area age distribution across the different condition states instead of using counts.

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Table 55. Markov Transition Probability Matrix for Element 12.

	Condition 1	Condition 2	Condition 3	Condition 4
Condition 1	0.99	0.01	0	0
Condition 2	0	0.98	0.02	0
Condition 3	0	0	0.997	0.003
Condition 4	0	0	0	1
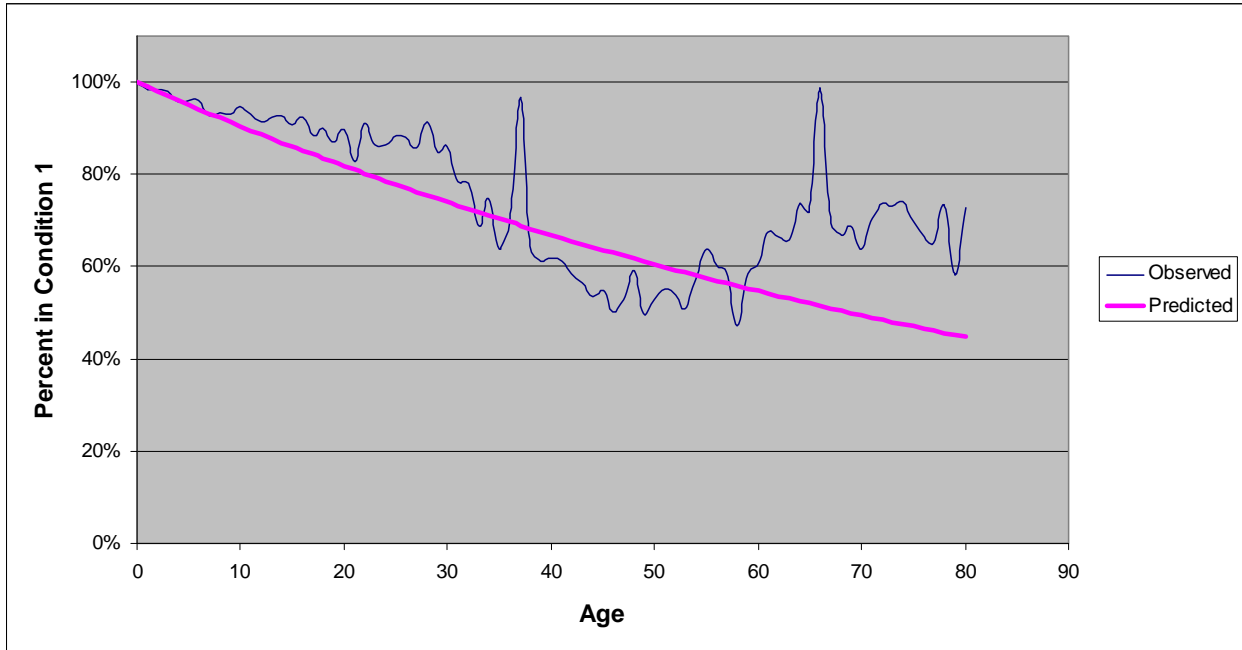
Figure 49. Markovian Deterioration Curve for Condition One for Element 12.
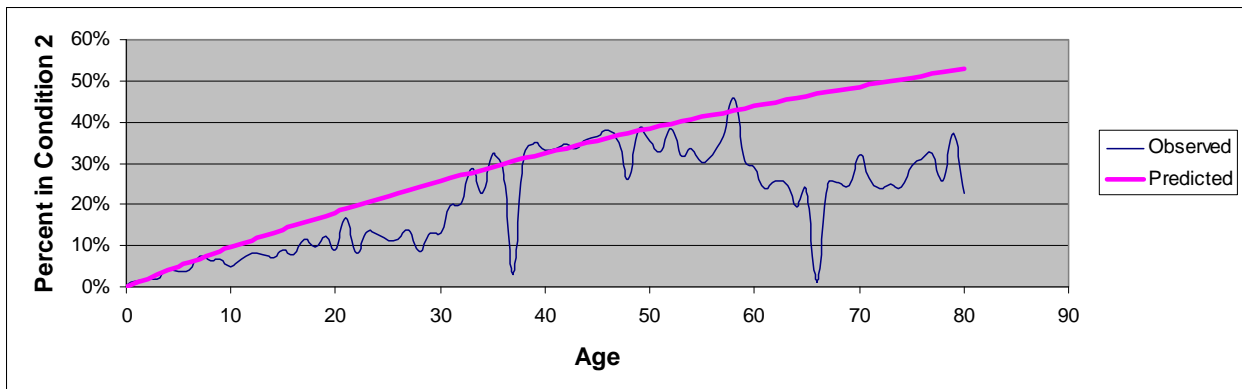
Figure 50. Markovian Deterioration Curve for Condition Two for Element 12.
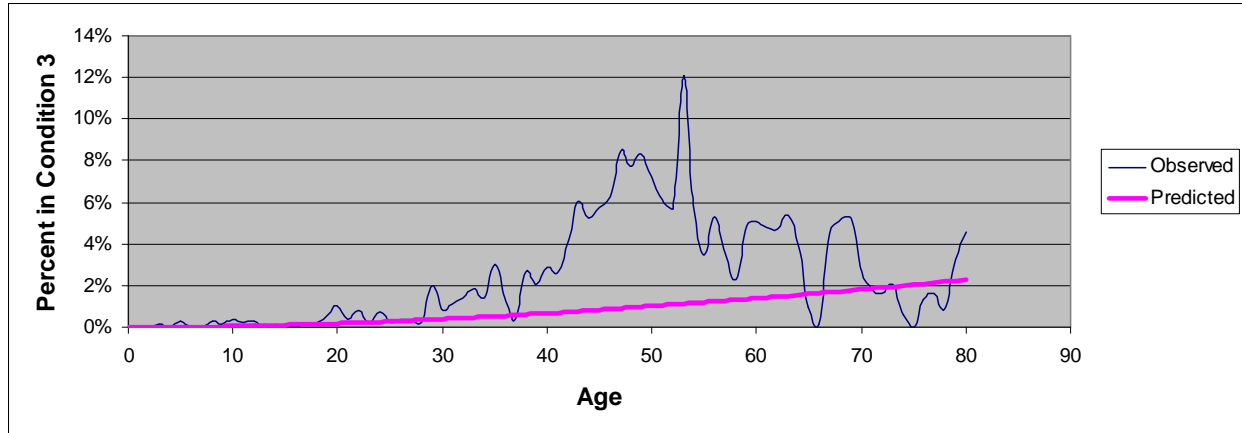
Figure 51. Markovian Deterioration Curve for Condition Three for Element 12.

Figure 52. Markovian Deterioration Curve for Condition Four for Element 12.

RECOMMENDATIONS

The researchers have the following recommendations:

1. Update TEBSS at the state and district levels to incorporate the multi-objective project ranking/optimization approach documented in NCHRP 590.

2. Revise the decision trees documented in CoRe/Pontis to conform to maintenance activities currently used in Texas introducing the capability of grouping maintenance activities for several elements in one job. Assume, for example, that a bridge has painted steel girders, floor beams, stringers, and bearings, all at various levels of deterioration. With enough extent of total deterioration. The District Engineer would want the decision tree models to generate a total paint system replacement option, which automatically assigns the appropriate MR&R action (with appropriate costs) for each condition state of each steel element.

3. Develop Markovian transition matrices based on the available historical data for elemental inspections in Texas for all relevant elements that could drive bridge performance measures such as the BHI. Implement the developed Markovian bridge deterioration models in a system to forecast bridge needs. A reliable system to forecast bridge needs and condition is in constant demand to answer questions from the Texas Legislature about future impacts on the Texas bridge infrastructure due to restricted funding scenarios. Computerize the process of updating the matrices using established statistical procedures.

4. Develop a computerized module to streamline the analysis of the impacts of changes in truck size and weight regulations as documented in reference (*50*).

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This chapter contains conclusions and recommendations resulting from this research study. As mentioned in Chapter 6 of this report, TxDOT anticipates implementing the next release of Pontis; however, the research team is not familiar with this release since it was not available during the time period of this research project. Originally, the team planned to generate recommendations for a modular approach to BMIS development activities and for linking available data sources into a single database or system. The recommendations in this chapter are now oriented toward what TxDOT personnel should consider when implementing Pontis and also includes recommendations for possible customization of Pontis to TxDOT needs with additional BMIS modules.

CONCLUSIONS

In general, the researchers found that the Design and Construction Information System (DCIS), the Bridge Inventory, Inspection, and Appraisal System (BRINSAP), Pontis, PonTex, and BridgeLog information systems provide core data for bridge infrastructure management. Other systems, notably, the Maintenance Management Information System (MMIS), Main Street Texas (MST), and the Financial Information Management System (FIMS), provide supplemental or supporting data for bridge infrastructure management. However, districts may need information such as bridge plans and detailed inspection information that is not currently available from these sources.

Researchers successfully developed a short-term BMIS architecture, with a proof-of-concept prototype, which links bridge-related data sources at TxDOT that enables the production of queries and reports needed for various analytical purposes. The proof-of-concept prototype allows extraction of summary bridge statistics and data for producing bridge cost estimates and related quality control checks.

Researchers found that Pontis, which is the main bridge management software developed by AASHTO for the FHWA, is used by several states but mostly implemented at the database level (i.e., storing National Bridge Inventory and element level data), with more sophisticated tools such as forecasting having lower levels of implementation. Sixteen states are not using Pontis at all.

Researchers reviewed NCHRP Synthesis 397, Bridge Management Systems for Transportation Agency Decision Making (Transportation Research Board, Washington D.C., 2009); the authors of that synthesis conducted a survey of the states. The planning component of the survey asked whether particular features of the agency's BMS were used to support the planning process. A total of 17 agencies responded to this question. About 30 percent to 40 percent of respondents reported using their Bridge Management System (BMS) for higher-level management functions, including budgeting, scenario testing, trade-off analyses, generating quantifiable parameters to provide guidance in project selection, and documenting past and planned bridge projects by political jurisdiction. Fewer than 10 percent of the respondents used their BMS for economic

analyses—that is, for life cycle cost (LCC) analysis or computation of avoidable user costs as a function of alternative budget scenarios. These results show that as the level of complexity of BMS modeling increases, such as with the use of LCC analysis, the level of implementation decreases.

From discussions with TxDOT personnel in the Bridge Division and six districts, the researchers concluded that the following need to be included in TxDOT's BMIS:

- Inventory system with elemental descriptions in graphical format.
- Mechanisms for districts to interact with the system (possibly a revision to PonTex). The system would allow districts to update cost and inspection information.
- Bridge project prioritization scheme that is easy to understand and is easy for TxDOT to incorporate.
- Budget forecasting system.
- Additional database attributes and multimedia capabilities.
- Additional functions to store, enter, query, report, and track attributes and multimedia from these databases.
- More effective coordination and integration between information systems.
- Mechanisms to streamline production of reports.
- Coordination with bridge owners and entities responsible for maintenance.

One major benefit of adopting a BMIS is the drastically reduced time needed for users to obtain information to make appropriate decisions relating to bridge inspection, design, construction, maintenance, and project programming activities. For example, the proof-of-concept prototype developed under the study reduced the time needed from a matter of weeks to a matter of minutes for extraction of summary bridge statistics and data for producing bridge cost estimates.

RECOMMENDATIONS

TxDOT personnel should determine if the next release of Pontis can address the user and data needs documented in Chapter 6 of this report.

TxDOT personnel should determine if Pontis has the capability of linking the available data sources identified in Chapter 2. If it cannot, TxDOT personnel should consider further developing the prototype database application described in Chapters 3 and 4 so that it can provide needed information to Pontis.

As stated in Chapter 7, a customized web interface needs to be added to allow the user to search for specific bridge or bridges through different criteria such as: Structure ID, County, and other search criteria selected by the user. This feature will be particularly useful for TxDOT districts that have a high number of bridges making it difficult to locate specific bridges in the interactive map.

All new bridges should be required to have Microstation plans available that add information about elemental breakdown of the structure with dynamic database links to inspection history. These "smart" drawings would be particularly powerful in managing required maintenance and inspection information. Since it may take some time to implement the next release of Pontis,

TxDOT personnel should consider using the TxDOT MapZapper database application and ArcMap to display bridge inspection data and generate maps using this data.

As stated in Chapter 8, the researchers recommend updating TEBSS at the state and district levels to incorporate the multi-objective project ranking/optimization approach documented in NCHRP 590.

Also as indicated in Chapter 8, the researchers recommend revising the decision trees documented in CoRe/Pontis to conform to maintenance activities currently used in Texas introducing the capability of grouping maintenance activities for several elements in one job. Assume, for example, that a bridge has painted steel girders, floor beams, stringers, and bearings all at various levels of deterioration. With enough extent of total deterioration. the District Engineer would want the decision tree models to generate a total paint system replacement option, which automatically assigns the appropriate MR&R action (with appropriate costs) for each condition state of each steel element.

The researchers also recommend in Chapter 8 to develop Markovian transition matrices based on the available historical data for elemental inspections in Texas for all relevant elements that could drive bridge performance measures such as the Bridge Health Index (BHI). Implement the developed Markovian bridge deterioration models in a system to forecast bridge needs. A reliable system to forecast bridge needs and condition is in constant demand to answer questions from the Texas Legislature about future impacts on the Texas bridge infrastructure due to restricted funding scenarios. Computerize the process of updating the matrices using established statistical procedures. Develop a computerized module to streamline the analysis of the impacts of changes in truck size and weight regulations.

The team believes that the TxDOT BMIS should include the following four modules. TxDOT personnel will need to determine if the next release of Pontis can incorporate such modules:

- State Level Prioritization Module. This module will include the prioritization techniques described in Chapter 8 and will be targeted for prioritization of federally funded HBP projects statewide. To reflect TxDOT's long-range policy, development of this module will have to go through a definition of attributes to define priorities and compliance with long-term goals such as existing TxDOT goals like percentage of bridges in good or better condition, or any future defined goals such as Bridge Health Index targets for the network.
- State Level Budget and Performance Forecasting Module. This module will allow the user to forecast overall bridge network conditions under different budget scenarios and compare these conditions with established performance targets. This module would be particularly useful in providing answers to legislators' requests on bridge network performance under different funding availability scenarios.
- District Oriented BMIS module. This module would streamline day-to-day operations at the district, allowing expedited information handling that goes beyond what is currently available in PonTex. A good starting point to illustrate this module is the system currently in use by the Fort Worth District, which allows the user to store information like plans, forms, and pictures of the bridge inventory. Improvements to this system will

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include the addition of geo-referenced information in a graphical user interface and improved ways of scheduling and prioritizing regular maintenance.

- District Prioritization Module. The researchers envision this module to be oriented toward the prioritization of regular maintenance funds available at the district level. This system would incorporate revised decision trees and prioritization techniques based on elemental inspections that are based on the concepts discussed in Chapter 8.

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APPENDICES

APPENDIX A. DOCUMENTS USED IN PRESENTATIONS TO TXDOT PERSONNEL

PROPOSED TXDOT BMIS

INTRODUCTION

The proposed TxDOT BMIS should include the following:
- An inventory system with elemental descriptions in graphical form (i.e., using a bridge diagram, click on particular elements and obtain inspection and cost information).
- A way for the districts to interact with the system (possibly a revision to Pontex). The system will allow the districts to update cost and inspection information.
- A prioritization system that is easy to understand and is easy for TxDOT to incorporate.
- A budget forecasting system.

SUGGESTED USER INTERFACES

Network Level Graphical

Start with an interface similar to the TxDOT Load Restricted Bridge Application and modify it as required (http://www.txdot.gov/business/motor_carrier/roadways/restricted_bridge.htm). This interface can be used to identify bridge locations; review bridge inspection data in tabular format (including load posting, is it rated as structurally deficient or functionally obsolete, vertical and horizontal clearances, etc.); and review bridge programming information (i.e., scheduled for rehab or replacement).
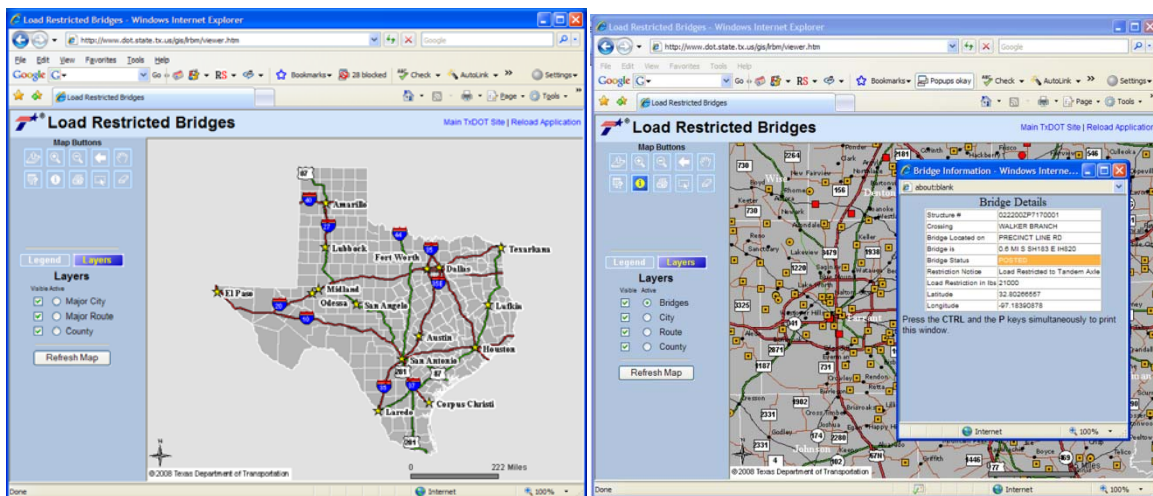
Figure A-1. Images from TxDOT's Load Restricted Bridges Web-Based Application.

Also consider using the Harris County web-based viewer as a template for displaying bridge inspection-related data.
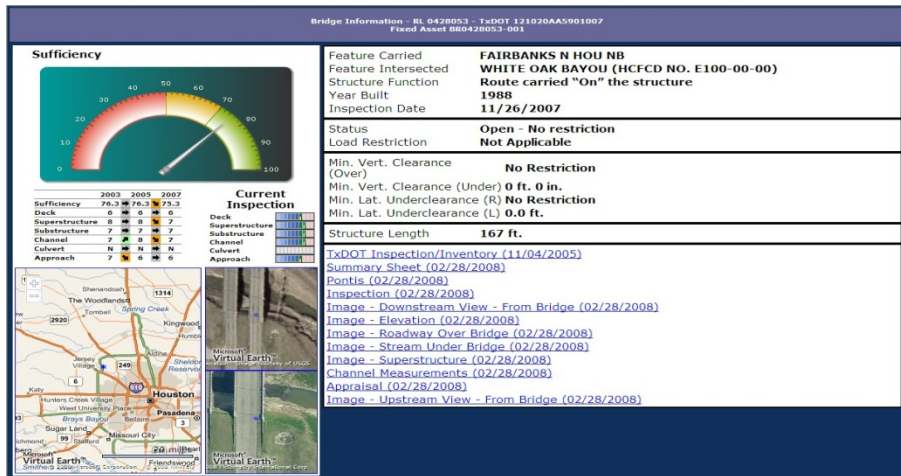
Figure A-2. Harris County Asset Management Web-Based Viewer.

Project Level Graphical for Inspection and Elemental Data

Start with graphics from bridge layout sheets and intelligently link elemental data, photos, and other data to the sheets. The system should have the ability to store "intelligent" drawings that connect with the pertinent data (dynamic link between the drawings, graphics, and data). A link between inspections and rehab or maintenance costs is desirable (i.e., click on a structural element and look at the inspection data)
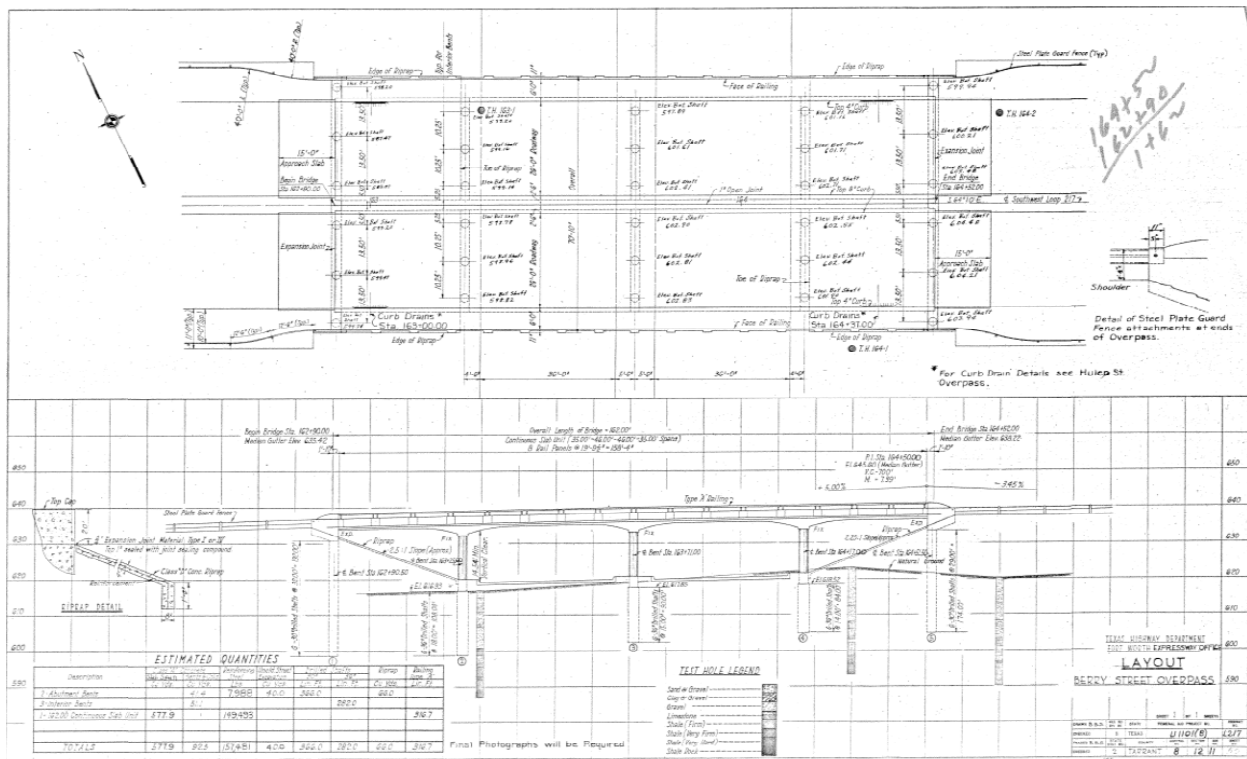
Figure A-3. Example Bridge Layout Sheet.

Bridge Inventory and Inspection Records

For users that want to review bridge inventory and inspection records (including photos) on a computer, start with a system similar to what the Fort Worth District has developed and is what is currently being developed for Pontex (i.e., a "virtual office" where all of the bridge inspection data is stored in a PC database). Consider incorporating video taken by inspectors and elemental data in this system.
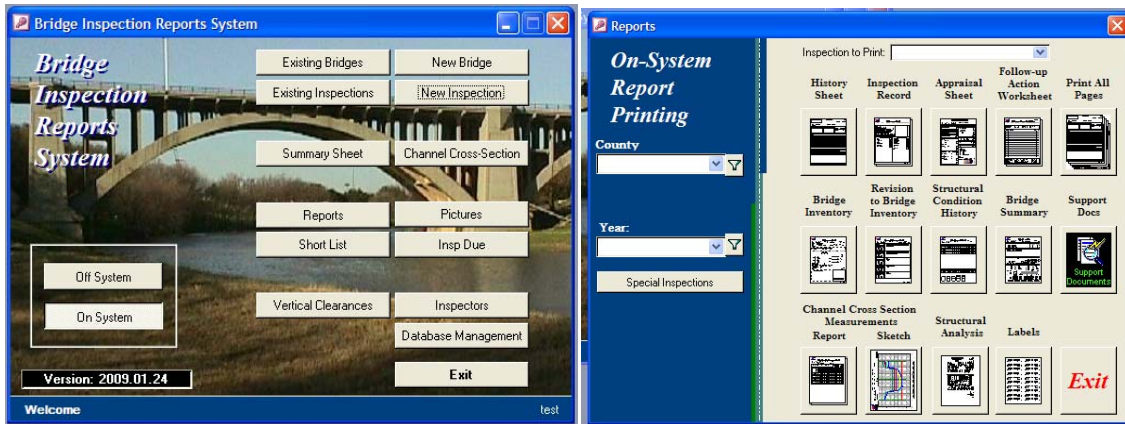
Figure A-4. Bridge Inspection Reports System.

Figure A-5. Sample Worksheet and Photos from the Bridge Inspection Reports System.

RECOMMENDATIONS

TxDOT should establish a data collection protocols or procedures for the following:
- Inventory.
- Inspection (including audits).
- Collecting data for tracking deterioration (using elemental data as a possible basis).
- Obtaining descriptions, dates, and costs of maintenance or rehabilitation activities.
- Coding maintenance activities (these data may be stored in MMIS/MMS).
- Requirements for obtaining photos or videos.

TxDOT should establish state level and district level modules, considering the needs for division and district level users. An approach for the state and an approach for the district need to be developed (both research and business approaches). The business strategy will be a consequence of this effort.

TxDOT should establish more effective definitions for bridge quality levels. Currently a loose definition exists for an inadequate bridge. A recent GAO report said that there is no way for planning for the future with the current system (such as the consequences of investment or funding on quality levels). After quality levels are defined, TxDOT needs to establish effective forecasting procedures.

PROPOSED ACTIVITIES BY THE RESEARCH TEAM

The team will study how to define a bridge (i.e., how it is inventoried). The team proposes to revisit the elemental approach (i.e., study AASHTO CORE specification) by "breaking down" a few bridges into core elements. This exercise will help us decide if the approach can be used in terms of collecting historical data and cost data.

Determine the most effective way to intelligently link graphics to data (i.e., what is the bridge between graphics and data).

TxDOT should have BRINSAP feed DCIS (or the equivalent) with the appropriate data. The team will study elemental data deterioration rates for selected bridge components (i.e., concrete box beams versus prestressed concrete beams)

OTHER CONSIDERATIONS

The public wants smooth and safe roadways. Engineers know that the preservation of investment is critical. Engineers use analytical models (numerical approach), then use engineering judgment, and then make decisions based on the models and judgment.

FORT WORTH DISTRICT BRIDGE INSPECTION REPORTS SYSTEM
Taylor Buckner, P.E., TxDOT Fort Worth District

Current Features:

I.   Report Generation
   A. Bridge Inspection Record (1085)
   B. Appraisal Worksheet
   C. Channel Cross-Section Measurements Record -
         Data kept for each date measurements are taken
   D. Channel Cross-Section Sketch -
         Channel Profiles drawn for each date measurements are
         recorded – drawn in different colors and sketches compared
         from inspection date to inspection date
   E. Bridge Inventory Record
   F. Revision to Bridge Inventory Record
   G. Bridge Structural Condition History
   H. Bridge Summary Sheet
   I. Bridge Inspection Follow-Up Action Worksheet
   J. Fort Worth Comment (History) Sheet
   K. Structural Analysis
   L. Photos
   M. Labels
   N. Follow-Up Action Summary (Short List)
   O. Inspections Due by:
         i. 1 Month, 3 Months, 6 Months, 12 Months, 24 Months
        ii. County
       iii. City
        iv. Maintenance Section

II.   Opening Support Documents from Source File
   A. Scanned Documents
   B. .doc, .xls, .mdb, .txt, etc.
   C. Microstation Files (.dgn)
   D. Microsoft Streets & Trips (.est)
   E. Image Files (Photos, i.e. .jpg, .gif, .tif, etc.)

III. Data for Appraisal is Auto-Embedded Into Appraisal Worksheet From Bridge Inspection Record (1085)
   A. Traffic Safety Features
      i. Bridge Railing
      ii. Transition
      iii. Approach Guardrail
      iv. Guardrail Terminal
   B. Superstructure Rating
   C. Substructure Rating
   D. Culvert Rating

IV. History Sheet
   A. Ability to List Special Inspections/Considerations:
      i. After Heavy Rain Inspection
      ii. Dry Season Inspection
      iii. Large Boat Inspection
      iv. Small Boat Inspection
      v. Under Bridge Inspection Vehicle (Moog Truck)
      vi. Steel Needs Bird Guano Cleaning
      vii. Immediate Deck Surface Repair
      viii. Bird Habitat
      ix. Other
   B. Notation Areas For
      i. Initial Load Rating with Comment Area including Plans Storage Number
      ii. Widening/Extension Load Rating with Comment Area
      iii. Map Number
      iv. Recommended Weight Limit Restrictions
      v. Temporary Weight Limit Restrictions with Comment Area
      vi. Posted Vertical Clearances
      vii. Measured Vertical Clearances
      viii. Bridge Inspection Follow-Up Action Worksheet comment area – Imports automatically into Bridge Inspection Follow-Up Action Worksheet report
      ix. History of Corrective Actions
      x. Miscellaneous Comment Area
      xi. Special Inspection Instructions

Additional Features Desired:
Red – High Priority
Orange – Medium Priority
Green – Low Priority
Purple – Has Been Incorporated into Bridge Inspection Reports System -> Now is a Current Feature

I. **Auto Import of NBI data into:**
    A. **Bridge Inventory Record**
        i. **Latitude/Longitude**
        ii. **Bridge Length**
        iii. **Deck Width**
        iv. **Lanes On**
        v. **Lanes Under**
        vi. **Skew Angle**
        vii. **Approach Roadway Width**
        viii. **Vertical Over-Clearance**
    B. **Appraisal Worksheet**
        i. **Traffic Safety Features**
            a) **Bridge Railing**
            b) **Transition**
            c) **Approach Guardrail**
            d) **Guardrail Terminal**
        ii. **AADT**
        iii. **Roadway Width**
        iv. **Designated Level of Service**
        v. **Functional Classification**
        vi. **Vertical Clearance**
        vii. **Minimum Vertical Clearance**
        viii. **Underpass Lateral Clearance**
            1. **Right Clearance**
            2. **Left Clearance**
        ix. **Inventory Rating**
        x. **Operating Rating**
        xi. **Bridge Posting**
        xii. **Waterway Adequacy**
        xiii. **Approach Roadway Alignment**

II.   Generate NBI Data Report (NBI Sheet)
   A. **From Mainframe and/or**
   B. **PC based database**

III.   Vertical Clearances & Horizontal Data - Linked/Relational Database
   A. **From existing VC data (need VC data in 1 database) need to:**
      1. Generate Database of Complete VC Inventory Showing
         i. Posted VC
         ii. Measured VC
         iii. Difference between Posted VC and Measured VC
            a.   LE 2 inches
            b.   LE 3 inches
            c.   Where Measured is equal to or GT Posted
         iv. Highlight those records showing differences above
         v.   Generate Reports
   B. Be Able to Track and Generate Reports for where existing VC signs
       need Maintenance Attention
         1. At Structure
            i.   Missing
            ii.   Showing Improper VC Value
            iii. Improper Sign Reflectivity Material
         2. Advance Signs
            i.   Missing
            ii.   Showing Improper VC Value
            iii. Improper Sign Reflectivity Material
   C. Communicate & Coordinate Vertical Clearance and Horizontal Data
       with TxDOT Oversize/Overweight Permit Office

**IV.   Traffic Control – Be able to List and Track required Traffic Control for all
       functions involving the Bridge Structure - Linked/Relational Database**
   A. **Fracture Critical Inspections**
   B. **Routine Safety Inspections**
   C. **Checking Vertical/Horizontal Clearances**
   D. **Special Inspections**
   E. **Coordination with Railroads for Inspection over RR –**
   Linked/Relational Database
   F. **Contact Information**
   G.   **Sequence of Required Steps**
   H. **DOT Railroad Crossing Number or RR Location Number**
   I. **Time Duration Required for Inspection over RR**

V. Coordination with Bridge Owners or Entity Responsible for Maintenance ->
   We have a working program called Bridge Incident Tracking System (BITS)
   (i.e., high load collision incidents) from which this can be modeled (with
   feedback features from other sections including Maintenance, Bridge Design,
   etc.)

A. **Correspondence**
B. **Auto Generation of "Bridge Inspection Follow-Up Action Worksheet"**
   i. **Feedback feature for Bridge Owner/Maintainer to respond back when Corrective Actions (Follow-Up Actions) are taken**
   ii. **Corrective Actions (Follow-Up Actions) entered into 1 field (i.e., "Bridge Inspection Record") and exported to:**
      a. **"Bridge Inspection Follow-Up Action Worksheet"**
      b. **"History Sheet" memo (text) field**

VI. **Contact Information for Bridge Owner or Entity Responsible for Maintenance - Linked/Relational Database**
   A. **County Judges / County Commissioners**
   B. **City Managers / Mayors / Engineers / PW Director / Community Development Director**
   C. **TxDOT Area Engineers / Maintenance Section Supervisors**
   D. **UTA, Trinity River Authority, Tarrant Regional Water District, Corps of Engineers, FEMA, etc.**

VII. **Elemental Data - Linked/Relational Database**
   A. **Data Entry**
   B. **Data Query**
   C. **Report Generation**
   D. **Coordination with Bridge Inspection Safety Data**
   E. **Retrieval of Related Documents or Photos**

VIII. **Additional Information not included in NBI data - Linked/Relational Database**
   A. **Data Entry**
   B. **Data Query**
   C. **Report Generation**
      1) **Road Closed to Traffic**
      2) **2 – Column Bent With Protection**
      3) **2 – Column Bent Without Protection**
      4) **No Crash Wall (Single Column Bent)**
      5) **Cap Problems**
      6) **Joint Problems**
      7) **Bearing Problems**
      8) **Beam End Problems**
      9) **Cracked Riprap**
      10) **Riprap Joint Problems**
      11) **Cracked Box Beams**
      12) **Lateral Movement**
      13) **Channel Migration**
      14) **Spread Footing With Undermining**
      15) **Spread Footing Exposed Without Undermining**
      16) **Two Girder**
      17) **Timber Pile Abutments**

18) Use Small Boat
   a. Personal Flotation Devices (Life Vests)
   b. Trolling Motor
   c. Deep Cycle Battery
   d. Paddles
   e. SHIFLO
   f. Weighted Drop Line
   g. Throw Cushion (Throwable PFD)

19) Use Large Boat
   a. Personal Flotation Devices – PFD - (Life Vests)
   b. Paddles
   c. SHIFLO
   d. Weighted Drop Line
   e. Throw Cushion (Throwable PFD)
   f. Air Horn
   g. Working Lights – Front & Back
   h. Registration Card (Attached to Keys)
20) Use Hip/Chest Waders
21) Temporary Repairs
   a. Date of Repair
   b. Description of Repair
   c. Project CSJ
   d. Required Work to make repair Permanent
22) Permanent Repairs
   a. Date of Repair
   b. Description of Repair
   c. Project CSJ
23) Fracture Critical Box Cap
24) Fracture Critical Plate Cap
25) Crown Span
26) Temporary Structure
27) Load Posting Not Required
28) Improperly Posted
29) Weight Limit Revised
30) Missing Signs
31) Maintained By U.T.A.
32) Maintained By City Fort Worth
33) Structure Resides In DFW Airport Area
34) Pedestrian Crossing
35) North Bridge
36) Center Bridge
37) South Bridge
38) East Bridge
39) West Bridge
40) Heavy Truck Route

41) School Bus Route
    a. ISD Name & Contacts
    b. Maximum Gross Weight of Bus on Route
    c. Map of Bus Route
42) Dry Season Inspection
    a. Date of Dry Season Inspection
    b. Feature Monitoring
        i. Exposed/Undermined Spread Footing
        ii. Exposed Piling
        iii. Exposed Drilled Shaft
        iv. Exposed Pile Cap
        v. Exposed Trestle Piles
    c. Lowest Observed Channel Elevation
    d. Relative Measureable Feature Condition
    e. General Comments
43) After Flood inspection
    a. Date of After Flood Inspection
    b. High Water Mark
    c. Approximate Water Velocity
    d. Bridge Deck or Approach Roadway Overtopped
    e. Relative Amount of Floating Debris
    f. Channel Cross Section Measurements (Weighted Drop Line (Low Flow) or SHIFLO (depth finder (transducer) mounted on Ski) during High Flow)
    g. Photos/Video
    h. General Comments
44) Winter Season Inspection
    a. Date of Winter Season Inspection
    b. Feature Monitoring
    c. Vegetation Level
    d. Lowest Observed Channel Elevation
    e. Relative Measureable Feature Condition
    f. General Comments
45) Use MOOG/Snooper
    a. Working from Top of Bridge Deck or Below Bridge Deck
    b. Tools/Equipment Required
        i. Generator
        ii. Welder
        iii. Oxy-Acetylene Torch
        iv. Air Compressor
        v. Hydraulic Wrench
        vi. Electric Drill
        vii. Electric Impact Wrench
        viii. Cordless Drill
        ix. Chain Saw

          x.   **Portable Generator**
          xi.   **Traffic Counter**
          xii.   **SHIFLO (depth finder on ski)**
          xiii. **Weighted Drop Line**
          xiv. **2-Way Radios**
          xv.   **Chain Drag Equipment**
          xvi. **Air Monitor**
          xvii. **Fracture Critical Tools**
          xviii. **Dye Penetrant Kit**

46) **Load Factor Method Requested**
    a. **Date Requested**
    b. **Entity to Perform Structural Analysis**
    c. **Estimated Completion Date**
    d. **Method Used**
    e. **Inventory Rating (IR) & Operating Rating (OR) Results**

47) **Load Guidance Requested**

48) **History of Scour Problems**
    a. **Spread Footings**
        i. **Exposure**
        ii. **Undermining**
        iii. **Leaning**
    b. **Exposed Piling**
    c. **Exposed Drilled Shafts**
    d. **Steep Embankment**
    e. **Loss of Embankment Material**
    f. **Failure of Embankment Protection**
    g. **Unknown Foundation**
    h. **Lateral Stream Migration**
    i. **Erodible Channel Material**
    j. **Vertical Degradation**
    k. **Debris Accumulation History**
    l. **Channel Direction not Aligned with Bridge Opening (skew angle)**

49) **History of Debris Problems**

50) **Historical (NHR Eligible)**

51) **Land Locked**

52) **Impact/High Load Damage**
    a. **Coordinate with existing Bridge Incident Tracking System (BITS)**
    b. **Document cumulative history and affected member condition(s) related to Impact Damage**
    c. **Approximately cumulative cost related to Impact Damage**

53) **Structure Programmed for Replacement**
    a. **CSJ**
    b. **Entity preparing PS&E**
    c. **Approximate Cost of Project**
    d. **Estimated completion of PS&E**
    e. **Estimated Letting Date**

54) **Structure Programmed for Rehabilitation**
    a. **CSJ**
    b. **Entity preparing PS&E**
    c. **Approximate Cost of Project**
    d. **Estimated completion of PS&E**
    e. **Estimated Letting Date**

55) **Equivalent-Match Project - EMP**
    a. **CSJ Number**
    b. **Associated with PWP number**
    c. **Date Agreement Signed**
    d. **Deadline Date for Completion of Work**

56) **Participation-Waived Project – PWP**
    a. **CSJ Number**
    b. **Associated with EMP number (if any)**
    c. **Date Agreement Signed**
    d. **Design Consultant**
    e. **Date Contract Begins**
    f. **Date Final PS&E Due**
    g. **Estimated Letting Date**

57) **Maintenance Contract - Structure Programmed for Preventive Maintenance**
    a. **CSJ**
    b. **Entity preparing PS&E**
    c. **Approximate Cost of Project**
    d. **Estimated completion of PS&E**
    e. **Estimated Letting Date**

58) **Maintenance Contract Completed with Year**

59) **No Plans Available**

60) **Bridge Cost GE $500,000**

61) **Wearing Surface Type and Thickness**

62) **Deck – Top and Underside**
    a. **Material**
    b. **Type construction**
    c. **Forms Left In Place**
    d. **Deck Thickness**
    e. **Reinforced**

63) **Joints**
    a. **Type**
    b. **Repair Methods Required**
    c. **Ease of Repair**
    d. **Repair Cost**

64) **Bearings**
    a. **Type**
    b. **Repair Methods Required**
    c. **Ease of Repair**
    d. **Repair Cost**

      65) Drainage System
        a.   Type
        b.   Functioning
        c.   Below Deck
        d.   Piping
        e.   Pipe Supports
        f.   Outlet
      66) Unknown Foundations
        a. Prioritize Investigation of Foundation Depth
          i.   Substructure Type
            1) Piles
            2) Spread Footings
            3) Drilled Shafts
            4) Pile Cap on Piles
            5) Trestle
            6) Frame
            7) Single Column
            8) Tie Beam
          ii.   Steep Slopes (Embankments)
         iii.   Slope Protection / Type
         iv.   Erodible Channel Material
          v.   Degradation
         vi.   Lateral Channel Migration
        vii.   Debris
       viii.   Priority Level for Unknown Foundation Investigation
             Red/Yellow/Green
            1) Entity to perform Unknown Foundation Investigation
            2) Contract Number
            3) Contract Cost
            4) Estimated Date of Completion
    D. Retrieval of Related Documents or Photos

IX.   **Ability to notate "Corrective Actions" in the "Bridge Inspection Record" (1085) and have that note automatically import to:**
    A.   **"History Sheet" under "History of Corrective Actions"**
    B.   **"Bridge Inspection Follow-Up Action Worksheet" 2nd page under "Corrective Actions Taken" or "Follow-Up Actions Taken"**

X.   **Ability to have required sign summary items filled out in "Bridge Summary Sheet" report (Materials Needed) to automatically import to:**
    A.   **Excel file "Summary Of Needed Load Posting Materials.xls"**

XI.   **Load Posting Data - Linked/Relational Database**
    A.   **Data Entry**
    B.   **Data Query**
    C.   **Report Generation**

APPENDIX B. BRIDGE INSPECTION DATA MAPPING PROCEDURE

This appendix describes the procedure to map bridge inspection data with the TxDOT Mapzapper database application and ArcMap™. In order to generate maps with this method, the user must have:

- MS Access 2003 ™.
- The TxDOT MapZapper Database Application (available from the TxDOT Construction Division) containing PMIS data.
- ArcMap Version 9.3 or later installed.
- A file in Dbase 4 ™ format containing bridge inspection information from the Bridge Division.

Click on the file named pmismzxp. MS Access 2003 will then start. A screen similar to the following screen may appear:
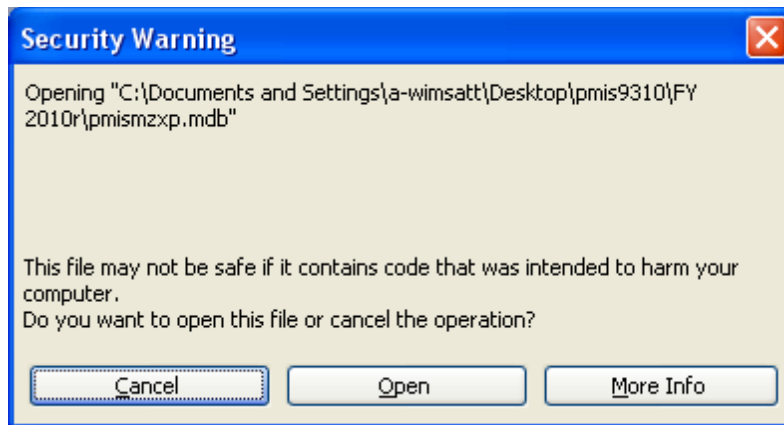
Figure B-1. Security Warning Screen.

Click on the Open button. A screen similar to that below should appear:
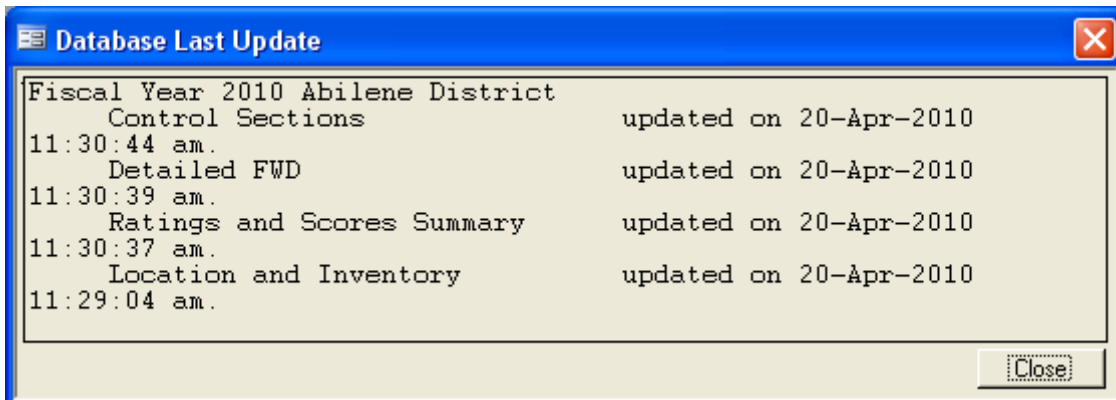
Figure B-2. Database Last Update Screen.

If not, please contact the Construction Division for a copy of the MapZapper application with PMIS data.

Click on the Close button.

The window below should then appear.
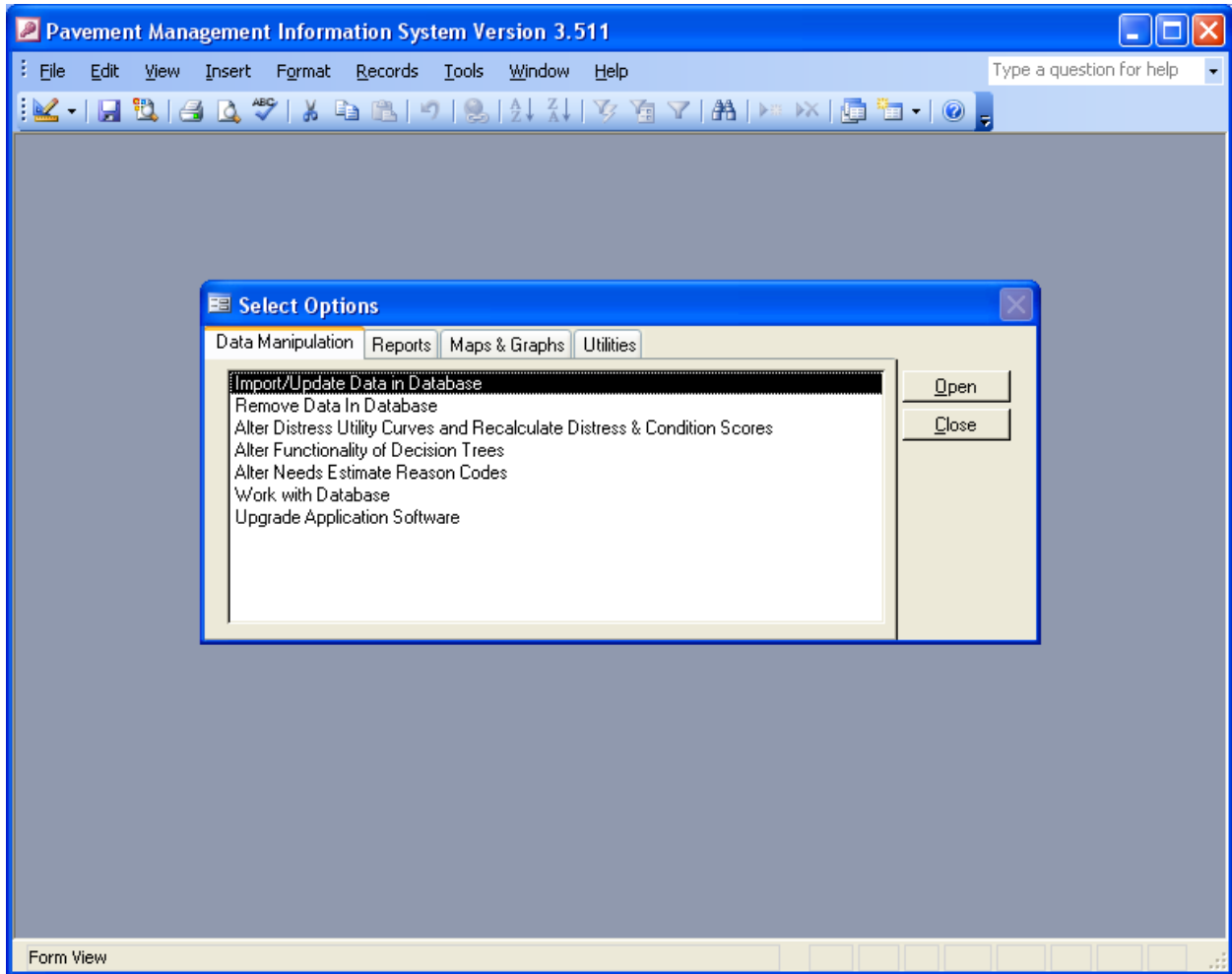
Figure B-3. Select Options Screen in MapZapper – Data Manipulation Tab.

Click on the Maps & Graphs tab, then click on "Map PMIS data using ArcMap" as shown below.
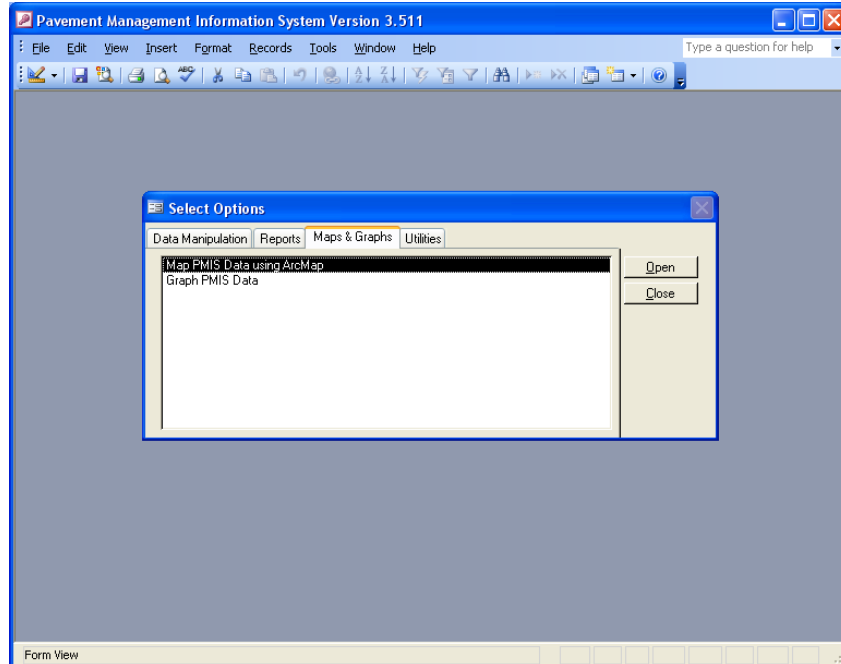
Figure B-4. Select Options Screen in MapZapper – Maps and Graphs Tab.

Click on the Open button. The window below should then appear.
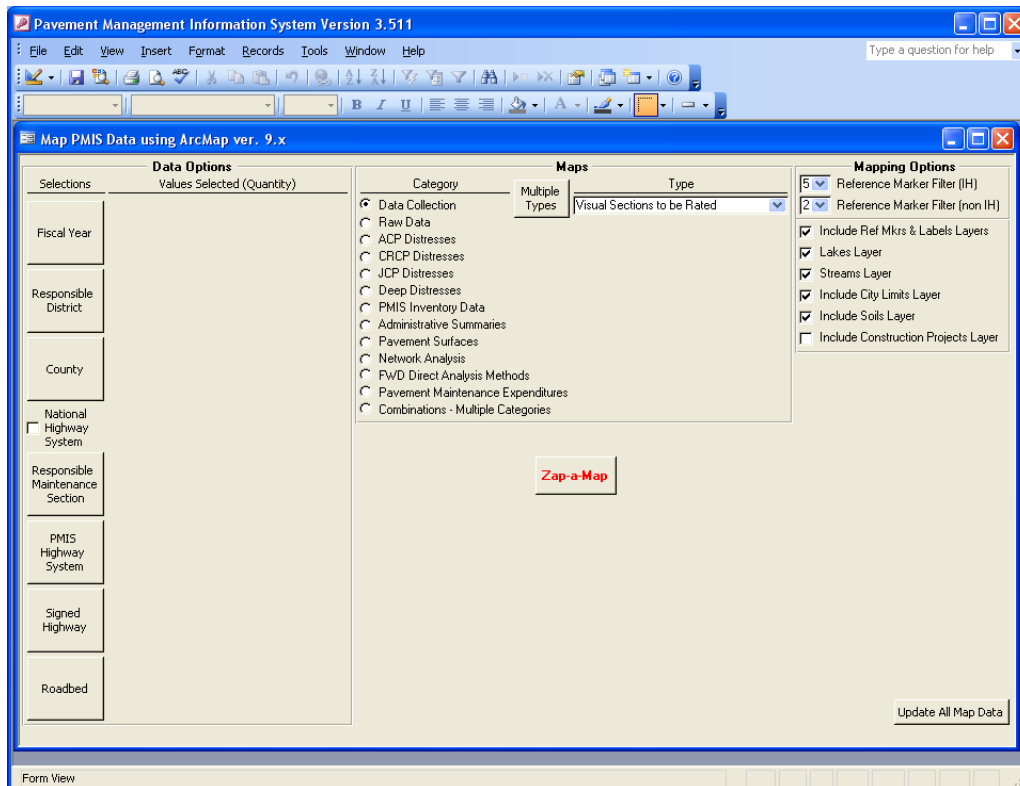
Figure B–5. Mapping Options in MapZapper.

Click on the Fiscal Year button to select the appropriate Fiscal Year. Click on the Responsible District button to select a district. Click on the button next to "PMIS Inventory Data" to select traffic information, maintenance costs, or other data to be mapped. For this example, FY 2010 map data for the Fort Worth District with ADT information will be used. The window should appear as shown below.
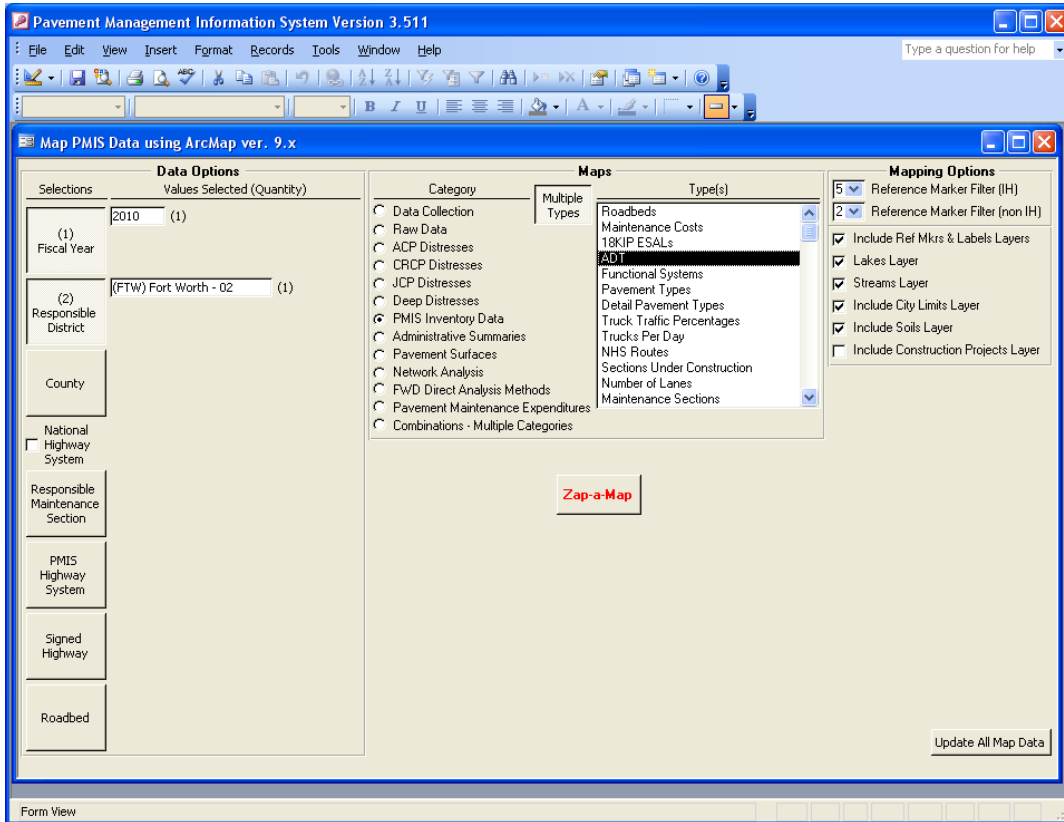
Figure B-6. Mapping Options in MapZapper with Selected Options.

Click on the "Zap-a-Map" button. After several minutes, Arcview will then start and a map similar to that below should appear.
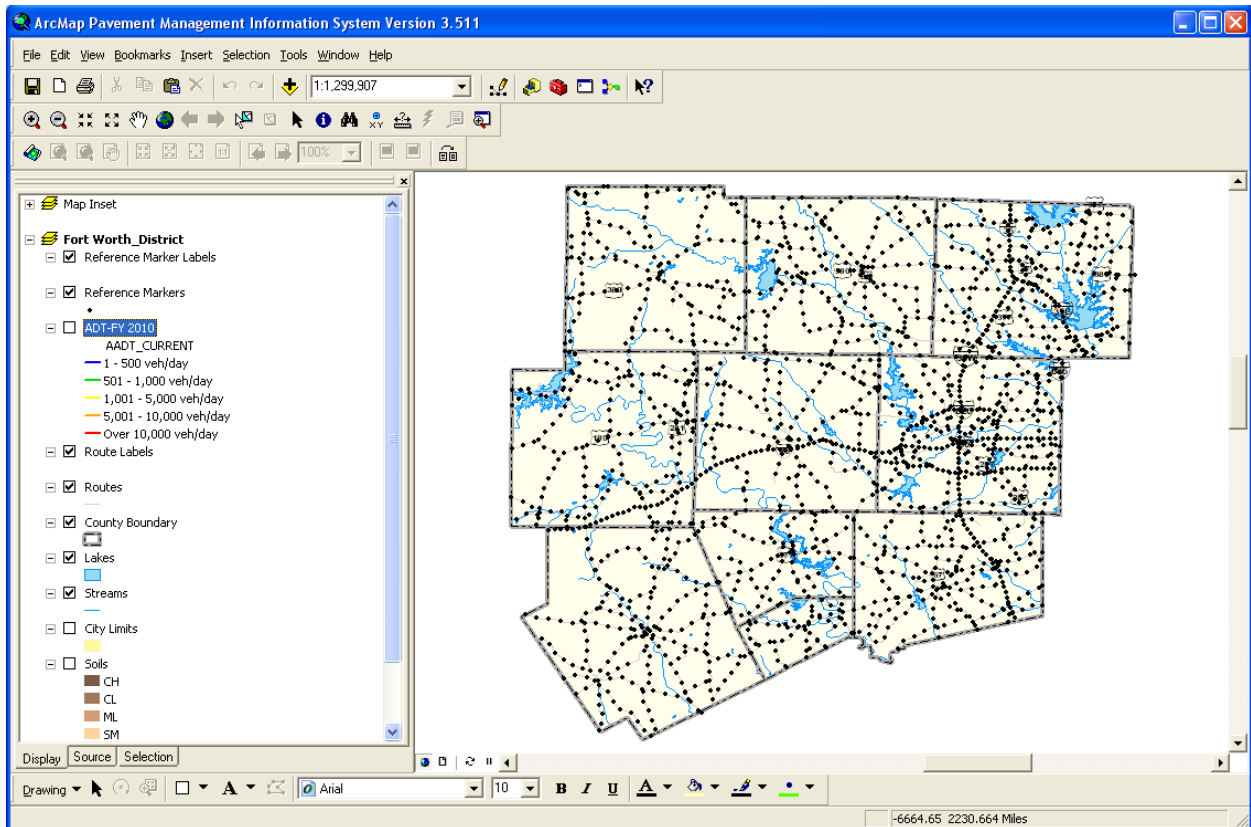
Figure B-7. ArcMap Window Showing a Map of the Fort Worth District.

If desired, click off the check marks next to "Reference Marker Labels" and "Reference Markers." A screen similar to that below should appear. Click on the disk icon (circled in the screen below).
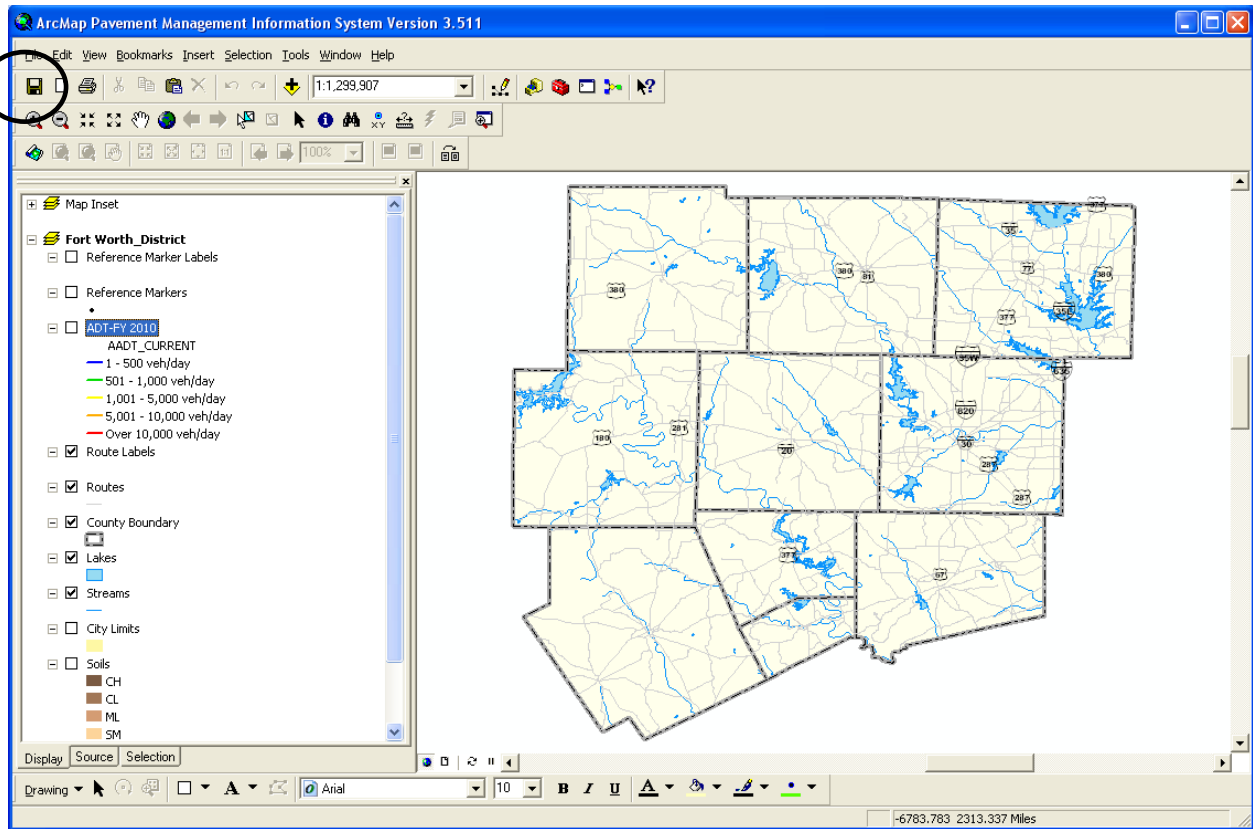
Figure B-8. ArcMap Window with File Save Icon Highlighted.

A dialog box will appear similar to what is shown below. Type in a name for the ArcMap document to be saved (in this case, use ftw.mxd). Click on the Save button.
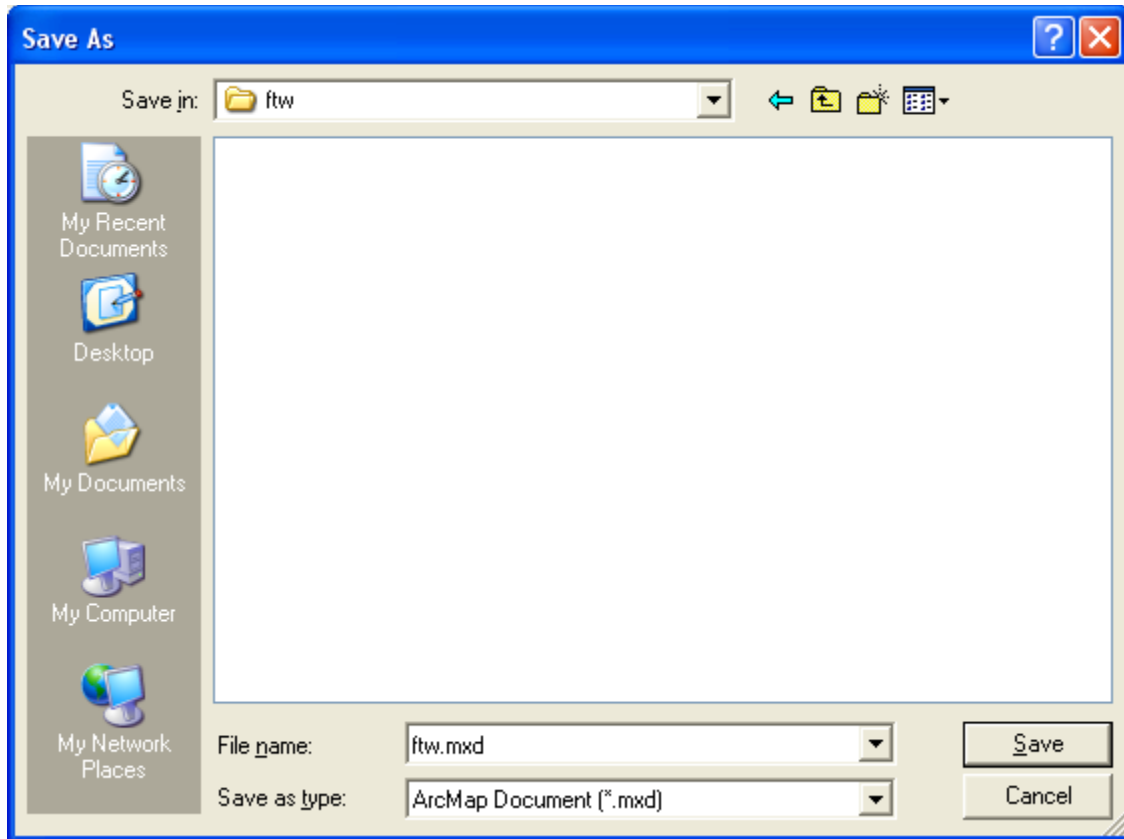
Figure B-9. Save As Window in ArcMap.

The dialog box will close. You have now created a file that will be used to map bridge inspection data. Exit ArcMap and MapZapper.

Go to the folder where the ftw.mxd file was saved. You should find two files in that folder. One will be named "ftw.mxd," the other will be named "ftw Geodb.mdb." Put the Dbase4 ™ file containing bridge inspection information into this folder. In this case, the file name is "OnSysBridges.dbf." The folder contents should appear as shown below.
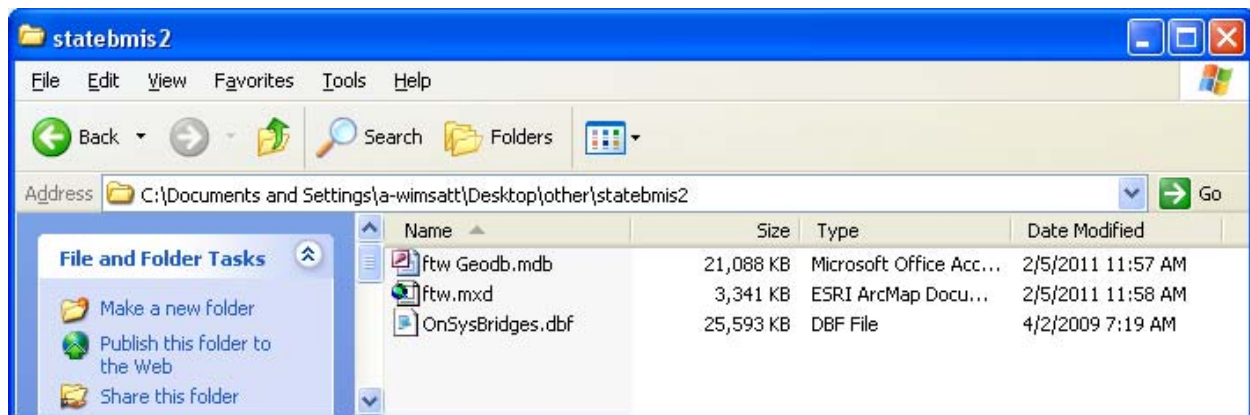
Figure B-10. ArcMap Files Stored on the Computer.

Double Click on the "ftw.mxd" file. ArcMap will then start and the following map should appear. To add bridge inspection data to the map, click on the "Tools" pull-down menu.
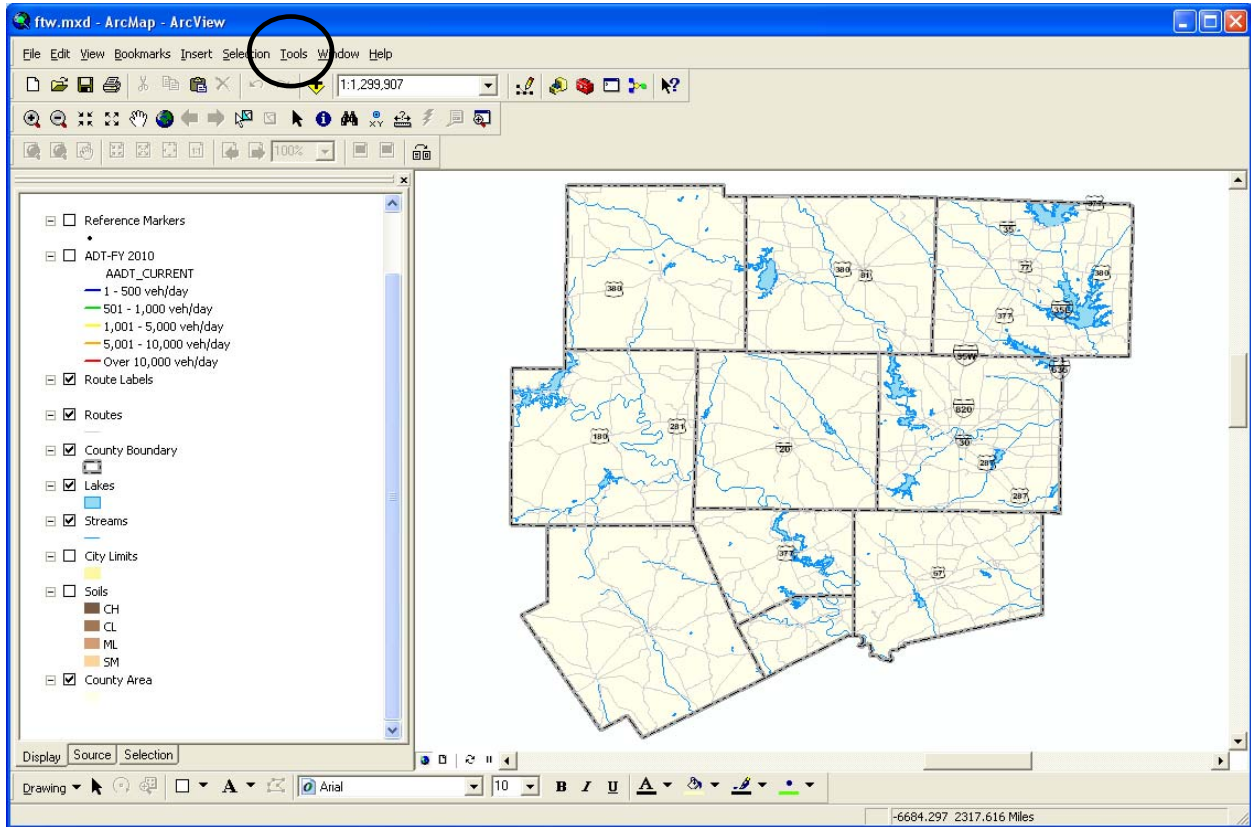
Figure B-11. ArcMap Window with the Tools Pull-Down Menu Highlighted.

Select "Add XY Data" as shown below.
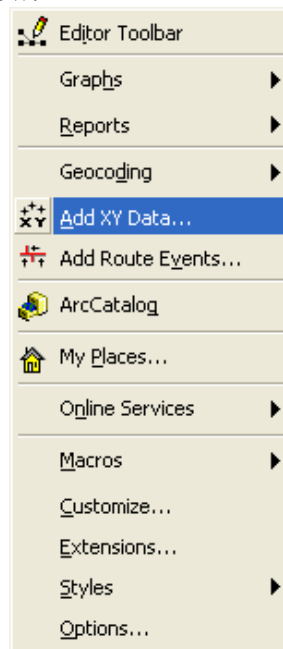
Figure B-12. Tools Pull-Down Menu in ArcMap.

The following dialog box will appear. Click on the folder icon which is circled on the screen below.
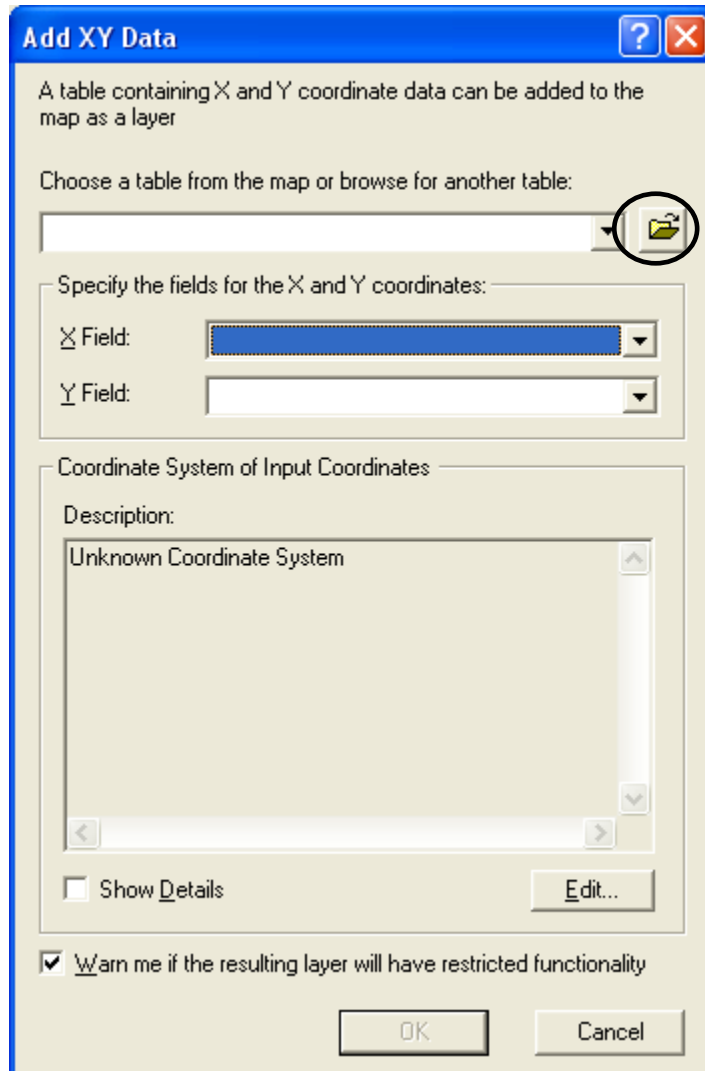
Figure B-13. Add XY Data Window in ArcMap with Folder Icon Highlighted.

The following screen will appear. Click on "OnSysBridges.dbf" and click on the Add button.
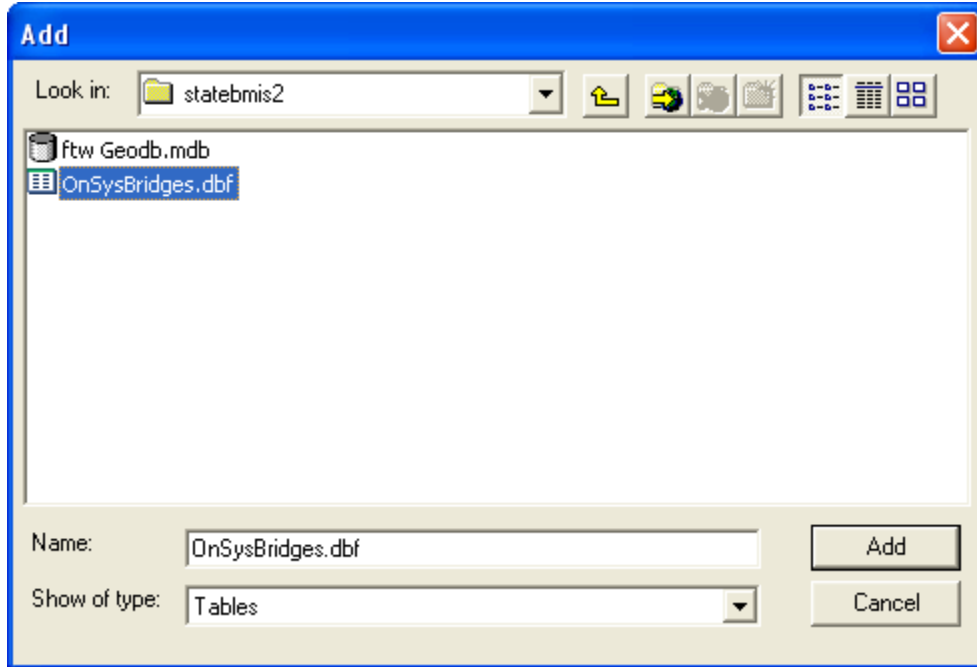
Figure B-14. Add Window in ArcMap with On System Bridge Data File Highlighted.

The dialog box should appear as shown below. Click on the OK button. If the screen does not appear as shown below, please contact the Bridge Division to obtain a file with longitude and latitude information.
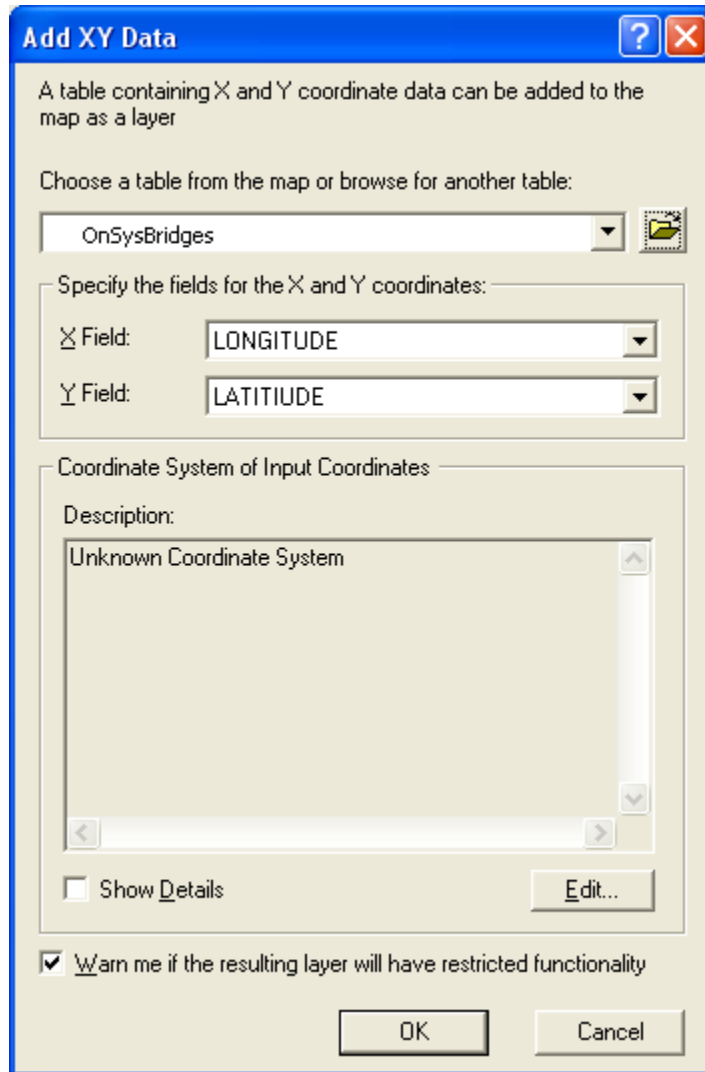
Figure B-15. Add XY Data Window in ArcMap.

The ArcMap window should then appear as shown below. All of the on system bridge locations are shown.
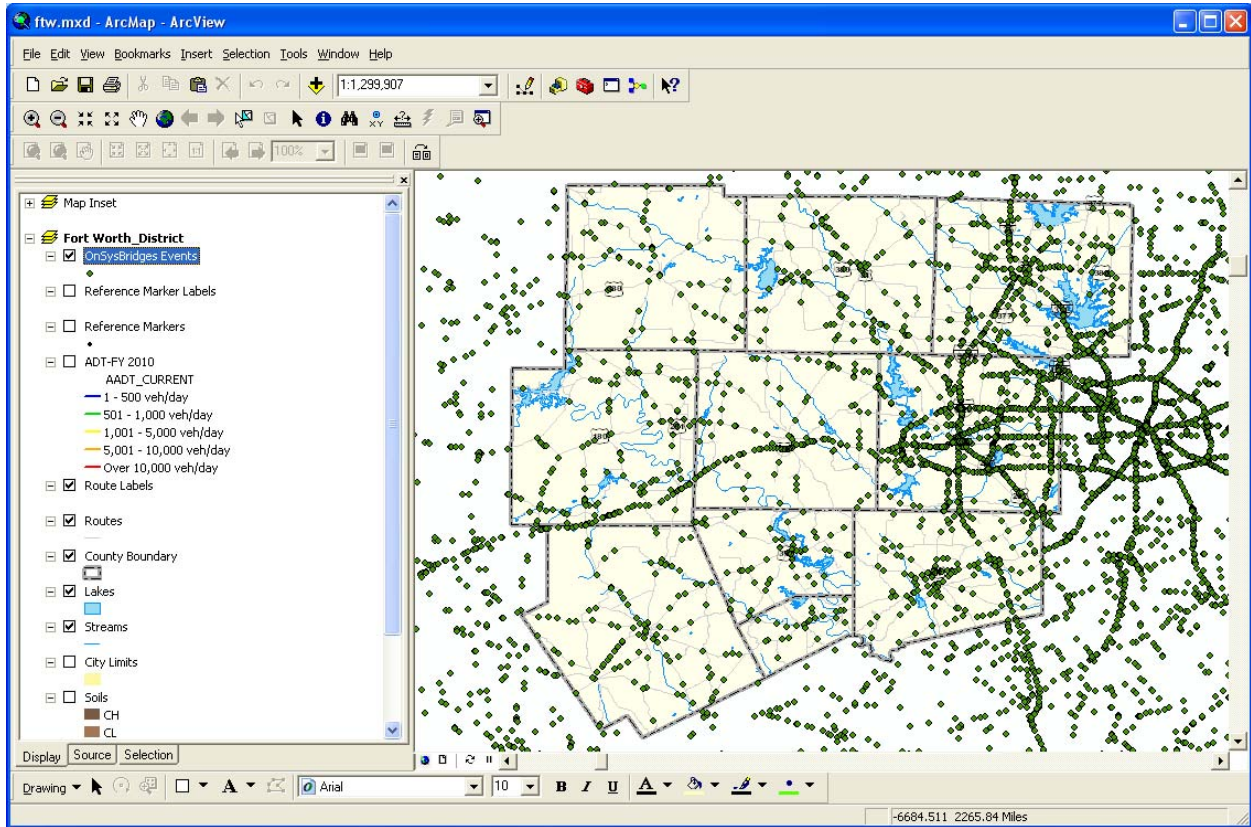
Figure B-16. ArcMap Window Displaying Bridge Locations.

As an example, in order to show only district bridges with superstructure ratings less than 5, double click on "OnSysBridges Events."

The following Layer Properties window will appear. Click on the Definition Query Tab, and then click on the "Query Builder" button.
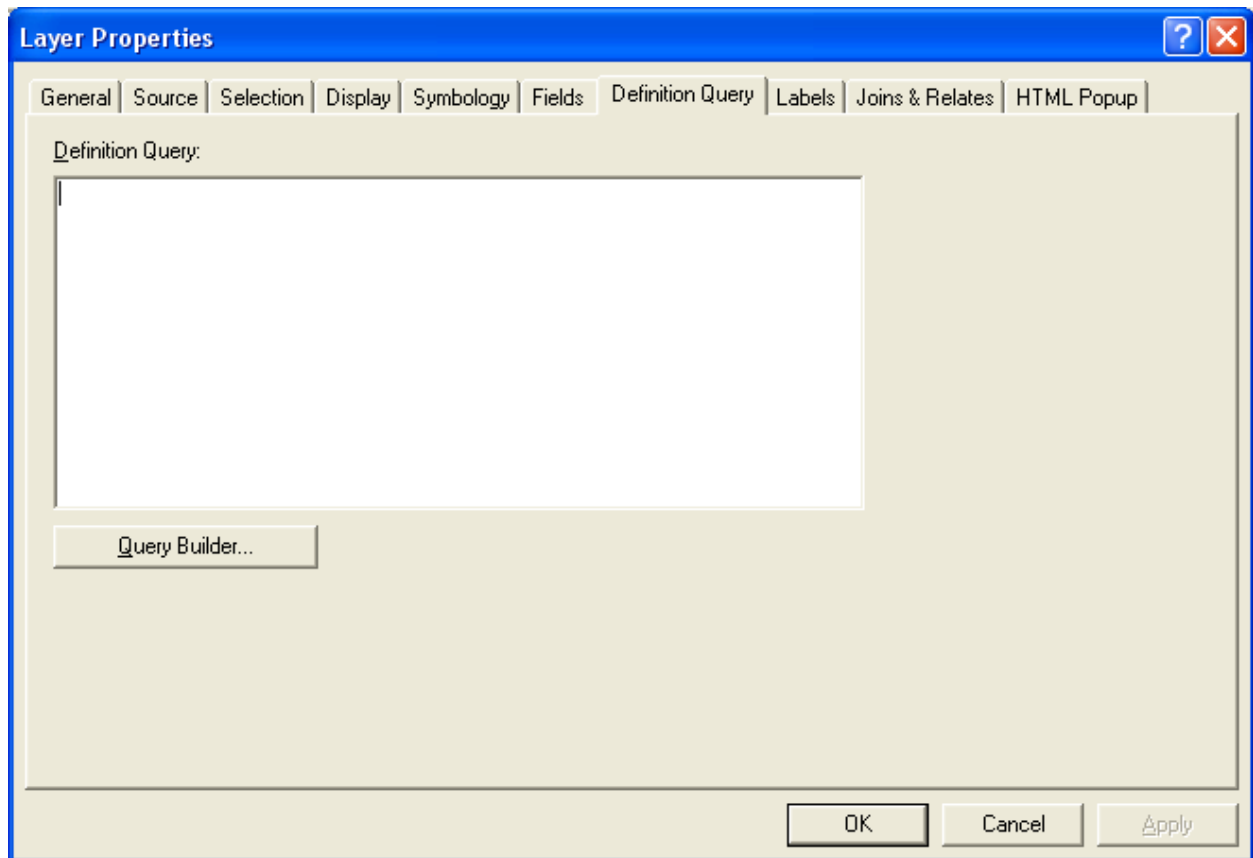
Figure B-17. Layer Properties Window in ArcMap.

The window below will then appear.

Double click on "2_District." Then click on the "Get Unique Values" button, which is circled.
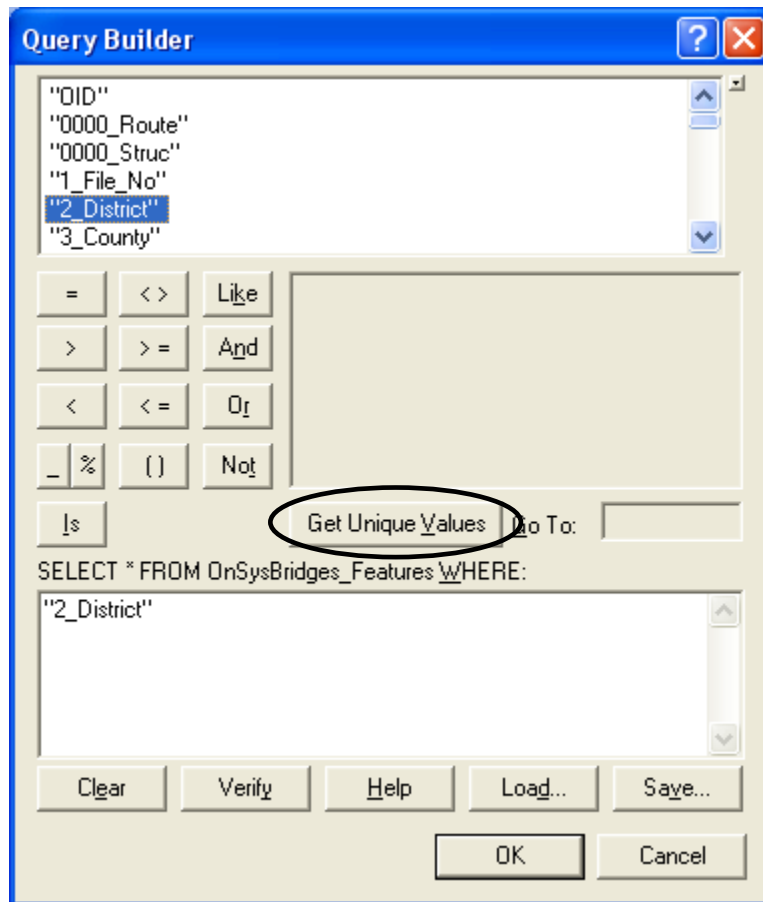
Figure B-18. Query Builder Window in ArcMap.

The window should then appear as shown below.
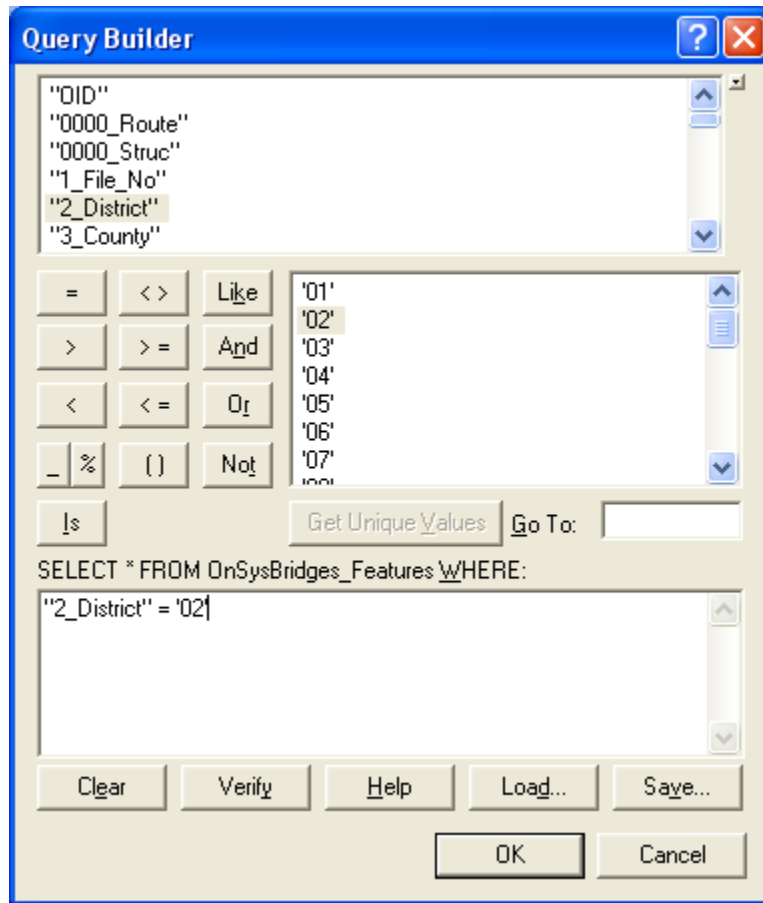
**Figure B-19. Query Builder Window in ArcMap with District Query.**

Click on the equal sign, then double click on '02' (for Fort Worth).

The window should then appear as shown below.

To show only bridges with superstructure ratings less than 5, click on the "And" button and then use the scroll bar on the upper right side of the window to locate "59_Super_C." Double click on "59_Super_C." Double click on the "<" button, then click on the "Get Unique Values" button, then double click on the "5" value. The window should then appear as shown below.
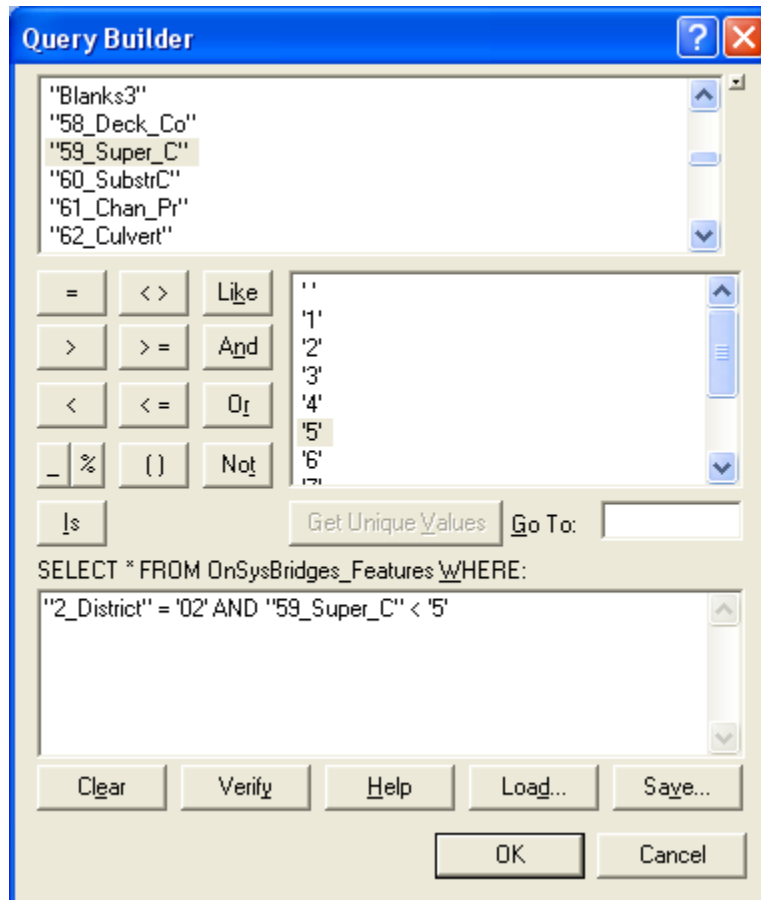
**Figure B-20. Query Builder Window in ArcMap
with District and Superstructure Query.**

Click OK.

The Layer Properties Window should appear as shown below.
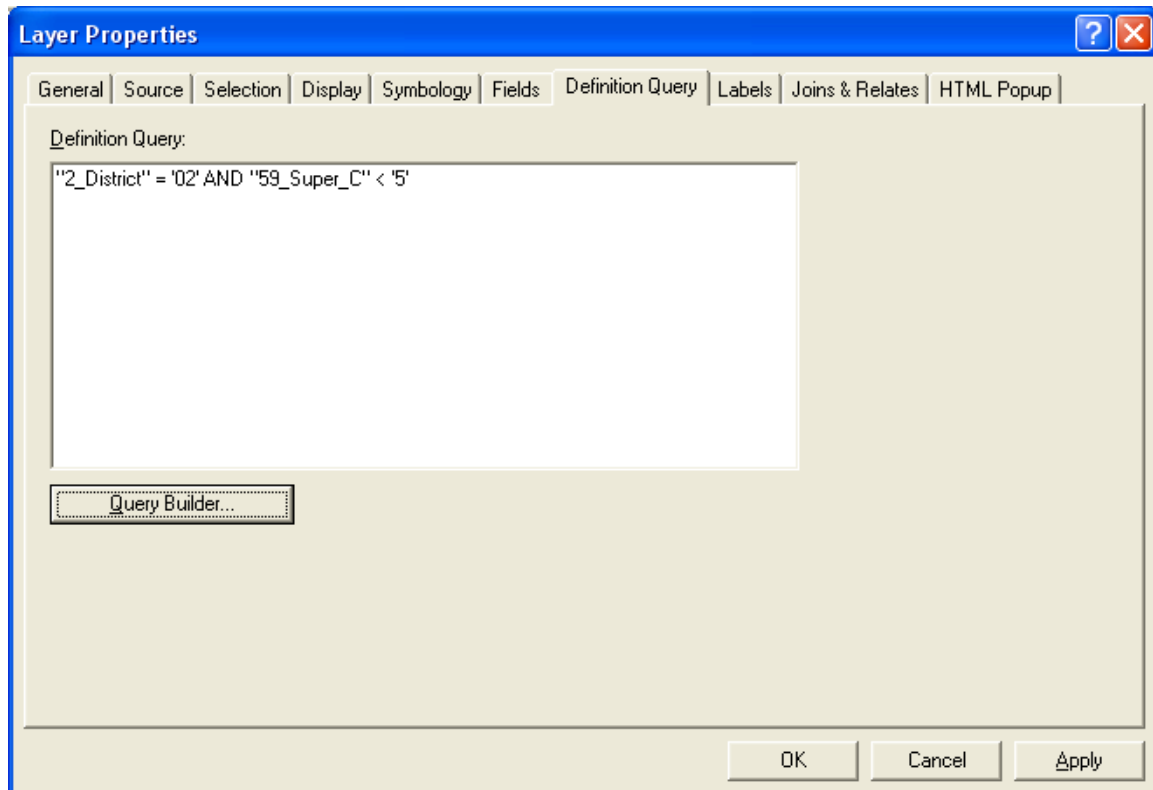
Figure B-21. Layer Properties Window in ArcMap with Definition Query.

Click on the Apply button and then the OK button.

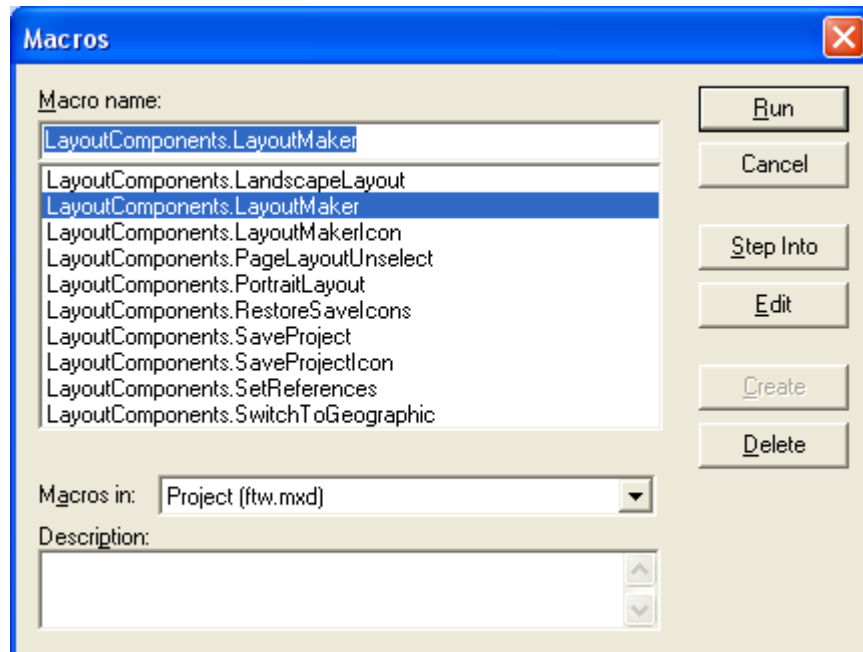The ArcMap window should appear as shown below.
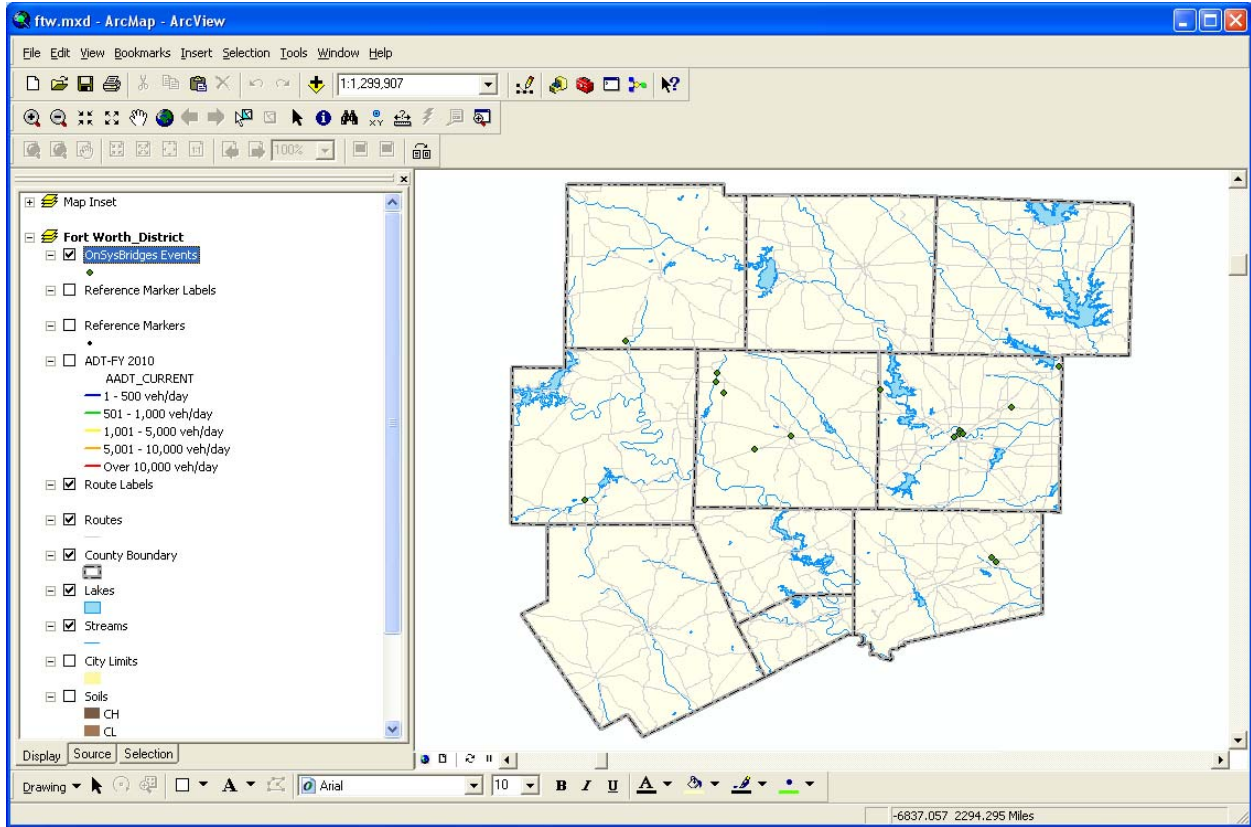
Figure B-22. ArcMap Window Showing Bridge Locations with a Superstructure Rating below 5.

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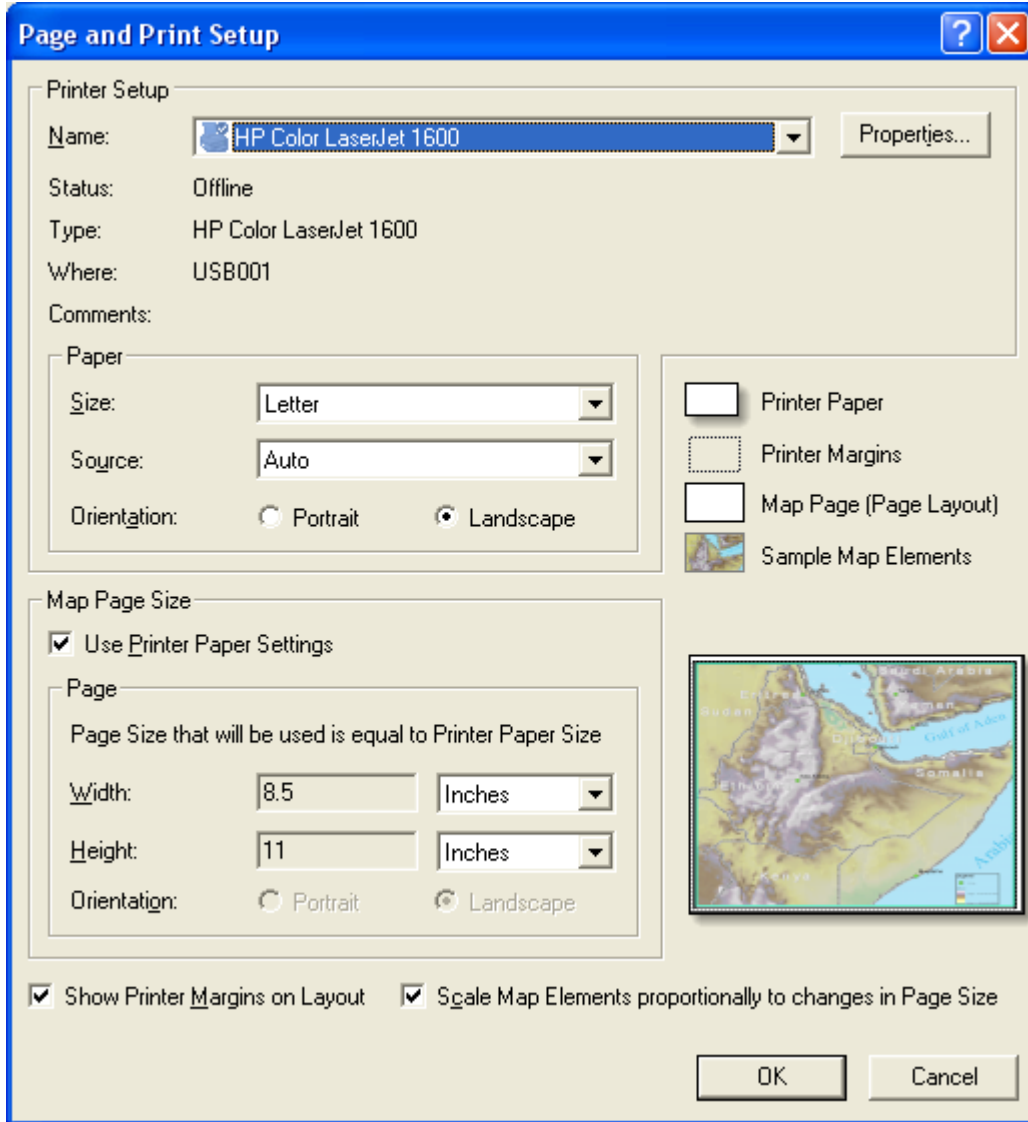To generate a map suitable for printing, go to the "Tools" pull-down menu and select "Macros" as shown below.
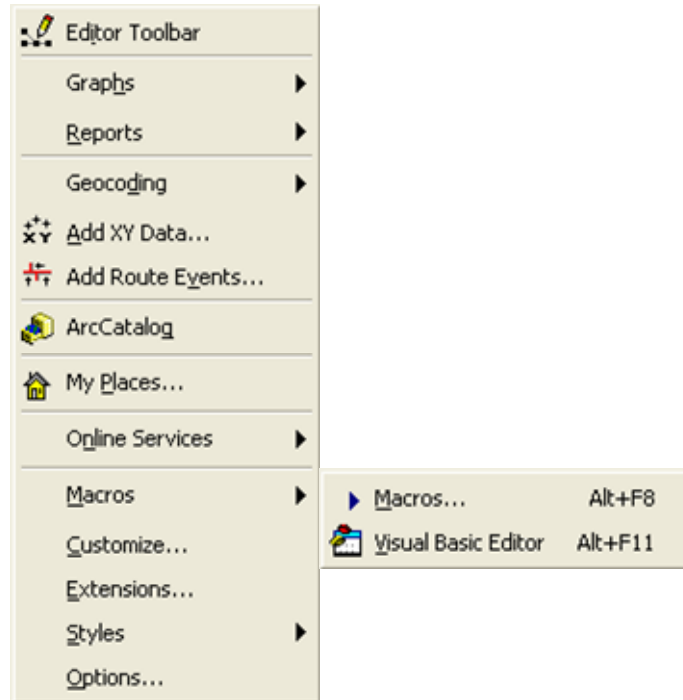
Figure B-23. Tools Pull-Down Menu in ArcMap with the Macros Option Selected.

The following window will appear. Click on "LayoutComponents.LayoutMaker" and click the Run button.

Figure B-24. Macros Window in ArcMap.

The following window will appear. Click the OK button.

Figure B-25. Page and Print Setup Window in ArcMap.

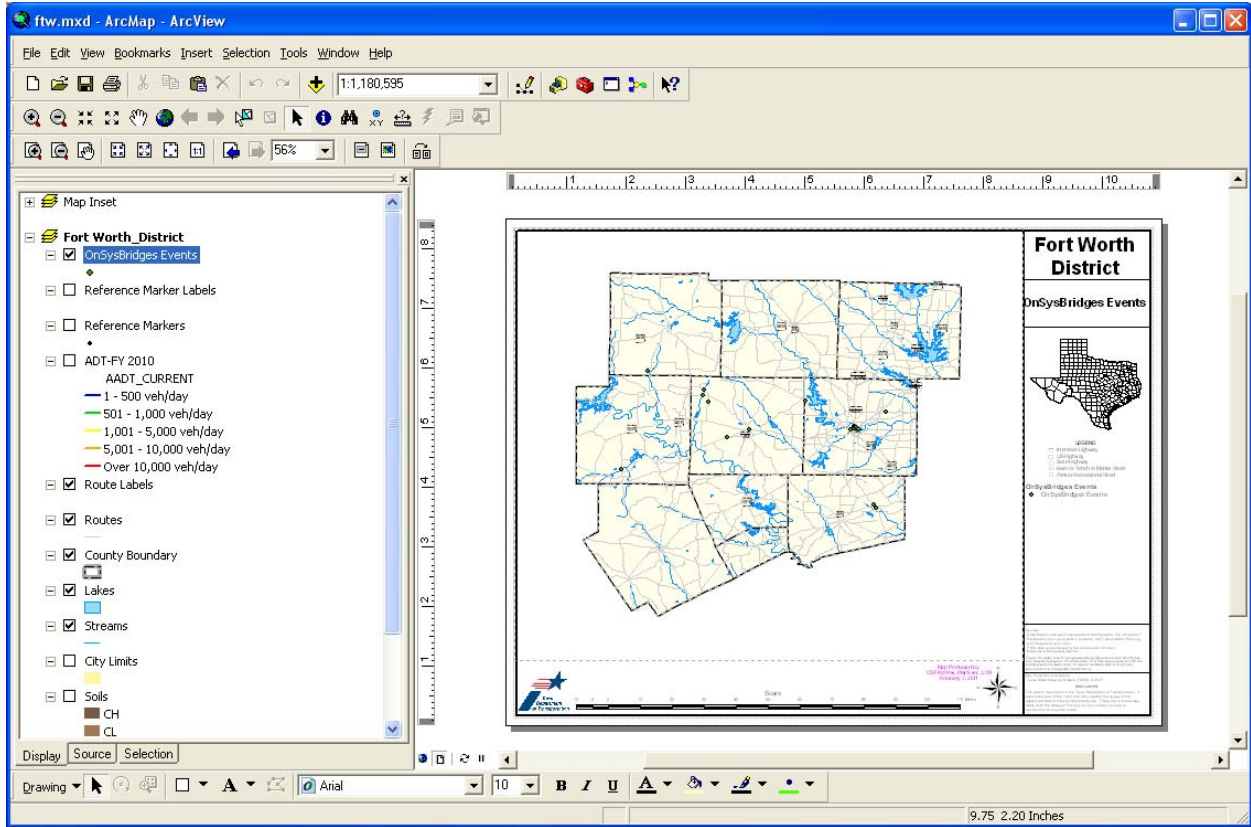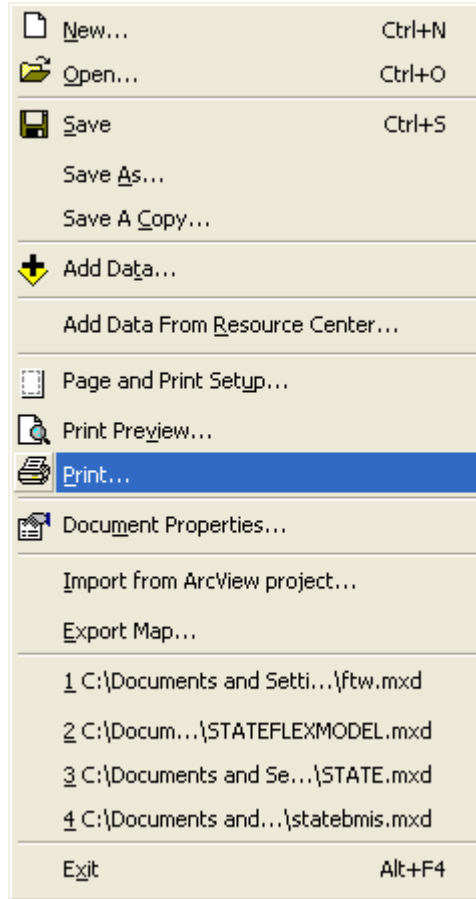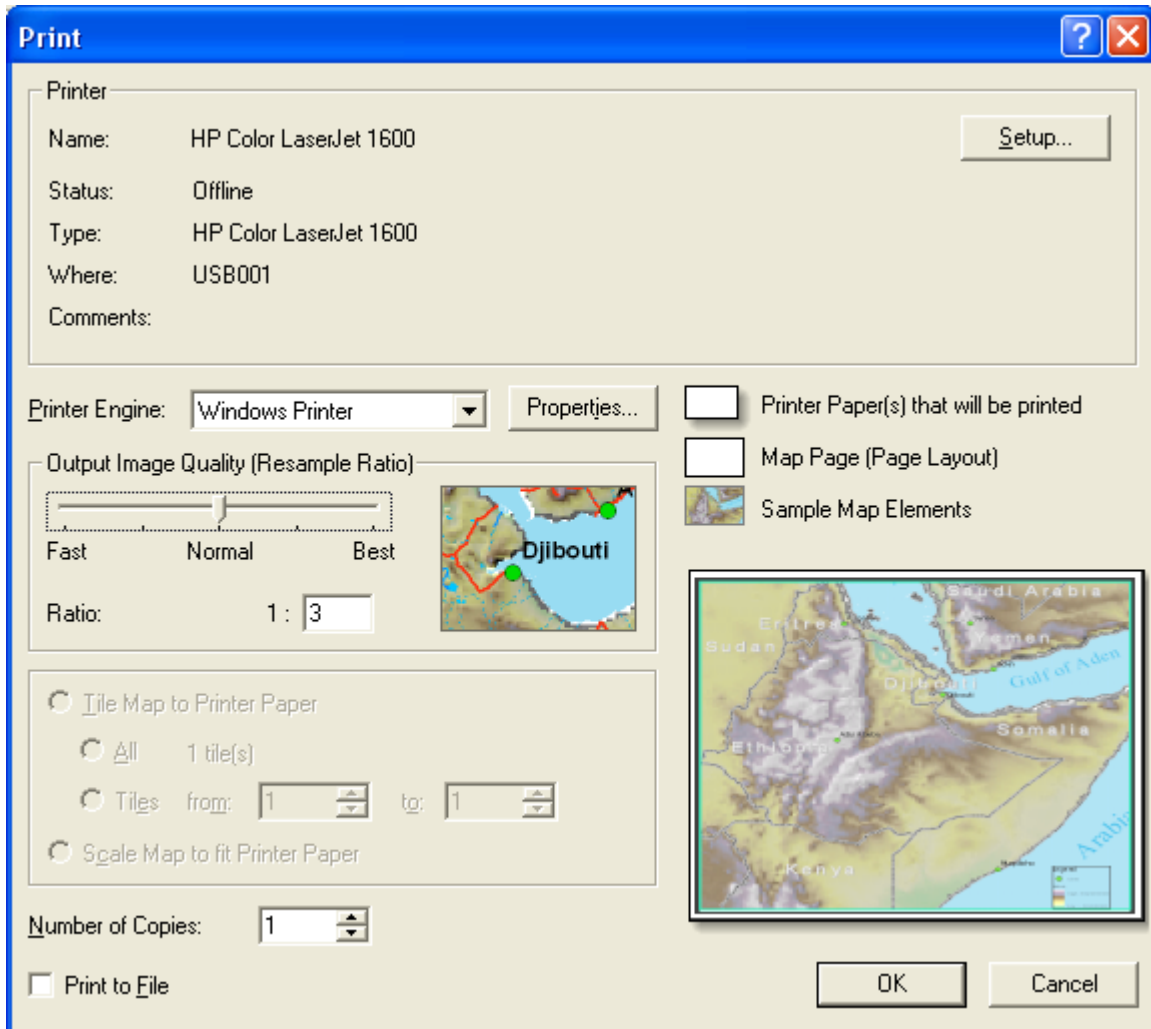The ArcMap Window should appear as shown below.

Figure B-26. ArcMap Window with Formatted Map.

To print the map, go to the "File" pull-down menu and click on "Print."

Figure B-27. File Pull-Down Menu with the Print Option Highlighted.

A window similar to the one below will appear. Be sure the proper printer is selected, then click on the OK button.

Figure B-28. Print Window in ArcMap.

APPENDIX C. SYNTHESIS OF FINDINGS FROM PROJECT 0-6389

This appendix contains a synthesis of the findings from TxDOT Research Project 0-6389, Framework for Comprehensive Bridge Management and Information System (BMIS). In general, the researchers found that the Design and Construction Information System (DCIS), the Bridge Inventory, Inspection, and Appraisal System (BRINSAP), Pontis, PonTex, and BridgeLog information systems provide core data for bridge infrastructure management. Other systems, notably, the Maintenance Management Information System (MMIS), Main Street Texas (MST), and the Financial Information Management System (FIMS), provide supplemental or supporting data for bridge infrastructure management.

Researchers successfully developed a short-term BMIS architecture, with a proof-of-concept prototype, which links bridge-related data sources at TxDOT that enables the production of queries and reports needed for a variety of analytical purposes. The proof-of-concept prototype allows extraction of summary bridge statistics and data for producing bridge cost estimates and related quality control checks.

One major benefit of adopting a BMIS is the drastically reduced time needed for users to obtain information to make appropriate decisions relating to bridge inspection, design, construction, maintenance, and project programming activities. For example, the proof-of-concept prototype developed under the study reduced the time needed from a matter of weeks to a matter of minutes for extraction of summary bridge statistics and data for producing bridge cost estimates. Researchers found that Pontis, which is the main bridge management software developed by AASHTO for the FHWA, is used by several states but mostly implemented at the database level (i.e., storing National Bridge Inventory and element level data), with more sophisticated tools such as forecasting having lower levels of implementation. Sixteen states are not using Pontis at all.

Researchers reviewed NCHRP Synthesis 397, Bridge Management Systems for Transportation Agency Decision Making (Transportation Research Board, Washington, D.C., 2009); the authors of that synthesis conducted a survey of the states. The planning component of the survey asked whether particular features of the agency's BMS were used to support the planning process. A total of 17 agencies responded to this question. About 30 percent to 40 percent of respondents reported using their Bridge Management System (BMS) for higher-level management functions, including budgeting, scenario testing, trade-off analyses, generating quantifiable parameters to provide guidance in project selection, and documenting past and planned bridge projects by political jurisdiction. Fewer than 10 percent of the respondents used their BMS for economic analyses—that is, for life cycle cost (LCC) analysis or computation of avoidable user costs as a function of alternative budget scenarios. These results show that as the level of complexity of BMS modeling increases, such as with the use of LCC analysis, the level of implementation decreases.

From discussions with TxDOT personnel in the Bridge Division and six districts, the researchers concluded that the following need to be included in TxDOT's BMIS:

- Inventory system with elemental descriptions in graphical format.
- Mechanisms for districts to interact with the system (possibly a revision to PonTex). The system would allow districts to update cost and inspection information.
- Bridge project prioritization scheme that is easy to understand and is easy for TxDOT to incorporate.
- Budget forecasting system.
- Additional database attributes and multimedia capabilities.
- Additional functions to store, enter, query, report, and track attributes and multimedia from these databases.
- More effective coordination and integration between information systems.
- Mechanisms to streamline production of reports.
- Coordination with bridge owners and entities responsible for maintenance.

The researchers concluded that the following modules need to be included in TxDOT's BMIS:

- State Level Prioritization Module. This module will include the prioritization techniques described in the final report and will be targeted for prioritization of federally funded Highway Bridge Program (HBP) projects statewide. To reflect TxDOT's long-range policy, development of this module will have to go through a definition of attributes to define priorities and compliance with long-term goals such as existing TxDOT goals like percentage of bridges in good or better condition, or any future defined goals such as Bridge Health Index targets for the network.
- State Level Budget and Performance Forecasting Module. This module will allow the user to forecast overall bridge network conditions under different budget scenarios and compare these conditions with established performance targets. This module would be particularly useful in providing answers to Legislators requests on bridge network performance under different funding availability scenarios.
- District Oriented BMIS. This module would streamline day-to-day operations at the district, allowing expedited information handling that goes beyond what is currently available in Pontex. A good starting point to illustrate this module is the system currently in use by the Fort Worth District, which allows the user to store information like plans, forms, and pictures of the bridge inventory. Improvements to this system will include the addition of geo-referenced information in a graphical user interface and improved ways of scheduling and prioritizing regular maintenance.
- District Prioritization Module. The researchers envision this module to be oriented toward the prioritization of regular maintenance funds available at the district level. This system would incorporate revised decision trees and prioritization techniques based on elemental inspections that are based on the concepts discussed in Chapter 7.

APPENDIX D. METHODOLOGY FOR BMIS SYSTEM

This appendix presents the methodology that the researchers used on how to make a fragmented system into a BMIS system that provides needed data and results for users.

The first step is to identify and review existing data sources. In this step, the researchers found the following TxDOT information systems that contain data pertaining to the design, construction, operation, and maintenance of bridges. Those systems were:
- Design and Construction Information System (DCIS).
- Maintenance Management Information System (MMIS).
- Bridge Inventory, Inspection, and Appraisal System (BRINSAP).
- PonTex.
- Pontis.
- Financial Information Management System (FIMS).
- Texas Permit Routing Optimization System (TxPROS).
- Permanent Structure Number (PSN) application.
- Bridge Shop Plan.

The second step is to identify and review the current TxDOT GIS-based practices, plans, and applications. The researchers found that TxDOT's GIS production data reside on an Oracle database. The structures production GIS data sets include:
- **BRINSAP_MST_PNT**. This data set contains points that represent the location of bridges and structures. The data set includes structures that are on the TxDOT route system (on system) and that are not on the TxDOT route system (off system).
- **BRINSAP_PNT**. This data set also contains points that represent the location of on- and off-system bridges or structures.
- **LRBM**. This data set is a set of points that identify the location of structures that have safety load restrictions, are closed, or are land locked. The data set includes on- and off-system structures.

The third step is to develop a system diagram that shows high-level relationships between the several bridge-related systems identified previously. For this step, researchers produced the diagram shown in Figure D-1 (also in Chapter 2 of this report). Systems not depicted in Figure D-1 include FIMS, TxPROS, and Bridge Shop Plan. FIMS reprocesses bridge-related data, TxPROS is a consumer of bridge-related data, while Bridge Shop Plan is in development. In general, DCIS, BRINSAP, Pontis, PonTex, and BridgeLog provide core data for bridge infrastructure management. Other systems, notably, MMIS, MST, and FIMS, provide supplemental or supporting data for bridge infrastructure management.
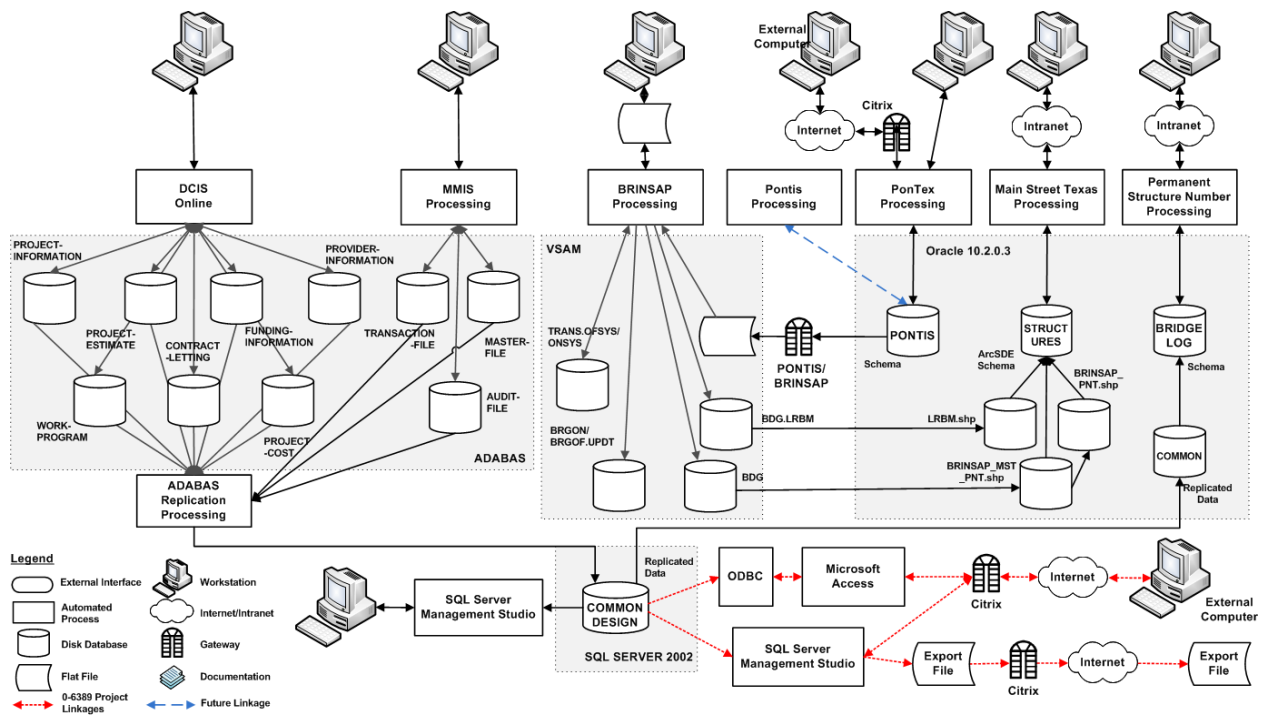
Figure D-1. Bridge-Related Systems at TxDOT.

The fourth step is to develop a short-term BMIS architecture, with a proof-of-concept prototype, which links bridge-related data sources at TxDOT that enables the production of queries and reports needed for a variety of analytical purposes. Based on feedback provided by Bridge Division officials for their greatest data reporting needs, the researchers produced:

- A prototype database application to extract summary bridge statistics needed for the annual bridge report and other similar queries (Figure D-2, which is also in Chapter 3 of this report).
- A prototype database application to extract data for the production of bridge cost estimates and related quality control checks (Figure D-3, which is also in Chapter 4 of this report).
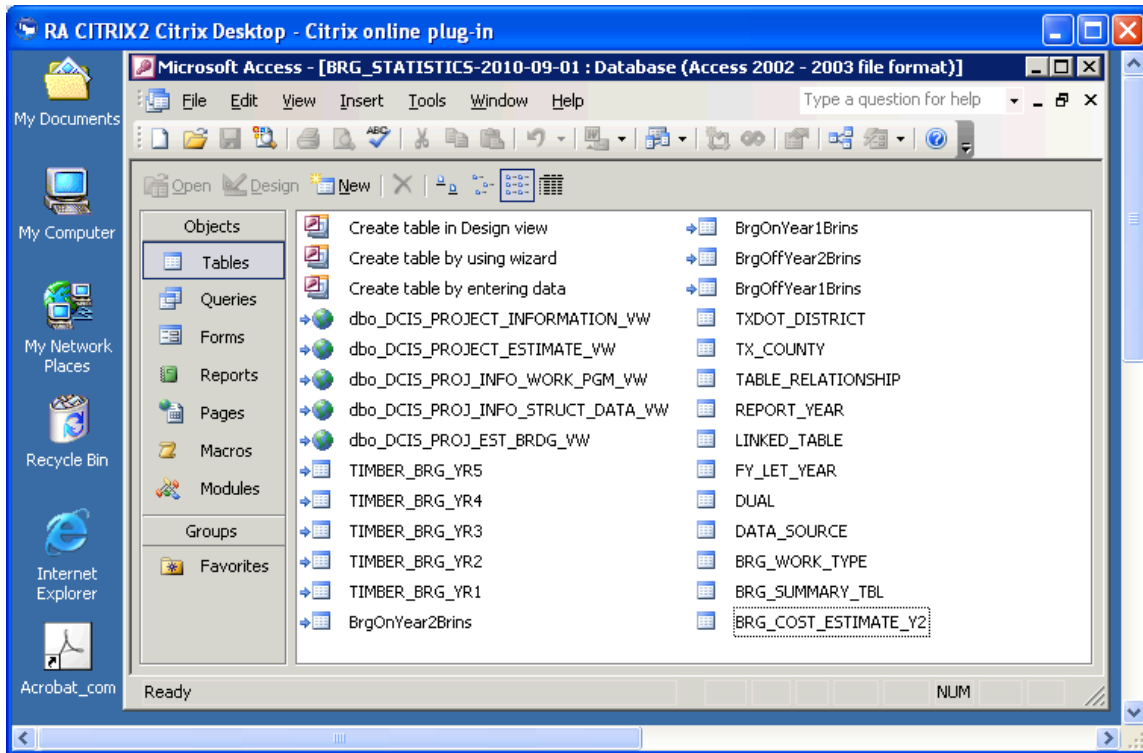
Figure D-2. Citrix Desktop with Microsoft Access Summary Bridge Statistics Prototype.
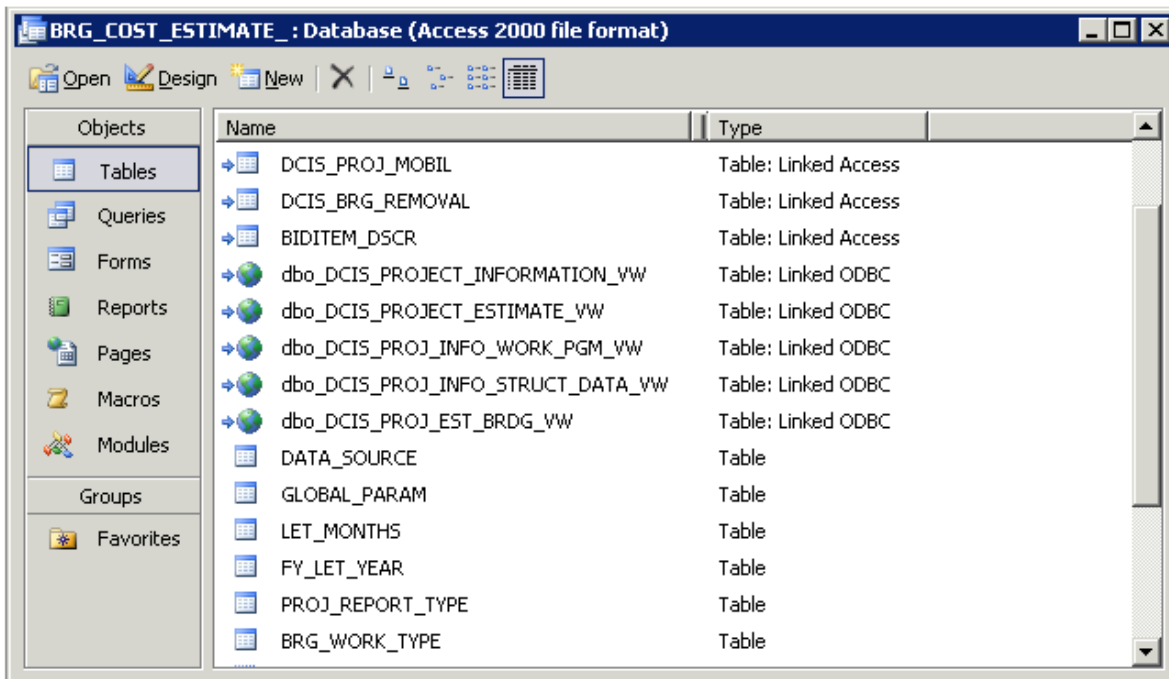
Figure D-3. Tables in the Bridge Cost Estimate Prototype.

The fifth step is to identify user needs for development of a long-term enterprise-wide BMIS architecture. For this step, researchers presented features of a proposed BMIS to TxDOT personnel in the Bridge Division and six districts. Researchers obtained feedback from those presentations to help identify those needs, which are described in more detail in Chapter 6 of this report. In particular, at the highest level, users indicated that comprehensive bridge data management at TxDOT would include the following features:

- Inventory system with elemental descriptions in graphical format (i.e., using a bridge diagram, click on particular elements and obtain inspection and cost information).
- Mechanisms for districts to interact with the system (possibly a revision to PonTex). The system would allow districts to update cost and inspection information.
- Bridge project prioritization scheme that is easy to understand and is easy for TxDOT to incorporate.
- Budget forecasting system.
- Additional database attributes and multimedia capabilities.
- Additional functions to store, enter, query, report, and track attributes and multimedia from these databases.
- More effective coordination and integration between information systems.
- Mechanisms to streamline production of reports.
- Coordination with bridge owners and entities responsible for maintenance.

The sixth step is to identify the data needs, data attributes, and relationships required for each user need. During the meetings with stakeholders, users provided specific details of their needs and data requirements to address those needs. Chapter 6 of this report identifies the user need, the specifics of the user need, and associated missing data attributes to meet that need.

The seventh and final step is to develop a BMIS system using the results of the previous six steps. In particular, TxDOT personnel will need to determine (1) if the next release of Pontis can effectively address the results and (2) develop specifics on the physical structures and implementation specifications based in part on the findings of this research.