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16. Abstract

This report summarizes important content and operational details about five different materials and pavements databases currently used by the Texas Department of Transportation (TxDOT). These databases include the Pavement Management Information System, the Maintenance Management Information System (MMIS), The Road Life Database (RL), The Texas Reference Marker Database, and SiteManager.

Information about each database was largely gained from internal TxDOT literature and from in-person interviews with expert TxDOT staff. Knowledge of the contents, operation, and updating procedures of these databases can be instrumental in evaluating each as a data source for a proposed materials-performance-monitoring database.

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A SUMMARY OF PAVEMENT AND MATERIAL-RELATED DATABASES WITHIN THE TEXAS DEPARTMENT OF TRANSPORTATION

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Research Report Number 1785-1

Research Project 0-1785
Project Title: *Develop Basic Information to Be Used for Developing a Plan to Monitor Performance of Materials*

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
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Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

The purpose of Project 0-1785, *Develop Basic Information to Be Used for Developing a Plan to Monitor Performance of Materials,* is to develop a database-oriented plan to monitor the performance of materials. To accomplish that purpose and to create the proposed database, a diverse set of tasks is required.

One task performed by the Center for Transportation Research (CTR) research team was holding an expert task group (ETG) meeting on January 22, 1998. This meeting generated the ideas, concepts, and opinions that would guide the information development of this project. During that meeting, the attendees unanimously agreed that a key phase of this project would be determining what data are currently being collected for and stored in other Texas Department of Transportation (TxDOT) databases.

TxDOT maintains and collects large volumes of data for a variety of other databases concerning subjects ranging from aviation and railroads to bridges, pavements, and maintenance. Consequently, the expert group attendees suggested that, rather than reinventing the wheel with the proposed materials database, the research team should develop a search engine and determine what data could be “mined” from those other TxDOT databases. Such a search engine could potentially ensure that project objectives take full advantage of TxDOT’s current capabilities, and that final recommendations are compatible with the methods already in place at TxDOT.

Any recommendations regarding important data and other elements should be developed with the capabilities of TxDOT in mind (i.e., not in a vacuum). Consequently, there are three compelling objectives requiring an investigation of the database data sources within TxDOT to be coupled with an analysis of important materials properties. These objectives include:

1. Providing TxDOT with crucial information regarding the locations of vital materials-related data within its testing and information systems so that sources of data will be known when the proposed database is actually created.
2. Locating significant “data mines” from which relevant materials data could be extracted for inclusion in the proposed materials database.

3. Providing TxDOT with some of the means to assess the economic feasibility of collecting and storing data that are considered to be important for a database whose objective is to monitor the performance of transportation materials.

The first objective entails providing TxDOT with a much-needed summary of its often distributed testing and data storage capabilities. With that summary, it will be easier for this research to identify the important data mines for the proposed database/search engine. The third objective notes that information regarding the material data for which TxDOT tests and the storage locations of that data can be invaluable in evaluating what types of data can be more easily stored in the proposed database. Furthermore, such information can help indicate which databases and testing procedures are the most valuable data sources for the proposed database. This principle is further discussed in Chapters 5 and 6 of Report 1785-2. An evaluation of the databases within TxDOT is provided below.

While this report is an important reference for Project 0-1785, it contains additional information that could be helpful to all of TxDOT. Consequently, while the bulk of the information in this report is related to that project, additional background information is provided that has a broader application. For this reason, this is a stand-alone report. Additional information on testing sources of data as well as a summary of this report is contained in the main report for this project (Report 1785-2).

1.1 METHODOLOGY FOR OVERVIEW OF TXDOT DATABASES

Because the proposed material properties database may need to import large amounts of data from other databases, it is important to know not only the contents of these databases, but also how they operate and how they will evolve in the future. Chapters 2 through 6 summarize information regarding each of TxDOT's major pavement and materials databases.

Five TxDOT databases were reviewed for this study; they include the Pavement Management Information System (PMIS), the Road Life Database (RL), the Maintenance Management Information System (MMIS), the Texas Reference Marker Database (TRM), and SiteManager (SM). While the first four of these databases are currently operated in some capacity or another by TxDOT, SiteManager is incomplete and not in operation. However, it was selected for inclusion here because, with its material testing data, it has the potential to be the single most important of the five. While these five databases assuredly do not represent the only bodies of electronically stored materials data within the department, they do represent the bulk of systematic, reliable electronic data storage reservoirs within TxDOT; that is, they are the only dependable, department-wide sources of such data. Other databases that store such data are not likely to be available at the department level, making it more difficult for the proposed database to access them.

As part of this study, each database was evaluated with regard to its background, data elements and structure, uses and applications, updating and maintenance procedures, hardware/software components, and future. As detailed below in the approach description, the sources for this section include prior Center for Transportation Research studies, live interviews with TxDOT personnel, and literature obtained both independently and through those interviews. Some of the critical information regarding these databases is summarized in Table 1.1.

It is important to outline briefly the approach used to complete this evaluation of databases within TxDOT. Fortunately, a brief review of the main pavement and materials databases operated within TxDOT has already been performed by Victorine in *Concepts and Data Elements for Pavement Forensic Investigations in Texas* (Victorine 98). Victorine provided an extensive list of important databases and related data elements. However, this study required a deeper understanding of the operational requirements of these databases as well as more detailed information about the extent of the population of these databases. Consequently, using Victorine's list of TxDOT experts familiar with each database, the research team scheduled for March and April of 1998 a set of interviews with these experts. The purpose of the interviews was to fill in gaps in the research team's knowledge regarding these databases. TxDOT employee experts from the Design (DES), Information Systems Division (ISD), Transportation Planning and Programming (TPP), and various other divisions provided information regarding RL, PMIS, MMIS, TRM, and SiteManager. Each database review followed similar steps:

1. A literature review was performed for each database.
2. A list of important, unanswered questions about each database was generated.
3. That question list was discussed at each interview.

4. Support materials relevant to the use and operation of each database, including printouts, data dictionaries, and user manuals, were provided by the experts during the interviews.
5. Upon completion of the interviews, question-by-question summaries of each answer were compiled, along with additional, unanswered questions. This material was forwarded to each expert.
6. Each expert corrected and approved the list of answers and responded to any new questions about each database.
7. The responses were organized, resulting in a substantial body of new knowledge about each database.
8. Each document discussed at the interviews was analyzed and examined for additional useful information.

The result of this procedure was a body of new knowledge about each database. Table 1.1 synthesizes the database information gathered during the interviews and literature reviews that were a part of this study.

Table 1.1: Summary of Data Aspects of Five TxDOT Materials and Pavements Databases

	PMIS	MMIS	TRM	Road Life	SiteManager
Section/ Division Responsible	DES	CMD	TPP	DES	CST
Data Contents (see partial listing in Appendix B)	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 6	1, 2, 8, 10	1, 2, 8, 10, 12	1, 2, 6, 7, 8, 10, 11
Control Section Size	½ Mile	Distance between TRMs	Continuous	Homog. Sections	Not Applicable
Data Updating Party	District PMIS Coordinator	Maintenance Crew Chief	District TRM Coordinator/ TPP	Ad Lib	Varies
Data Collection Party	District Level	District Level	District Level and TPP	Ad Lib	Varies
Frequency of Data Updating	Annually/ Biannually	As Needed	As Needed	Ad Lib	Varies
Degree of Population	Complete	Complete	Complete	Sparse	Not Applicable
Material ID Scheme	General Types – Not Specific	Not Applicable	General Types – Not Specific	General Types – Not Specific	Serial Number
Imports from	TRM, RL, MMIS	Not Applicable	Traffic Database	TRM	Unknown
Exports to	Not Applicable	PMIS	PMIS, RL	PMIS	Unknown

Key to Table Data Types	
Number Code	Type of Data
1	Pavement/Material Location Data
2	Pavement Type and Characteristics Data
3	Visual Distress Data
4	Nonvisual Distress Data
5	Pavement Condition Scores
6	Maintenance Data
7	Climatic Data
8	Cross-Section Data
9	Traffic Data
10	Materials Testing Data
11	Construction Administration Data
12	Pavement Feature/Geometry Data

CHAPTER 2. THE PMIS DATABASE

Information about the PMIS database was synthesized from a variety of sources. Initial information about the data elements contained within the database was obtained from Victorine (Victorine 98). Additional information came from interviews with TxDOT staff.

One staff member, a former pavement engineer in the Pavements Section of TxDOT's Design Division (DES), proved to be a particularly unique source of PMIS information. Most recently, this engineer was employed by the City of Austin, Texas. The expert's main duties required extensive interactions with both the PMIS and Road Life databases for the Design Division.

One major task that this particular expert undertook annually was creating the survey, *Condition of Texas Pavements,* which is produced in large part from data stored in the PMIS. Furthermore, the interviewee spent a great deal of time analyzing collected and reported PMIS data for glaring inconsistencies, with additional time then spent determining the causes of such outlying data.

The interviews conducted by Victorine and by the researchers in this study have uncovered much published and unpublished background literature on the PMIS database, including *Pavement Management Information Systems (PMIS) User's Manual: September 1994* (TxDOT 94)*, Pavement Management Information System Rater's Manual for Fiscal Year 1995* (TxDOT 95) and *Condition of Texas Pavements: PMIS Annual Report FY 1993–1996* (TxDOT 97). These sources, among others, have provided background information and reference information that have been and will continue to be valuable.

2.1 BACKGROUND AND INTRODUCTION

The PMIS, or Pavement Management Information System Database, is an automated system used by TxDOT for "storing, retrieving, analyzing and reporting information to help with pavement-related decision making processes" (TxDOT 94). It is an analysis tool to aid pavement management in the process of "providing, evaluating, and maintaining pavements in a serviceable condition according to the most cost effective strategy" (TxDOT 94). PMIS supports a wide range of activities, including planning, highway design, maintenance and rehabilitation, evaluations, research, and even extensive, detailed reporting to a variety of decision makers.

The PMIS database, in use since May 1993, fulfills the Federal Highway Administration's (FHWA's) mandate that all states create pavement management systems. However, PMIS is just the current embodiment of what was originally the Pavement Evaluation System (PES). The PES was created in 1982 to provide data concerning the present condition of the Texas highway system, monitor the changes in the condition of highways, and acquire the funds needed to improve the system (Victorine 98). Thus, the current PMIS carries data collected from 1983 to the present (Victorine 98). Originally developed in the now-obsolete Maintenance and Operations Division, the PMIS is now the responsibility of the successor of that division, the Design Division.

2.2 PMIS Data Elements and Data Structure

The PMIS is made unique by the data elements that it alone stores. Since it is a statewide management tool for monitoring and improving Texas roadways, most of its data are related to pavement distress conditions for discrete roadway sections. As is discussed later in this report, PMIS imports and stores large amounts of data that are collected for and stored in other databases. It "mines" summary data in this way to a much larger extent than do the other four TxDOT pavement/materials databases; this is similarly the intent for the proposed material performance database that is considered in this study.

Generally, data stored in the PMIS are collected for and assigned to unique roadway sections. These sections, usually defined in half-mile increments, are identified by TxDOT district, county, and responsible maintenance section, among other variables. More specifically, however, these half-mile sections are identified and demarcated by their location within the Texas Reference Marker System, which is discussed in more detail in the TRM chapter of this report. Consequently, sections are uniquely identified by roadway designation, beginning and ending reference markers, and the corresponding displacements from each. These reference marker and displacement data are actually maintained in the TRM database and are annually imported into PMIS in order to update section location information. More detailed explanations of these location data are available in both the *PMIS Data Dictionary* (TxDOT – PMIS) and in Appendix A of this report.

PMIS stores the pertinent basic location data, visual distress data, nonvisual distress data, condition scores, maintenance data, climatic data, traffic data, pavement type data, and cross-section data that are pertinent to a given roadway section. To that end, it includes extensive data elements to describe visual distress, deflection, skid resistance, rutting, and ride quality. Additionally, PMIS stores corresponding roadway scores for such common distresses as general distress score, ride score, condition score, SSI score, and skid score. Clearly, though, the bulk of PMIS data are concerned with recording pavement distress types and severity for roadway sections throughout the state. However, PMIS also imports some of the summary data elements stored on other databases.

PMIS is extremely well populated. Interviews with PMIS and TRM experts from TxDOT revealed that both TRM and PMIS carry data for "on-system" roadways only. The TRM expert added that on-system roadways, or those on the TRM system, are limited to 77,000 miles of TxDOT-maintained roadways. According to a TRM expert, the remaining 220,000 miles of roadways under TxDOT's care are stored in a different database. Since PMIS receives its section location parameters from TRM, it stores data only on roadways currently on the TRM system. However, for those on-system roads, data population in the PMIS is complete.

2.3 PMIS Uses and Applications

As noted above, the primary purpose of the PMIS is to aid in making pavement-related decisions through its storage of pavement distress data. However, probably the most important function that the PMIS serves is creating the *Condition of Texas Pavements* (TxDOT 97) Annual Report. This report is created for district and department personnel as well as those in the Texas Legislature who are interested in pavement conditions and distress. Thus, while the people who make decisions using this report likely never interact with the database, in some sense they are its users. For instance, according to one TxDOT expert, monetary allocations from TxDOT to the twenty-five districts are partially dependent on the average PMIS scores tabulated for each district and stored in the PMIS.

Additionally, PMIS has a variety of intrinsic reporting options that organize the data it stores into a useful, concise format. For instance, PMIS is capable of creating not only simple raw distress data reports for its half-mile control sections, but also more complex graphical data reports, Needs Estimate Reports, and various administrative reports (TxDOT 94). Consequently, PMIS can serve both as a data-reporting tool and as a simple analysis engine. A more extensive discussion of the reporting options possible in PMIS is available in the *Pavement Management Information Systems User's Manual* (TxDOT 94).

Finally, according to one expert, one of the most significant functions of PMIS is its ability to aid in the creation of pavement performance curves. These curves allow the engineer to predict the future condition of a roadway with respect to time passed and maintenance dollars allocated. PMIS, by providing TxDOT with data on the condition of Texas roads at discrete points in time after allocation of maintenance dollars, allows TxDOT to identify the predefined pavement performance curve upon which the road must lie. This allows TxDOT to predict the future performance of a roadway. Thus, such curves, by giving the engineer a way to predict the future, allow sound decisions to be made regarding pavement management. An example of a particularly relevant pavement performance curve is developed and described in *Distress Prediction Models for Rigid Pavements for Texas Pavement Management Information System* (Robinson 96).

2.4 PMIS UPDATING AND MAINTENANCE PROCEDURE

Data collection for PMIS has always been performed on a district basis. Each district staffs a PMIS coordinator, who organizes the annual data collection for that district. The PMIS coordinator assembles ad hoc personnel to collect the required distress and condition data on half of the highway miles and on all of the interstate miles (i.e., 50% highway and 100% interstate sample sizes annually) in a given district. Then, starting on September 1 of a given calendar year, that group collects data as is specified in the *Pavement Management Information System Rater's Manual for Fiscal Year 1995* (TxDOT 95). As PMIS data are collected throughout the year, they are continuously entered into the system remotely. Generally, the 50% of highway sections that are surveyed each year do not change every other year, except in those cases of unspecified contingencies such as major highway realignments. While some amount of data collection occurs in districts throughout the year, nearly half of the districts, according to one TxDOT expert, had already collected 100% of the required distress data for this year as of March. A sample printout from the PMIS database listing the percentages of required PMIS sections to be rated by district is shown in Figure 2.1.

TEXAS DEPARTMENT OF TRANSPORTATION 13:24 TUESDAY, MARCH 24, 1998 1
PAVEMENT MANAGEMENT INFORMATION SYSTEM (PMIS)
SUMMARY STATUS OF REQUIRED SECTIONS TO BE RATED

FISCAL-YEAR 1998

DISTRICT	ACP VISUAL STORED	ACP AUTORUT STORED	ACP RUTTING STORED	ACP DISTRESS SCORES AVAILABLE	ACP RIDE SCORES AVAILABLE	ACP CONDITION SCORES AVAILABLE	RIGID DISTRESS SCORES AVAILABLE	RIGID RIDE SCORES AVAILABLE	RIGID CONDITION SCORES AVAILABLE	TOTAL DISTRESS SCORES AVAILABLE	TOTAL RIDE SCORES AVAILABLE	TOTAL CONDITION SCORES AVAILABLE
	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT	PERCENT
PARIS	87.5	93.7	93.7	84.4	97.5	84.3	69.1	99.1	68.2	84.2	97.5	84.0
FORT WORTH	89.6	71.9	71.9	70.0	81.1	69.6	73.4	58.7	55.4	70.7	76.7	66.8
WICHITA FALLS	97.1	0.0	0.1	0.1	0.0	0.0	91.3	0.0	0.0	8.6	0.0	0.0
AMARILLO	99.9	96.1	96.1	96.1	100.0	96.1	100.0	100.0	100.0	96.2	100.0	96.2
LUBBOCK	100.0	83.4	83.4	83.4	99.4	83.4	100.0	99.6	99.6	84.4	99.4	84.4
ODESSA	99.6	98.1	98.1	97.9	98.5	97.7	100.0	100.0	100.0	97.9	98.5	97.7
SAN ANGELO	97.8	87.5	87.5	86.0	91.1	85.7	.	.	.	86.0	91.1	85.7
ABILENE	99.2	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.1	0.0	0.0
WACO	72.6	61.3	61.3	48.8	62.4	47.6	0.0	48.1	0.0	48.1	62.2	46.9
TYLER	97.8	93.6	93.6	92.9	94.0	92.7	86.6	0.0	0.0	92.9	93.7	92.4
LUFKIN	99.2	98.2	98.2	97.6	98.0	96.2	.	.	.	97.6	98.0	96.2
HOUSTON	92.5	68.8	96.7	91.6	87.7	80.2	92.6	82.0	75.5	92.0	85.7	78.6
YOAKUM	99.8	88.9	88.9	88.9	88.9	88.7	85.7	80.0	80.0	88.9	88.8	88.7
AUSTIN	91.2	94.4	94.4	88.4	94.7	88.4	.	.	.	88.4	94.7	88.4
SAN ANTONIO	96.4	82.0	97.7	95.7	88.8	86.5	26.7	100.0	26.7	95.3	88.8	86.2
CORPUS CHRISTI	100.0	97.8	97.8	97.8	99.1	97.2	100.0	100.0	100.0	97.9	99.1	97.2
BRYAN	94.5	94.1	94.1	89.7	97.0	89.0	95.4	100.0	95.4	89.8	97.0	89.1
DALLAS	85.1	60.9	64.3	59.3	66.6	59.1	83.8	82.6	73.1	66.2	71.1	63.0
ATLANTA	97.2	81.0	81.0	78.6	85.5	78.6	0.0	88.8	0.0	77.3	85.6	77.3
BEAUMONT	0.0	80.8	80.8	0.0	76.3	0.0	0.0	89.4	0.0	0.0	77.7	0.0
PHARR	98.7	93.1	93.1	91.8	95.1	91.5	100.0	96.2	96.2	91.8	95.1	91.5
LAREDO	97.0	98.0	98.0	96.4	97.7	96.0	.	.	.	96.4	97.7	96.0
BROWNWOOD	97.2	90.8	93.6	93.1	93.6	92.4	.	.	.	93.1	93.6	92.4
EL PASO	99.8	94.8	94.8	94.8	98.0	94.7	100.0	100.0	100.0	95.0	98.1	95.0
CHILDRESS	98.7	84.1	84.1	83.5	99.3	83.5	100.0	100.0	100.0	84.2	99.4	84.2
ALL	91.5	79.7	81.7	76.3	83.6	75.2	75.2	76.2	58.5	76.9	83.6	75.1

Figure 2.1: Summary of County-by-County Sections to Be Rated on 3-24-98

PMIS is capable of displaying and printing numerous similar inventory reports. An important note worth mentioning is that on miles of roadway upon which data are collected, it is collected only for the lane having the greatest amount of a given distress.

2.5 PMIS COMPUTER HARDWARE AND SOFTWARE

As is the case with many TxDOT pavement- and material-related databases, PMIS is stored in the TxDOT mainframe in two ADABAS-type files. More specifically, it is stored in a data collection file (file No. 216) and in a file of the one-year section limits and traffic data that are updated with data imported from the TRM database (file No. 217). PMIS may be accessed remotely through either CICS or ROSCOE software. Consequently, PMIS is accessible from any properly connected personal computer.

CICS is an acronym for Customer Information and Control System. According to TxDOT's *Pavement Management Information Systems User's Manual* (TxDOT 94), "CICS provides a direct access environment with easy to use menus for accessing PMIS" (TxDOT 94). With CICS, preliminary database manipulations and inquiries can be performed directly. However, more complex functions are handled by submitting batch jobs from the menus. Another operating system is the Remote Operating System Conversational On-Line Environment (ROSCOE). According to the PMIS User's Manual, "ROSCOE provides a batch job environment for reviewing jobs submitted from the PMIS/CICS environment" (TxDOT 94). Clearly, each of these operating systems provides different advantages to the user because one (ROSCOE) sacrifices user friendliness for tasking power, while the other (CICS) does the opposite.

2.6 THE FUTURE OF PMIS

The future of the PMIS database is unclear. There has been speculation about it being merged with other databases, such as the Road Life database. Victorine indicated that such a merger would occur and that the control sections used on PMIS at some point would be switched from half-mile to kilometer increments (Victorine 98). One TxDOT expert expressed a few ideas on the future of PMIS. This expert anticipated PMIS becoming PC-based, at which point Road Life would be merged with it. However, the expert noted that

Road Life and PMIS would continue to maintain separate identities and would be merged only when data were jointly extracted from each of them for reporting purposes. With regard to PMIS operating more closely with Road Life, the expert lamented the fact that Road Life is very incomplete at this point, making integration very difficult. Later, when asked about the possible interactions between PMIS and the developing SiteManager software, the expert indicated insufficient familiarity with SiteManager to know much about that future interaction. However, the expert did speculate that data from SiteManager, such as last seal coat and overlay, could be helpful in establishing pavement performance curves for analysis with PMIS data. Clearly, uncertainty from a PMIS expert indicates that the future of PMIS and especially its future interaction with SiteManager are not fully known. Another TxDOT expert, from the TPP Division, indicated that, along with TRM, PMIS might be merged with a variety of other TxDOT data programs and files into the "Planet Suite."

2.7 PMIS MISCELLANEOUS

One interesting aspect of the PMIS database is its interaction with the other major pavement/materials databases within TxDOT. PMIS receives traffic and lane data from TRM as well as the "coordinates" defining the half-mile and smaller control sections that compose the core of PMIS (Victorine 97). Additionally, it receives section thickness and dates of construction from the Road Life database, allowing the PMIS user to better predict future pavement performance and performance response to maintenance allocations. Finally, PMIS receives data from MMIS regarding the costs of maintenance on a given control section. Maintenance costs are divided equally among all PMIS half-mile sections that fit into the section for which maintenance costs were reported. A TxDOT expert indicated during interviews that data from MMIS and TRM are downloaded into PMIS and into the appropriate data elements annually every August to limit the frequency with which the database is subjected to changes. Meanwhile, PMIS and Road Life data appear to be merged via special computer programs that negotiate their different length sections as required for analysis.

The consequence of all of the aforementioned connections between databases is that PMIS serves as a strong model for how a database like the proposed material performance database could be connected to a variety of other databases. The type of data “mining” that PMIS seems to rely on is at the very heart of this study. At this point, however, it is not clear how much work is involved in converting data from one database to another. Currently, as a TxDOT expert indicated, special computer programs must be written to allow for such transfers, so that the appropriate data in one format (i.e., a given section length) can be converted to that of another (on another database).

CHAPTER 3. THE ROAD LIFE DATABASE

The information for this chapter has, like that of the PMIS, been compiled from numerous sources. Victorine provided both basic and very detailed information regarding the data elements contained in Road Life (Victorine 98). Additional information came from interviews with TxDOT staff.

For this study, we found one TxDOT expert more knowledgeable than others on the status of Road Life. That expert had recently been placed in charge of the Road Life database for the Design Division of TxDOT.

At the time of the interview, the expert was heavily involved in projects attempting to simplify and streamline complex and confusing data entry screens associated with Road Life. More specifically, the expert wanted to merge all the data entry screens of the RLSE into one screen so that all of the data entry fields for a given roadway section were in one place. Additionally, the expert was working on a scheme to simplify the pavement layer section codes.

Additional information on the Road Life database can be found in the background literature collected during both projects. This literature includes the *Road Life Data Dictionary* (TxDOT – RL) and numerous guides to the Road Life Data Entry System.

3.1 BACKGROUND AND INTRODUCTION

The Road Life database (RL) was designed to aid investigations into the following: performance of pavements, rehabilitation design, life-cycle costs, and preventive maintenance. It was created to offer an immediate solution to the data collection needs of TxDOT (Victorine 98). RL was initially developed in the Traffic Programming and Planning (TPP) Division of TxDOT in the early 1990s before the Design (DES) Division adopted its maintenance in November 1995. Road Life was finally completed in June 1996 (Victorine 97). One TxDOT expert interviewee indicated that Road Life development was delayed somewhat while the TRM database was being developed and that its necessity has since been questioned, thus precluding additional, robust development. The system was originally designed as a prototype and, as such, has been used on a voluntary basis by only a handful of districts. Thus, while it is nominally under the supervision of the Design Division, the operation of Road Life is highly decentralized.

3.2 ROAD LIFE DATA ELEMENTS AND DATA STRUCTURE

It seems clear that the Road Life database is unique compared with other pavement/materials databases managed by TxDOT, primarily because of its unique data contents. No other TxDOT database stores as extensive a set of data on the material types, thickness, and construction dates for pavement cross sections as Road Life. Additionally, no other TxDOT database is updated and managed as informally as is this database.

Generally, data in Road Life consist of cross-section information as it pertains to discrete sections of Texas highways. However, unlike PMIS data, Road Life data are stored in whatever lengths are convenient to yield homogeneously constructed pavement sections, such as the interval from intersection to intersection. Consequently, while generally homogeneous, the sections used in Road Life are incompatible with those in databases to which Road Life exports data. The control sections, however, are delineated by the displacements from markers in the TRM system. The control sections used in Road Life are identified as "Control-Section-Jobs." Under this format, each section has a control section number related to the particular section of highway and a job number that reflects the number of times work has been performed on that control section.

The data stored in Road Life come in three types: maintenance data, cross-section data, and pavement type and characteristics data. Road Life, however, is dominated by the cross-section data that it contains. For instance, it contains "as built" section data in the following layer-based categories: original surface, base, subbase, subgrade, milled layer, last overlay, and last seal coat. Each such category contains extensive, layer-specific data elements including information on the type of materials used, the dimensions of the layer, and other variables. A more detailed listing of all of the data elements stored on Road Life is available in Appendix A. An example of a Road Life listing of important data elements for five different Control-Section-Jobs is shown in Figure 3.1. Note that for each section, the layer thickness, widths, relevant dates, and materials used are included as data.

TEXAS DEPARTMENT OF TRANSPORTATION
ROADWAY LIFE DATA ENTRY SYSTEM
DSN=D48.RLS.DATA.KSDS

10:14 THURSDAY, SEPTEMBER 5, 19

CSJ	HIGHWAY	BEGINNING REFERENCE MARKER	ENDING REFERENCE MARKER	RDBD	LAYER	MATERIAL USED	WIDTH (FEET)	THICKNESS (INCHES)	DATE
0016-02-023	IH0035	0212 +00.321	0221 +00.968	L	SUBGRADE	UNKNOWN	65.0	6.0	09/1961
					SUBBASE	CRUSHED LIMESTONE	40.0	12.0	09/1961
					BASE	CRUSHED LIMESTONE	40.0	12.0	09/1961
					ORIGINAL SURFACE	SURFACE TREATMENT	40.0	.	09/1961
					ORIGINAL SURFACE	ASPHALT CONCRETE PAVEMENT	24.0	2.5	09/1961
				R	SUBGRADE	UNKNOWN	65.0	6.0	09/1961
					SUBBASE	CRUSHED LIMESTONE	40.0	12.0	09/1961
					BASE	CRUSHED LIMESTONE	40.0	12.0	09/1961
					ORIGINAL SURFACE	SURFACE TREATMENT	40.0	.	09/1961
					ORIGINAL SURFACE	ASPHALT CONCRETE PAVEMENT	24.0	2.5	09/1961
0016-02-025	IH0035	0206 +00.621	0212 +00.321	L	SUBGRADE	UNKNOWN	65.0	6.0	02/1962
					SUBBASE	CRUSHED LIMESTONE	40.0	12.0	02/1962
					BASE	CRUSHED LIMESTONE	40.0	12.0	02/1962
					ORIGINAL SURFACE	SURFACE TREATMENT	40.0	.	02/1962
					ORIGINAL SURFACE	ASPHALT CONCRETE PAVEMENT	40.0	2.3	02/1962
				R	SUBGRADE	UNKNOWN	65.0	6.0	02/1962
					SUBBASE	CRUSHED LIMESTONE	40.0	12.0	02/1962
					BASE	CRUSHED LIMESTONE	40.0	12.0	02/1962
					ORIGINAL SURFACE	SURFACE TREATMENT	40.0	.	02/1962
					ORIGINAL SURFACE	ASPHALT CONCRETE PAVEMENT	40.0	2.3	02/1962
0016-02-059	IH0035	0206 +00.621	0221 +00.968	L	OVERLAY	SURFACE TREATMENT	40.0	.	06/1975
					OVERLAY	ASPHALT CONCRETE PAVEMENT	24.0	1.5	06/1975
				R	OVERLAY	SURFACE TREATMENT	40.0	.	06/1975
					OVERLAY	ASPHALT CONCRETE PAVEMENT	24.0	1.5	06/1975
0016-02-064	IH0035	0206 +00.621	0221 +00.968	L	OVERLAY	ASPHALT CONCRETE PAVEMENT	40.0	3.0	02/1984
				R	OVERLAY	ASPHALT CONCRETE PAVEMENT	40.0	3.0	02/1984
0016-02-070	IH0035	0213 +00.521	0217 +00.622	L	SUBGRADE	UNKNOWN	.	.	05/1991
					BASE	CRUSHED LIMESTONE	.	.	05/1991
					BASE	CRUSHED LIMESTONE	.	.	05/1991
					OVERLAY	ASPHALT CONCRETE PAVEMENT	55.0	2.0	05/1991
					OVERLAY	ASPHALT CONCRETE PAVEMENT	55.0	2.0	05/1991
				R			.	.	05/1991
							.	.	05/1991
					OVERLAY	ASPHALT CONCRETE PAVEMENT	55.0	2.0	05/1991
					OVERLAY	ASPHALT CONCRETE PAVEMENT	55.0	2.0	05/1991

Figure 3.1: Road Life Printout of Stored Data for Various Control-Section-Jobs (control sections)

Because Road Life is a relatively new database and its use by the districts is optional, it is virtually unpopulated. According to a TxDOT expert, only Districts 1, 7, 10, 12, 14, 16, 20, 22, and 23 have any data stored in Road Life. Of those, only Districts 1, 12, 14, and 23 have any significant bodies of data stored. Specifically, according to that expert, those districts have data in 7, 115, 31, and 227 control sections respectively.

3.3 ROAD LIFE USES AND APPLICATIONS

While Road Life is very poorly populated because of its optional, almost experimental status, it clearly contains detailed cross-sectional data that could be valuable for a material-performance monitoring database. For instance, according to one TxDOT expert, one of Road Life's most powerful applications is the use of its data in conjunction with the PMIS database to form accurate pavement performance curves. The date of construction information provided by Road Life allows a "new" condition to be established for the pavement section. This information can help identify a reasonable pavement performance curve for that section. (This type of data is apparent in Figure 3.1.) Consequently, Road Life and its contents —- used in conjunction with other databases — are better able to perform the various functions that it was developed to perform, including investigating performance of pavement, creating rehabilitation designs, analyzing life-cycle costs, and planning preventive maintenance.

3.4 ROAD LIFE UPDATING AND MAINTENANCE PROCEDURE

While literature regarding the updating of the Road Life database is extremely sparse, the one TxDOT expert was quite knowledgeable on this topic. That expert stressed the fact that individual districts are entirely free to update Road Life at their own leisure. Theoretically, Road Life, unlike PMIS, may be updated continuously. For instance, in the Brownwood District, which has input the most Road Life data, the data were entered into the system by having personnel examine old and new construction plans for the appropriate data. However, since using Road Life is optional, the degree to which a district populates it influences the effort involved in updating it. For example, a TxDOT expert noted that some districts may only want to enter data on roadways as new construction and maintenance occur, while others may want to enter data on pre-existing, unaltered roadways. One TxDOT expert indicated that all of the data required to make Road Life completely populated for the entire state are available within TxDOT on paper files and "as built" drawings. Although districts are responsible for Road Life data collection, this does not preclude other TxDOT entities from entering data. One TxDOT interviewee indicated that in the future, his office anticipates using temporary workers, such as summer interns, to examine old "as built" plans in order to add data to Road Life.

3.5 ROAD LIFE COMPUTER HARDWARE AND SOFTWARE

Like many of the other department-wide materials and pavement databases operated by TxDOT, Road Life is a mainframe database and is accessible through the CICS and ROSCOE formats, which are described in greater detail in Chapter 2. Like the PMIS, Road Life may be accessed from a properly connected personal computer. On the other hand, Road Life differs somewhat from the other TxDOT databases in that its files are SYBASE, rather than ADABAS based.

3.6 THE FUTURE OF ROAD LIFE

The future of the Road Life database is uncertain. Interestingly, Road Life is the focus of TxDOT Project 0-1779, which is developing guidelines for the data elements and population of the Road Life database. Clearly, though, the future of Road Life seems to hinge on how many TxDOT districts begin using and populating it. A TxDOT expert stated that he does not think it likely that districts will be required to populate Road Life in the near future. The expert did state that, through his work in the Design Division, he plans to enter some data into Road Life using "as built" drawings. Unfortunately, the expert qualified this by stating that such an effort would be at least 2 years in the future. Additionally, as noted above, one expert did express a desire to merge all data entry screens associated with Road Life into one screen. A sample of how this single data-entry screen may appear is shown in Figure 3.2.

Pavement Layer Database
DCIS Typical Section Screen

```
 1   ADD MODE             PROJECT TYPICAL SECTION (P8)   ENGLISH  PROJECT    DCIS.09B
 2   CTL-SEC-JOB ____-__-___    HWY NO __ _____     DIST __  CNTY ___        TYP-SEC  __
 3   BEG STA ____ +___.___   END STA ____ +___.___        LENGTH OF TSEC  MI  ___.___
 4   ROADBED _ _ _ _          NUMBER OF LANES __          TYP LANE WIDTH  FT   __._
 5
 6     LAYER   TYPE TRT DRAIN WIDTH  THICK  BINDER   AG-TYP AG-GRD RAP
 7    1  SC1   ___  __  _____ ___._  ___._  ________  ___    __    __
 8    2  OV2   ___  __  _____ ___._  ___._  ________  ___    __    __
 9    3  OV1   ___  __  _____ ___._  ___._  ________  ___    __    __
10    4  IL1   ___  __  _____ ___._  ___._  ________  ___    __    __
11    5  OS2   ___  __  _____ ___._  ___._  ________  ___    __    __
12    6  OS1   ___  __  _____ ___._  ___._  ________  ___    __    __
13    7  BS2   ___  __  _____ ___._  ___._  ________  ___    __    __
14    8  BS1   ___  __  _____ ___._  ___._  ________  ___    __    __
15    9  SB2   ___  __  _____ ___._  ___._  ________  ___    __    __
16   10  SB1   ___  __  _____ ___._  ___._  ________  ___    __    __
17   SUBGRADE  ___  __  STAB = __._  SWELL POTENTIAL _     TRIAX _._
18
19    SHOULDER LEFT ___ _  LEFT WIDTH  __._  SHOULDER RIGHT ___ _  RIGHT WIDTH __._
20        TIED LEFT _      TIE SPACING __._      TIED RIGHT _      TIE SPACING __._
21   COMMENT: ______________________________________________________________________
22   ENTER-PF1---PF2---PF3---PF4---PF5---PF6---PF7---PF8---PF9---PF10--PF11--PF12---
23         ID    FIN   EVAL  EST   SUM   PDP   STIP  TYP               METR  MENU
```

- Up to 10 layers of any combination could be entered.
- Underlined codes for layers could be modified.
- Underlined codes for layers would default to that last used.
- All fields would include sufficient spaces for either english or metric units.

Figure 3.2: The Proposed Future "One Location" Road Life Data Entry Screen

One TxDOT expert indicated that at a future date, such as when PMIS becomes PC-based, Road Life would be merged with PMIS. Road Life will then maintain its separate identity, but would be merged with files No. 216 and No. 217 of PMIS for reporting purposes. No TxDOT interviewee had any information that revealed a plan by which Road Life will interact with the SiteManager database.

CHAPTER 4. THE MMIS DATABASE

Information regarding the MMIS database originates from a variety of sources. Victorine (Victorine 98) collected the initial data, including extensive information on the data elements contained within MMIS. Additional information has come from interviews, especially one with a programmer with the Information Systems Division (ISD) of TxDOT. At the time of the interview, that staff expert was one of the foremost authorities on the MMIS database in ISD and was the MMIS project manager for TxDOT.

At the time of the interview, much of that expert's efforts were consumed with updating MMIS for Year 2000 changes. Additionally, interviews conducted both during this study and by Victorine have yielded a modest amount of background literature on the MMIS database, including a copy of the *MMIS Data Dictionary* (TxDOT – MMIS) and a few printouts of its access screens.

4.1 BACKGROUND AND INTRODUCTION

The Maintenance Management Information System (MMIS) is a TxDOT database system originally operated by what was formerly known as the Construction and Maintenance Division. MMIS is designed to monitor all the maintenance activities performed on all the roadways that fall under the jurisdiction of TxDOT. Full data collection for MMIS began on September 1, 1989 (Victorine 98). While MMIS was operated by the Construction and Maintenance Division, it seems clear that because of one expert's involvement in the database, ISD is involved with both the current operation and previous development of MMIS.

4.2 MMIS DATA ELEMENTS AND STRUCTURE

As with most of the databases maintained by TxDOT, MMIS is unique because of the type of data that it stores. It is the only TxDOT database that stores extensive maintenance data on every Texas Reference Marker. In fact, other databases, such as PMIS and Road Life, import maintenance data from MMIS.

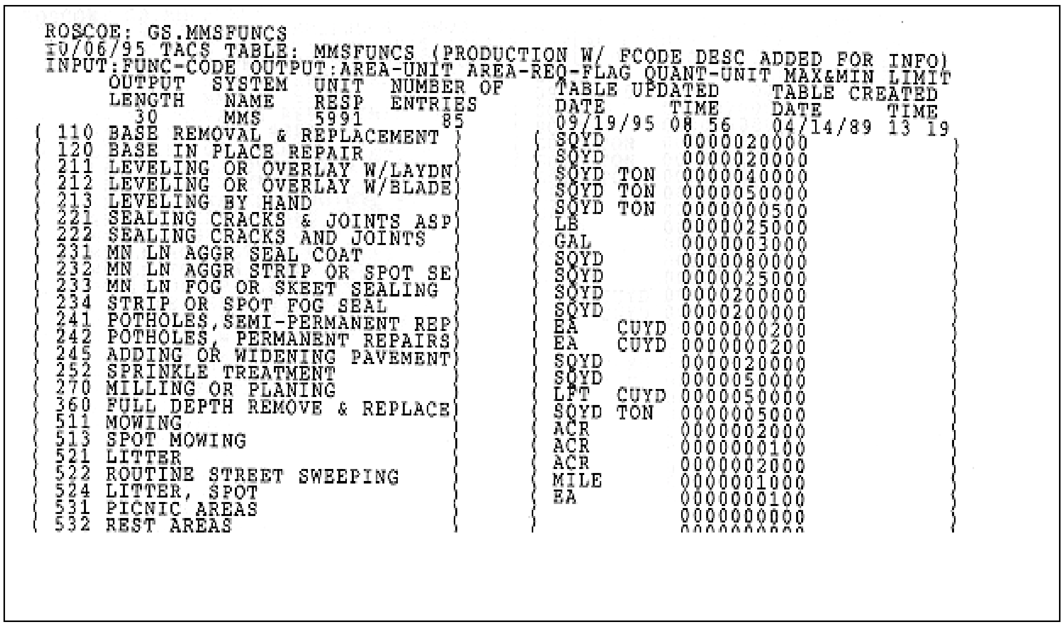
According to one expert, data on the MMIS are stored somewhat randomly in the TxDOT mainframe. Special data elements called *super-descriptors,* which come in a variety of forms, are used to sort and organize that data for reporting and analysis purposes. Super-descriptors consist of any combination of MMIS data elements and gather for display data that share common values in those data elements. A listing and description of the super-descriptors available in the MMIS may be found in the *MMIS Data Dictionary* (TxDOT – MMIS). For instance, the super-descriptor "superza" consists of the fields that contain the year, district, maintenance section, county, highway information, reference marker, and function code. Consequently, it will access records that share any valid combination of year, district, maintenance section, county, highway information, reference marker, and function code, allowing the user to view the cost and material usage amounts for maintenance activities on that record.

In the MMIS database, data are entered for maintenance information as it pertains to a given maintenance project; however, data are stored in terms of the Texas Reference Markers upon which a given maintenance project was performed. That is, associated with any unique Texas Reference Marker will be a set of maintenance-related data. A complete summary of these data elements is available in Appendix A. Specific materials are not stored within MMIS.

Maintenance work is recorded in only as much detail as is the type of work performed. In order to determine the type of maintenance materials used on a project associated with a reference marker (a determination that might be needed for the proposed database), a connection between the type of maintenance and the materials used would have to be made. Clearly, the appropriate materials for a given function code (type of maintenance work) can vary with geography and other factors, even within the same maintenance job. Consequently, to make any correlation between materials and performance, the link between the function code for maintenance work on a given section and the material used would have to be established independently of the MMIS.

It is also worth noting how unique sections are generated within the MMIS database. Data records are made unique on MMIS by their valid combination of fiscal year (associated with a project), district, maintenance section, county, highway name, reference marker

(TRM), function code, contract number (if applicable), and the reference markers that bound the unique section in which the recorded TRM falls. For example, the same highway in the same district in the same maintenance section is considered to be a separate, bounded section when it crosses county lines, so it has a new set of identifying beginning and ending reference markers. Figure 4.1 displays a listing and explanation of the function codes that may be stored in the MMIS database, as it appears in the *MMIS Data Dictionary* (TxDOT – MMIS).



```
ROSCOE: GS.MMSFUNCS
10/06/95 TACS TABLE: MMSFUNCS (PRODUCTION W/ FCODE DESC ADDED FOR INFO)
INPUT:FUNC-CODE OUTPUT:AREA-UNIT AREA-REQ-FLAG QUANT-UNIT MAX&MIN LIMIT
      OUTPUT  SYSTEM  UNIT  NUMBER OF     TABLE UPDATED     TABLE CREATED
      LENGTH   NAME   RESP  ENTRIES       DATE      TIME    DATE      TIME
        30     MMS    5991       85       09/19/95 08 56    04/14/89 13 19
( 110 BASE REMOVAL & REPLACEMENT )      ( SQYD      0000020000
( 120 BASE IN PLACE REPAIR       )      ( SQYD      0000020000           )
( 211 LEVELING OR OVERLAY W/LAYDN)      ( SQYD TON  0000040000           )
( 212 LEVELING OR OVERLAY W/BLADE)      ( SQYD TON  0000050000           )
( 213 LEVELING BY HAND           )      ( SQYD TON  0000000500           )
( 221 SEALING CRACKS & JOINTS ASP)      ( LB        0000025000           )
( 222 SEALING CRACKS AND JOINTS  )      ( GAL       0000003000           )
( 231 MN LN AGGR SEAL COAT       )      ( SQYD      0000080000           )
( 232 MN LN AGGR STRIP OR SPOT SE)      ( SQYD      0000025000           )
( 233 MN LN FOG OR SKEET SEALING )      ( SQYD      0000200000           )
( 234 STRIP OR SPOT FOG SEAL     )      ( SQYD      0000200000           )
( 241 POTHOLES,SEMI-PERMANENT REP)      ( EA   CUYD 0000000200           )
( 242 POTHOLES, PERMANENT REPAIRS)      ( EA   CUYD 0000000200           )
( 245 ADDING OR WIDENING PAVEMENT)      ( SQYD      0000020000           )
( 252 SPRINKLE TREATMENT         )      ( SQYD      0000050000           )
( 270 MILLING OR PLANING         )      ( LFT  CUYD 0000050000           )
( 360 FULL DEPTH REMOVE & REPLACE)      ( SQYD TON  0000005000           )
( 511 MOWING                     )      ( ACR       0000002000           )
( 513 SPOT MOWING                )      ( ACR       0000000100           )
( 521 LITTER                     )      ( ACR       0000002000           )
( 522 ROUTINE STREET SWEEPING    )      ( MILE      0000001000           )
( 524 LITTER, SPOT               )      ( EA        0000000100           )
( 531 PICNIC AREAS               )      (           0000000000           )
( 532 REST AREAS                 )      )                                )
```

Figure 4.1: Explanation of MMIS Function Codes from the *MMIS Data Dictionary* (TxDOT – MMIS)

The MMIS is extremely well populated. Currently, MMIS stores records on every referenced (via TRM) mile of Texas highways. It keeps records of work performed (both contractual and "in house") for both the current and previous fiscal year. Only maintenance activities are recorded, which means new construction is not a part of the scope of this database. While the existence of all referenced road miles statewide is stored by MMIS, maintenance must have occurred on a particular reference marker for it to hold substantial information. All told, according to one TxDOT expert, each fiscal year contains roughly

750,000 unique (as defined above) records. Additionally, TxDOT stores 10 previous years' records on tape (not on mainframe). The historical data are difficult to access and are generally reserved for legislative and legal reporting in an ad hoc, nonstandard form.

4.3 MMIS USES AND APPLICATIONS

The MMIS provides for a variety of reporting options. For instance, MMIS can create a listing of all the road sections (by TRM) in the state of Texas. Additionally, MMIS can produce statewide reports ranking highway types and different functions (types of maintenance work) by dollars spent, just to name two capabilities. It would be an overstatement to say that MMIS has any real analysis capabilities. Rather, the MMIS is used as a tool to create reports involving such things as the reference markers within Texas and the maintenance work and costs associated with each. It would be more accurate to say that the MMIS is really only capable of querying and organizing data that it stores for reporting. A printout from the MMIS system showing a listing of some of its on-line reporting options is shown in Figure 4.2.

4.4 MMIS UPDATING AND MAINTENANCE PROCEDURE

The Maintenance Management Information System is largely updated at the district level to reflect new maintenance jobs performed on TxDOT-managed roads. Thus, according to one TxDOT expert, it is updated when a "crew chief" from one of a given district's maintenance sections records information regarding newly performed maintenance work. The crew chief, who has limited access to the MMIS on the TxDOT mainframe, enters information concerning the maintenance work, such as date, contract number (if applicable), the task number (a key data element that makes the data entry unique), the reference markers of the section worked on, and some meaningful quantity of work performed. When these data are entered, according to one expert, TxDOT accountants/bookkeepers assign standard dollar amounts for each data item entered. Both the updates from the field-crew chief and from accounting occur on a daily basis. Furthermore, both are screened for their validity and uniqueness (e.g., work cannot be entered on the same task number for the same unique section more than once). When data are entered, the amount of work and dollar amounts either are added to an existing record or are placed in a new record in a month-to-date-per-year fashion. Additionally, if a quantity of work is performed over a section of road that spans more than one reference marker, that quantity of work is subdivided and assigned equally to each reference marker of the road section. The remainder of work is added to the last marker in the section on which work was performed. That is, if resurfacing was performed over five reference markers, five records would be augmented or created (one per marker), with the appropriate work quantities assigned to each.

```
MMIS58099 - JOB HAS BEEN SUCCESSFULLY SUBMITTED
                   MAINTENANCE MANAGEMENT INFORMATION SYSTEM        (MMMS672)
                   *** MMIS STATEWIDE REPORT GENERATION  ***
------------------------------------------------------------------------------
 SELECT ONE OF THE FOLLOWING REPORTS   ===>

 COST SUMMARIES                        RANKINGS
  1 - HIGHWAY TYPE COST SUMMARY         20 - HIGHWAY COST RANKING
  2 - FUNCTION COST SUMMARY             21 - FUNCTION CODE COST RANKING
                                        22 - HIGHWAY TYPE COST RANKING
                                        23 - HIGHWAY COST RANKING BY FUNCTION

                                       MISCELLANEOUS
 PRODUCTION RATES                       30 - ROADWAY INVENTORY
 10 - FUNCTION RATES                    31 - STATEWIDE BUDGET SUMMARY
 11 - FUNCTION RATES BY HIGHWAY         32 - FIELD ENGINEER REPORT
 12 - FUNCTION RATE COMPARISON          33 - EXPENDITURES BY FUNCTION CODE
                                        34 - FUNCTION COST BY REFERENCE MARKER

------------------------------------------------------------------------------


 PF1=HELP              PF4=PREV MENU       PF10=MAIN MENU            PF11=EXIT
```

Figure 4.2: MMIS Screen Listing Some of its Reporting Options

4.5 MMIS COMPUTER HARDWARE AND SOFTWARE

Like other major materials/pavements databases maintained by TxDOT, the MMIS is stored on the TxDOT mainframe. The MMIS is stored in Audit, Transaction, FIMS-ENC41, and Master files on the mainframe and may be accessed remotely through the CICS or ROSCOE software (discussed earlier in this report). The data are stored in ADABAS files and programmed in NATURAL, a language that is compatible with such files.

During an interview, one TxDOT expert briefly attempted to explain the way the various MMIS files interact. The expert mentioned that the Audit File is "pulled out" of the Transaction File and is frequently empty. Furthermore, the expert noted that the FIMS-ENC41 File holds contract numbers and that it sends data and transactions to the MMIS for nightly updates. According to the definitions in the *MMIS Data Dictionary* (TxDOT – MMIS) provided by one expert, the Audit File keeps a record of all changes to the MMIS Master File. That is, it will contain records for highways that are deleted, highways that are added, and milepost/reference marker limits that are changed. The records on the Audit File are cleared and copied to tape on a daily basis. The *MMIS Data Dictionary* continues by noting that the Master File contains information on every reference marker on every TxDOT-maintained highway for a 2-year period. Finally, the Transaction File contains records on maintenance activity for a specific highway section. Each record in the Transaction File then contains a highway location, an amount of work performed, and various dollar amounts. The Transaction File is updated daily.

4.6 THE FUTURE OF MMIS

The future of the MMIS database is not well known. Neither the work of this study nor that of Victorine yielded any conclusive information on this topic. One TxDOT expert spoke of changes that needed to be made to the database for the Year 2000; however, these changes were not discussed in depth. Additionally, that expert confessed a lack of familiarity with the SiteManager database, and, accordingly, was unable to comment on its future interaction with MMIS. That interviewee's expert knowledge on the MMIS, coupled with this uncertainty regarding SiteManager's future with MMIS, suggests that it is unclear as to how SiteManager and MMIS will interact, if at all.

4.7 MMIS MISCELLANEOUS

One interesting comment made by an expert is that the MMIS database does not "mine" data from any of the other databases maintained by TxDOT. It simply receives data updates from the field and from accounting through its back-reporting process. Other databases such as PMIS do read from the MMIS master file from time to time.

CHAPTER 5. THE TRM DATABASE

Information regarding the TRM database comes from a variety of sources. The initial data, including very extensive information on the data elements contained within TRM, were collected in June of 1997 by Victorine (Victorine 98).

Additional information has come from discussions with various TxDOT experts, especially from one in particular. At the time of the interview, that expert was the director of Data Management for the Transportation Planning and Programming (TPP) Division of TxDOT. During the interview, it was noted that the expert had been involved with the TRM database throughout the database's entire 6-year development from 1989 until 1995. The expert added that developing the TRM database was an extremely difficult project because three divisions were involved in it and because with a 6-year timeline it was difficult for project team continuity to be maintained.

The aforementioned primary expert introduced the research team to the TRM user coordinator for the TPP Division. The TRM user coordinator and the coordinator's four analysts correspond and communicate with the TRM coordinators in each of the twenty-five TxDOT districts. The TRM user coordinator is considered the foremost TxDOT expert on the operational aspects of the TRM database.

Subsequently, the expert introduced to the CTR research staff another TPP employee who is a computer systems/programming expert analyst and who was also involved in the full 6-year development of the TRM database. The expert remarked that this computer systems/programming expert analyst had written much of the *TRM User's Manual* and had played a critical role in the design of the TRM database. The expert remarked that this computer systems/programming expert analyst would be a knowledgeable contact through whom any computer-oriented TRM questions could be answered.

The interviews conducted by Victorine and by our research team during this study have yielded a significant amount of background literature on the TRM database. This body of literature includes a listing of the critical files that compose the TRM database, a sample of an Automated Roadway Inventory Diagram, a brochure entitled *Texas Reference Marker: Official Highway Key* (TxDOT 90), and a *TRM Data Dictionary* (TxDOT – TRM).

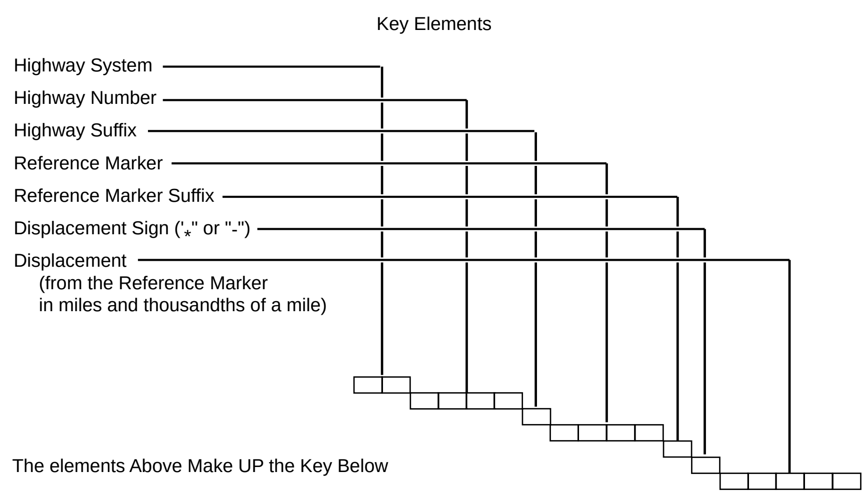
5.1 BACKGROUND AND INTRODUCTION

The Texas Reference Marker Database (TRM), taking its name from the roadway identification system that it uses to organize its data, is maintained by the Transportation Planning and Programming Division (TPP) of TxDOT and is designed to be a control location-based inventory of current roadway conditions within the TxDOT road network (Victorine 98). TxDOT created the TRM system to develop a statewide location system for "on-system" routes in the state of Texas, based on physical markers located in the field.

The development of the TRM system and the TRM database was a collaborative effort between the Design, Information Systems, and Transportation Planning and Programming Divisions (DES, ISD, and TPP) of TxDOT. The 6 years of development that led to the creation of the TRM database began in 1989 in compliance with TxDOT Executive Order 30-88. As a result, the TRM database was finally implemented on May 1, 1995. According to one expert, TRM was developed primarily because the prior control section-based system used by TxDOT was inadequate for statewide reporting. The TRM database was born as a component of the Road Inventory Network (RI) that uses the aforementioned control section-based identification system. However, TRM, as a component, stores data on the on system roads, which constitute 77,000 miles of TxDOT maintained roadways, while the RI stores both on-system and off-system data for a total of approximately 220,000 miles.

5.2 TRM DATA ELEMENTS AND DATA STRUCTURE

According to one expert, part of the greatest strength of TRM lies in its unique organization. TRM is the only roadway inventory database available within TxDOT with a statewide linear referencing system. Unlike the other TxDOT databases that have been reviewed in previous chapters, TRM is not organized into control sections of discrete length, but rather is organized in a continuous fashion. On the TRM database, data are tied to discrete, physical locations, accurate to 0.001 mile. The entire database relies on the Texas Reference Marker System, under which markers are installed throughout all of the on-system routes or roadways in Texas. These markers, which are not to be confused with mile markers, are unique when their "name" is combined with the route designation on which they reside. That is, there may be numerous markers labeled "3442A" in the state of Texas; however, there is only one 3442A on any given on-system route in the state. Each reference marker is designated by a set of rules that are explained more clearly in the brochure *Texas Reference Marker: Official Highway Key* (TxDOT 90). The elements that are critical to identifying a TRM location are shown in Figures 5.1 and 5.2.



Highway System Codes:

IH	Interstate Highway
BI	Business Interstate Highway
US	U.S. Highway
UA	U.S. Alternate Highway
UP	U.S. Highway Spur
SH	State Highway
NA	NASA 1
OS	Old San Antonio Road
BS	Business State Highway
SA	State Highway Alternate
SL	State Highway Loop
BW	Beltway
SS	State Highway Spur
FM	Farm-to-Market
BF	Business Farm-to-Market
FS	Farm-to-Market Spur
RM	Ranch-to-Market
RS	Ranch-to-Market Spur
RR	Ranch Road
RU	Ranch Road Spur
PR	Park Road
RE	Recreation Road
RS	Recreation Road Spur
PA	Principal Alternate (Pass)
MH	Metropolitan Highway

Highway Suffix Codes:

N ....North
S ....South
E ....East
W ....West

Note: Loops, Spurs, and Alternate Routes are included in Highway System codes.

For PR routes
..........................Blank
A-Z....................As required

For Business routes
A-Z....................As required excluding I and O

Note: Codes may be expanded in the future.

Figure 5.1: Key Elements for Specifying TRM Locations (TxDOT 90)

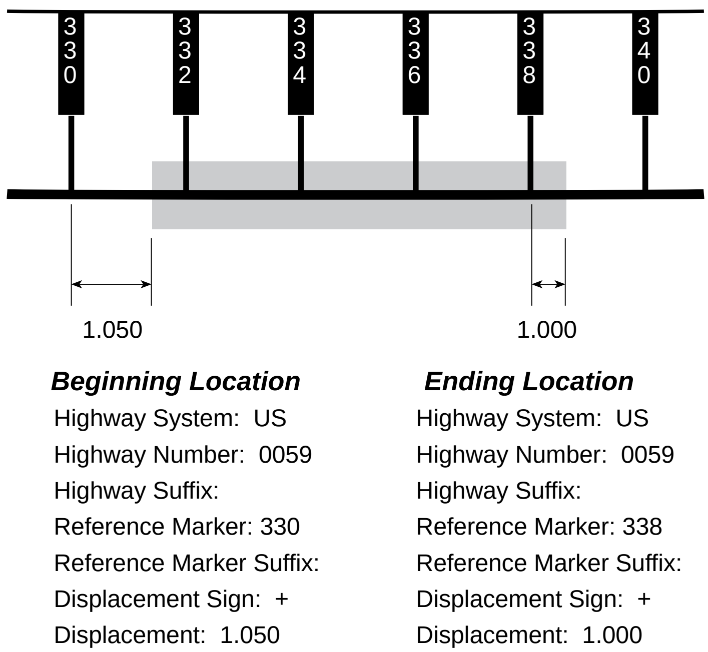


Figure 5.2: Definition of Sections and Discrete Locations Using the TRM System (TxDOT 90)

For each reference marker, a distance from the origin of a roadway, measured along the roadway's centerline, is assigned as its distance from origin (DFO) and is stored in the TRM master file. The distance from origin can change for a reference marker when highway realignments lengthen or shorten the roadway. According to a TxDOT expert, the location of each feature or change in roadway composition can then be easily identified by listing a reference marker in the direction of the origin from the feature and a displacement from that reference marker. That is, all feature locations are listed in relation to their distance from reference markers, rather than their distance from the origin of the entire route.

The organization of the Texas Reference Marker System gives the TRM database many advantages over the RI system (which uses control sections). First, when roadway realignments are made, only changes in the distance from origin of old markers and the distances of features from any new markers (as well as the DFOs of those markers) need to be changed in the Master File. That is, for remaining, old markers past the realignment (further along the route), the distances from origin are changed and must be updated.

Consequently, once the DFOs are changed, the locations of features are redefined automatically as they are related to the reference markers, not the route origin. This feature saves a great amount of time for the user since only the Master File need be changed every time a reference marker is moved owing to realignment of the route or other causes. Figure 5.3 shows an example of how realignment affects reference markers.

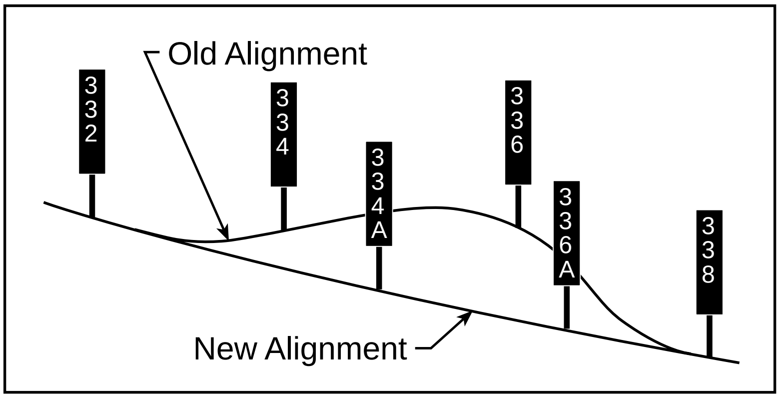


Figure 5.3: Schematic of How Realignment Affects Reference Markers (TxDOT 90)

Additionally, the control-section system was organized in terms of counties and was unrelated to meaningful, physical locations on the roadways. In contrast, reference markers are not restarted at county lines and are located both in computer memory and on the actual roadway. It is possible to find and stand next to reference marker XXX on IH XX. These advantages make TRM not only simple to update, but also much more adept for statewide reporting and reporting to the federal government. This organization also makes TRM easily adaptable to such reporting, which will be later discussed, as Automated Road Inventory Diagrams. Finally, according to one TxDOT expert, Texas Reference Markers on interstate highway routes do correspond to actual mile markers out of convenience, but those mile designations do not relate to the distance-from-origin mileage scheme of the reference markers.

Consequently, data in TRM are organized in terms of and assigned to specific locations on the Texas Road Network rather than being assigned to control sections of varying lengths. Features such as points of tangency and intersections, as well as locations where the material composition of the roadway changes, are "placed" on the database at locations accurate to 0.001 of a mile. Such features tend to describe all of the on-system routes within Texas. Unique locations must include a route, a related reference marker, and a displacement from that marker. The TRM database stores data elements in the following categories: traffic data, cross-section data, and pavement type/characteristics data. A more detailed summary of the data elements stored in TRM is available in Appendix A.

One relevant, surprising concept is that TRM is capable of storing materials/attributes information or testing data. When a material (e.g., surface type) or a material test result is assigned to a TRM location, the engineer can interpret that to mean that such a condition is true until a new material or property is discovered at a location further along the route. This next material feature would be represented by a break in the reference marker records in the database. Thus, TRM can identify, to within 0.001 of a mile, where materials such as surfaces, bases, curbs etc. change. It identifies materials features/attributes using a two-digit code. For instance, if a pavement consists of a surface-treated bituminous mix, the data element *surface-type-code* for that location would read 51.

TRM is not only well organized, but also extremely well populated. TRM, as previously noted, contains the feature and administrative data in nine files for some 77,000 on-system roadway miles. Theoretically, it contains every feature stored along those miles, constituting 100 percent population. Additionally, according to one TxDOT expert, TRM is capable of creating a report that lists which data are missing from its files.

5.3 TRM USES AND APPLICATIONS

Interestingly, the TRM database is capable of serving numerous purposes within the department and beyond. A TxDOT expert explained in an interview that one of the primary purposes of TRM is providing the federal government with information concerning the mileage and condition of Texas highways. This information is used to secure funding through the Highway Performance Monitoring System (HPMS). According to that expert, the federal government uses vehicle miles, lane miles, and centerline miles to appropriate transportation spending to the states. TRM provides a database to collect and report this data.

Additionally, TRM is capable of many internal functions. According to one TxDOT expert, TRM serves as a record of all of the on-system roadways within the state. In that capacity, TRM is capable of creating the extremely useful Automated Road Inventory diagrams (ARI). These diagrams, one of which a TxDOT expert provided the research team, take data stored within TRM and create a diagram of a section of an on-system Texas highway (using a workstation for printing). These diagrams include all of the section's relevant features. For instance, an ARI can display locations of points of curvature, locations of points of tangency, elevations, centerline features, changes in pavement types, and changes in material constituents in a linear, graphical format to an accuracy of 0.001 of a mile. Such diagrams can be helpful in countless situations, whenever the location of a roadway feature is in question or whenever an essentially "bird's eye" view of a Texas road is desired. Figure 5.4 is a reduced example of an ARI for a section of roadway.

5.4 TRM UPDATING AND MAINTENANCE PROCEDURE

In a more global sense, the rules by which markers and the Texas Reference Marker system are updated during a realignment or new construction project are governed by and described in *Texas Reference Marker: Official Highway Key* (TxDOT 90). However, in an interview, one TxDOT expert was able to provide a detailed explanation of TRM updating procedures for adding/changing feature data. According to that expert, the responsibility of maintaining and updating the TRM database falls on the shoulders of a variety of individuals within the different sub-organizations of TxDOT. Each of the twenty-five TxDOT districts has a TRM user coordinator who is responsible for coordinating the updating of feature and physical data within that district. One TxDOT expert also added that when the TRM system was initially developed, each district was responsible for installing Texas Reference Markers on all on-system routes within its boundaries. The districts then began appropriately locating and entering the existence of the features tracked by TRM. That expert also noted that most of the "initial" data were loaded from the existing Road Inventory file. Additionally, this expert noted that TRM receives its administrative data from TPP analysts.

As mentioned above, the research team was introduced to the TRM user coordinator. For TRM, the coordinator and four analysts maintain administration-type data, including "type of road" classifications, the system mileage, and, in general, the underlying linear network that comprises the TRM system. Unlike many TxDOT databases, the TRM database is not summarily updated at any specified time interval, but rather is updated as needed by the responsible district. That is, TRM is updated on-line whenever a new "feature" in a district needs to be added, or when the system's markers change name or distance from origin (DFO). It may be updated daily if necessary.

5.5 TRM COMPUTER HARDWARE AND SOFTWARE

The TRM database is centrally located on the TxDOT mainframe and, like many other TxDOT databases, may be accessed remotely, on-line, using CICS. A more detailed explanation of CICS was provided in Section 2.5 earlier in this report.

TRM resides in nine NATURAL ADABAS files. One TxDOT expert, in an interview, noted that one of those files is a transaction file that is accessible only to an authorized few within the TPP division. This transaction file is used to monitor changes to the TRM system that are made at the district level, in order to ensure that incorrect changes can be corrected. According to that expert, the other eight files are used for tracking different roadway inventory data. The administration file, one of the files maintained by the TPP division, contains mostly descriptions of the highway network, such as the classification of the roadway type. The feature file, updated at the district and TPP level, is used to store point feature data along the TRM system and stores such information as the location of bridges, intersections, and stockpiles. The geometric file stores information concerning the basic bearings, elevation, and curvature of the centerline of a given roadway section. The link file is used to handle the data that occur when two roads, like US 290 and IH 35 in Austin, run concurrently. The master file records data about all the Texas Reference Markers within the state, including the critical distance-from-origin data that uniquely pinpoint each marker along a highway route. The pavement file stores the location of all of the "breaks" in the type of pavement/base along the surface and subsurface of all on-system routes. The tracking file contains data on the past location of each of Texas' reference markers so that one seeking a historical perspective can make sense of the current location of markers. Finally, the traffic file stores, among other elements, annual average daily traffic (AADT) data associated with roadway locations. Data on the traffic file, including AADT, miles traveled, and air quality, are examples of data reported to the federal government so that such funding may be procured. Clearly, though, the nine-file organization system of TRM is quite intuitive.

5.6 THE FUTURE OF TRM

During one TxDOT interview, the expert seemed quite optimistic about TRM's future and spoke about a variety of issues. This expert noted that a recently created file (MPRME) allows TRM to be merged with data stored in the old control section format, which is still used by the Road Inventory file. The expert added that this MPRME file would allow better coordination between off-system and on-system data. Additionally, that expert gave the research team a chart showing a proposed organization of part of the TxDOT computer system and explained that, in the future, a SYBASE relational database will allow many of the TxDOT database files to be joined in what is termed the "Planet Suite." A diagram of this information structure of the future is shown in Figure 5.4.

This future configuration will result in many of these databases, including TRM and PMIS, being linked in a relational, client/server scheme. The TxDOT expert noted that this would also allow TRM to be better linked to a GIS infrastructure, permitting more detailed analysis and complex reporting. The expert did not address the possibilities of future interactions between the TRM database and the SiteManager database.

5.7 TRM MISCELLANEOUS

The TRM database interacts frequently with other TxDOT databases. During one TxDOT interview, the expert noted that TRM was developed parallel with the PMIS database when the Design Division and TPP Division shared a common facility. The expert was aware that PMIS imports data from TRM in order to define its control sections. Additionally, TRM imports data from the Traffic database onto its traffic file so that traffic data may be assigned to TRM locations.

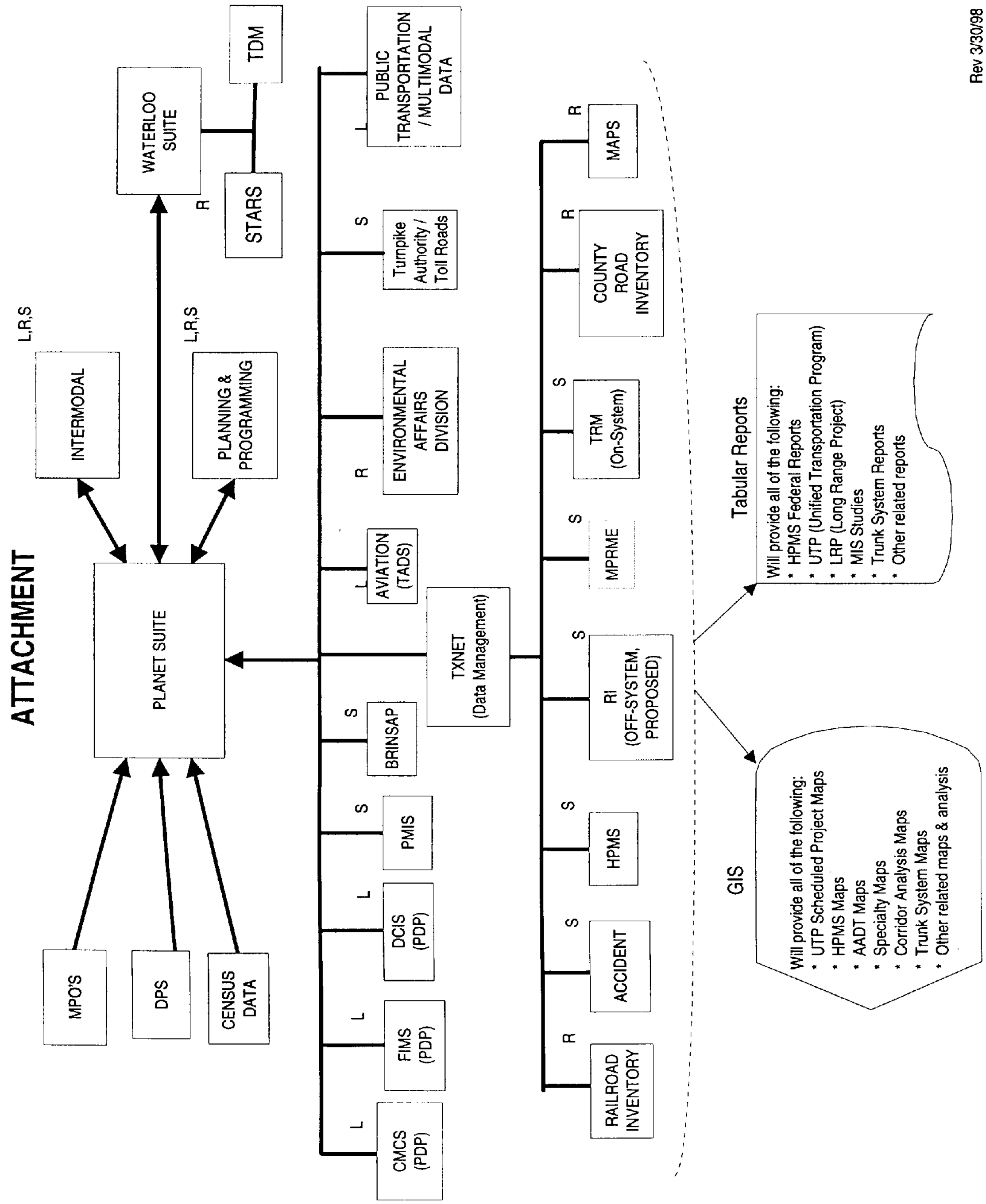


Figure 5.4: Schematic Diagram of TRM's Future in the "Planet Suite" Structure

Finally, TRM receives administrative data from TPP analysts and physical attribute (feature) data from the twenty-five TxDOT districts. In the future, load limit data on TRM will be provided by the Design Division through an automated merge with the TRM database.

CHAPTER 6. THE SITEMANAGER DATABASE

In November 1997, the CTR research team had the opportunity to attend a weeklong workshop in Austin, Texas, whose topic was the materials management module of SiteManager. This workshop was created so that the developers of SiteManager could solicit opinions from users employed by participating state DOTs regarding the improvement of features on SiteManager and its future development. While no clear, relevant conclusions were generated at this workshop, it allowed the research team to observe a demonstration of the current (unfinished) SiteManager version. Additionally, the research team was able to attend brainstorming sessions, during which teams of potential users shared ideas about improving the materials management aspect of SiteManager.

In an effort to build on the knowledge obtained through attendance at the SiteManager Workshop, the research team organized an interview with TxDOT SiteManager experts. The research team also generally discussed SiteManager with all experts who were interviewed about other databases and topics. During the main interview for SiteManager, the TxDOT experts and members of the CTR research team had the opportunity to discuss specifics about SiteManager as well as possible interaction between the proposed material performance database and SiteManager. Furthermore, the research team had a chance to obtain *The SiteManager Reference Manual Version 1.0* (AASHTO 98); according to TxDOT experts, this guide, along with a logic-programming manual for SiteManager, served as a guide through SiteManager beta testing for TxDOT.

At the time of the interview, all three interviewees worked in the recently reorganized Construction Division (CST) of TxDOT; the maintenance operations of TxDOT have since been disjoined from CST and have moved into a separate Maintenance Division (MNT). As of the July 1, 1998, date of the interview, two of the SiteManager experts worked in the Business Management Section of CST and were specifically responsible for automation systems and support. Furthermore, another expert was the director of technical operations for the Materials Section of CST. All three had been intimately connected to the development of SiteManager. For instance, one expert represented the management of the Materials Section during SiteManager beta test planning and will later be responsible for supporting the implementation, if approved. Another expert was an essential resource in testing the software for TxDOT and was then working on implementation planning. Finally, another expert had been a consultant to the materials management portion of the system and was particularly interested in seeing this portion fully functional and capable of interfacing with current and future systems and databases. The following summarizes the information gained from the aforementioned SiteManager workshop, the interview, and the *SiteManager Reference Manual* (AASHTO 98) regarding the data contents, operation, and future of SiteManager.

6.1 BACKGROUND AND INTRODUCTION

The initial development of SiteManager began with a meeting of the joint development representatives for the project in January 1990. The project officially started in October 1995 with the award of the contract for its creation to MCI Systemhouse. Upon its completion, according to some of the experts, SiteManager will be a comprehensive, state-of-the-art, jointly developed construction management system sponsored by AASHTO, eighteen state departments of transportation (DOTs), one Canadian province, and the Federal Highway Administration (FHWA). SiteManager will automate many of the administrative functions currently handled manually for construction projects. These functions include storage of materials testing information, quantities of work completed, daily diary information, EEO and DBE compliance information, and the automation of monthly construction estimates. Clearly, the materials management aspect of this database is the most relevant to the proposed material performance database, given that it contains extensive data about the testing of materials used in construction projects. Such test data could be quite valuable to the kind of short-term performance monitoring schemes that are the focus of the proposed database.

6.2 SITEMANAGER DATA ELEMENTS AND DATA STRUCTURE

Interestingly, SiteManager is not only a network database, but also a relational and an object-oriented database. That is, it works in a client-server environment as well as in a local- or wide-area network environment. However, the language in which it is written, PowerBuilder, is object-oriented. According to TxDOT experts, the database is a relational database.

Currently, TxDOT anticipates applying SiteManager to all new roadway construction projects; however, it has not been determined whether all active projects will be converted when it comes on-line. Furthermore, TxDOT has not yet decided if roadway maintenance projects will be handled through SiteManager.

At the time of the main SiteManager interview, the database had thirty standard screens that could handle approximately fifty-eight Texas test methods, three ASTM/AASHTO test methods, and numerous prefabricated materials; three other screens will not be used. Furthermore, according to one TxDOT expert, the flexibility of SiteManager will allow each DOT/user to create additional custom screens. A listing of the expected data elements of SiteManager is provided in Appendix A. This listing does not include many of the construction-administration data elements that dominate the database. It is important to realize that this partial list (SiteManager contains much nonmaterial-related data) is based on the *SiteManager Reference Manual* (AASHTO 98) and does not take into account customizations that TxDOT may subsequently make. During the interview, the research team requested but could not obtain a manual outlining these customizations because such document did not yet exist. According to some experts, such a document may be available shortly before implementation in June 1999 (at the earliest).

6.3 SITEMANAGER USES AND APPLICATIONS

While fulfilling the objectives and functions previously outlined, SiteManager is intended for the administration of construction projects to be used by field inspectors, workers in the area engineer's office, personnel in the district construction office, and others in the division offices, including the offices of Construction, Design, Information Systems, and Audit. SiteManager has extensive reporting capabilities, as summarized in the *SiteManager Reference Manual* (AASHTO 98).

6.4 SITEMANAGER UPDATING AND MAINTENANCE PROCEDURE

The Construction Division of TxDOT will operate, maintain, and collect data for SiteManager. The various types of SiteManager data will be collected at a variety of intervals as appropriate. For instance, test results will be collected and recorded when tests are performed, whereas daily, inspector diaries will be filled daily and predefined material gradations will be updated as they change. Thus, there is no uniform, systematic updating frequency. Clearly, updating procedures for each specific piece of data are likely to be dictated by current and future departmental procedures, including material testing schedules.

One point of concern about SiteManager is how long important material data will remain in the database. If the material data will not be in the database for any appreciable length of time, it is necessary to develop a procedure to transfer the data related to material performance into the proposed material database. Obviously, a construction project may last from 45 working days to as long as 5 or 6 years. SiteManager will store data for different lengths of time for each project, but once the project is completed, TxDOT expects to keep the data for another 3 years. During this 3-year period, all the stored material information will be available for extraction. Additionally, according to TxDOT experts, after the data are removed from SiteManager and archived, they can still be otherwise retrieved. Thus, TxDOT plans for the materials data on SiteManager to be available in some form for the foreseeable future. Currently, according to the TxDOT experts, the department does not anticipate storage of any historical data (i.e., completed construction) on SiteManager.

6.5 SITEMANAGER COMPUTER HARDWARE AND SOFTWARE

SiteManager is capable of running on Microsoft Windows 95, Microsoft Windows for Workgroups, Microsoft Windows NT, and IBM's OS/2 platform (AASHTO 98). It is written in PowerBuilder and relies on Crystal Report Writer as its query tool for ad hoc reporting. As was previously mentioned, SiteManager works in a client-server environment as well as in a local- or wide-area network environment. It may be accessed remotely on computers in the field for Pipeline and Zip operations, in which data are sent to and from the main database location.

6.6 SITEMANAGER MISCELLANEOUS (LIMS)

A variety of additional topics related to SiteManager were discussed during the interview. One of the most interesting branches of the discussion was about a new database information system in the conceptual stage of development, entitled Laboratory Information Management System (LIMS). According to the TxDOT experts, LIMS would complement SiteManager and would operate at a lower, more detailed level while passing refined data onto SiteManager. According to two of the TxDOT experts, LIMS would carry data from testing and would "grind" the numbers to create a flat file that could be exported to SiteManager. While SiteManager only carries data for 61 of the 195 materials tests performed by TxDOT, LIMS would carry data on the rest and export them to SiteManager. One TxDOT expert added that while states are having to fend for themselves in creating similar LIMS-type systems, AASHTO is considering another joint development project to expand the materials aspect of SiteManager with the creation of a system analogous to TxDOT's LIMS. Thus, LIMS, while very preliminary in its development, could greatly improve the work performed by the central testing lab of TxDOT and might even bring in the district labs.

Another topic of interest was the interaction between the proposed material performance database and SiteManager. The TxDOT interviewees clearly were interested in the idea of these two databases having extensive interaction; indeed, they felt such reliance by the proposed database on SiteManager would greatly enhance the value of SiteManager. They felt that SiteManager could help the development of the proposed material performance database and vice versa. The proposed database could help identify new needs for SiteManager and, in response, SiteManager could provide additional data for the new database, which would act as a search engine.

CHAPTER 7. OVERVIEW OF TxDOT TESTING PROCEDURES

7.1 INTRODUCTION

For many of the same reasons it is valuable to have a detailed understanding of the various department-wide pavement and materials databases operated by TxDOT, it is equally valuable to have knowledge of the material testing and sampling procedures, protocols and specifications within TxDOT. As previously suggested, this information, coupled with the database locations of various materials properties, can be valuable for ensuring that recommendations regarding the contents of the proposed database can make as much use as possible of TxDOT's current systems and testing programs. Ensuring such compatibility will be helpful both for prioritizing prospective data elements and for fulfilling the constraints and objectives of this project as set forth in Chapter 1.

7.2 RESEARCH METHODOLOGY AND IMPORTANT TESTING RESOURCES

This overview of the testing and sampling procedures used by TxDOT was compiled through the examination of four department-published documents and through interviews with TxDOT experts.

As a part of this study, a Materials and Tests Division employee, an expert on the material-testing regimen of TxDOT, was consulted/interviewed to gain general background on TxDOT material testing practices. At the time of the interview, that TxDOT expert was in charge of the department's Aggregate Quality Monitoring Program and in that capacity regularly fielded questions from district-level personnel about testing procedures, construction procedures, and specifications. This expert has been with TxDOT for 34 years. During the interview, the expert was able to answer very general questions related to very general topics, such as discrepancies among the Specifications and the Testing Manual, test protocol, and test data storage.

The first and most general publication examined was the three-volume *Materials and Tests Division Manual of Testing Procedures* (Testing Manual) (TxDOT [2] 97). This set of manuals provides a listing of the TxDOT-standardized tests, in ten numerical series, for the following categories: soils, bituminous, cement, concrete, asphalt, chemical, structural, coatings/traffic materials, calibration, and special procedures. These manuals, containing documents for each test in similar formats to ASTM- or AASHTO-type testing specifications, provide information regarding procedures, apparatus, calculations, and report contents for each test procedure. However, many TxDOT-standardized tests are no longer performed in practice; these tests can be identified through a thorough examination of the specifications used by TxDOT.

The next document examined was the TxDOT *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* (Standard Specifications) (TxDOT [2] 95). These specifications, published at irregular intervals, date from 1995, 1993, 1982, 1972, 1962, 1951, and 1938/41. The 1993 and 1995 versions are identical but for the fact that they are in metric and English units, respectively. While these publications provide standard specifications regarding general provisions and an appendix, the most important information related to this project is found in the Construction and Maintenance Details portion. The Construction and Maintenance Details, found in Part II of this publication, provide specifications for every material upon which TxDOT places such strictures. The divisions of Part II are entitled (TxDOT [2] 95):

1. Earthwork
2. Subbase and Base Courses
3. Surface Courses and Pavements
4. Structures
5. Incidental Construction
6. Lighting and Signage
7. Maintenance

Each of these divisions provides detailed specifications pertaining to relevant materials, products, techniques, and assemblies. For instance, a composite material (e.g., concrete) specification would list testing requirements for that material and either reference another, similar specification for constituent materials or list additional constituent testing requirements. While the tests listed are generally "Tex" series tests (designated with "Tex" followed by three numbers and a letter, e.g., Tex 410-A), the specifications occasionally require a test procedure standardized by an alternate organization such as ASTM or AASHTO. The current specifications are largely up to date. More specifically, according to the interviewee, Item 340 relating to hot mix asphalt is the only specification that is no longer up to date. Item 340 is "on hold" and is being reviewed while QC/QA specifications (items 3022 and 3116) are developed for hot mix asphalt. The interviewee also remarked that while the Standard Specifications rarely change, special project specifications that alter or amend the Standard Specifications are frequently used. Thus, with few exceptions, the Standard Specifications are particularly valuable because, even though dense and confusing, they unequivocally list every testing requirement for every material specified by TxDOT.

The third reference that was consulted for this research was the Materials and Tests Division's *Sampling and Inspection Guide Index* (Guide Index) (TxDOT [3] 95). The Guide Index is a compilation of documents that provide information regarding materials in question, such as the function of the project engineer, the function of the materials and tests division, sampling and testing, and remarks.

The Area Engineers' and Inspectors' Contract Administration Handbook (Engineers' Handbook) (TxDOT 96) was the final reference used for the research involved in this chapter. According to the interviewee, the Engineers' Handbook is the most useful source for the progress of this study. The purpose of this handbook is to "unify the management activities for highway construction projects," not including routine maintenance contracts and maintenance activities (TxDOT 96). It provides a concise list of tests that need to be performed for each construction material, as well as the frequency with which each test must be performed. This handbook also provides all of the information that a TxDOT employee would need in order to perform the minimum functions necessary to oversee execution of construction contracts.

While it primarily describes pre-bid and post-bid award activities, the handbook's most important information for the purposes of this project is that related to contract administration, which is found in Chapter 4, Section 6, *Control of Materials.* This section gives background information on the sampling and testing requirements on a job and explains the differences between "project" and "independent assurance" tests. Also important to this chapter is the table *Guide Schedule of Sampling and Testing* (Guide Schedule) (TxDOT 96) that provides the most valuable information. This Guide Schedule applies to all contracts under construction and specifies the minimum tests and test frequencies applicable to the following TxDOT-used materials: embankments, subbases, base courses, asphalt-stabilized bases, treated bases and soils, surface treatments, structural and miscellaneous portland cement concrete, portland cement concrete pavements, asphalt concrete pavements, and QC/QA asphalt concrete pavements (TxDOT 96).

The Guide Schedule provides information not only about the purpose of each test and the minimum frequency, but also about where the test sample should be obtained for both monitoring/acceptance tests and independent assurance tests (TxDOT 96). Thus, the Guide Schedule is particularly useful because it actually makes clear what tests are actually performed for what materials, information not provided by the Testing Manual. For example, in the Testing Manual, it is not clear for which materials a test such as Tex 410-A is designed and implemented. Tex 410-A inexplicably lies in the aggregate section of the manual, though many different materials require aggregates as constituents and use various Tex 400 series tests. By contrast, it is clear from the Guide Schedule that Tex 410-A pertains to coarse aggregates to be used in QC/QA asphalt concrete, but not on coarse aggregate used in granular bases (TxDOT 96). This kind of information is invaluable when trying to sort out which constituent properties affecting which materials and material properties are tested for and are available.

Consequently, using these four reference materials in isolation yields an incomplete description of the testing regime used by TxDOT. For instance, while the three-volume Testing Manual provides detailed information about every TxDOT-standardized test that can be run, it is unclear in the manual which tests are actually run in practice. The Standard Specifications clarify which tests are actually run for each material, but they are quite unwieldy and less clear about such details as testing and sampling frequencies. To complement the Standard Specifications, the Guide Schedule provides summary information about bare minimum sampling and testing requirements for different testing situations, as well as the frequencies for testing and sampling. Finally, the Sampling and Inspection Guide Index summarizes the responsibilities of TxDOT employees for various aspects of each material's testing and sampling. The interrelationship of all of these documents is shown in Figure 7.1. Clearly, each reference is part of a larger picture that provides information regarding which tests are applied on which materials, how often, and by whom.

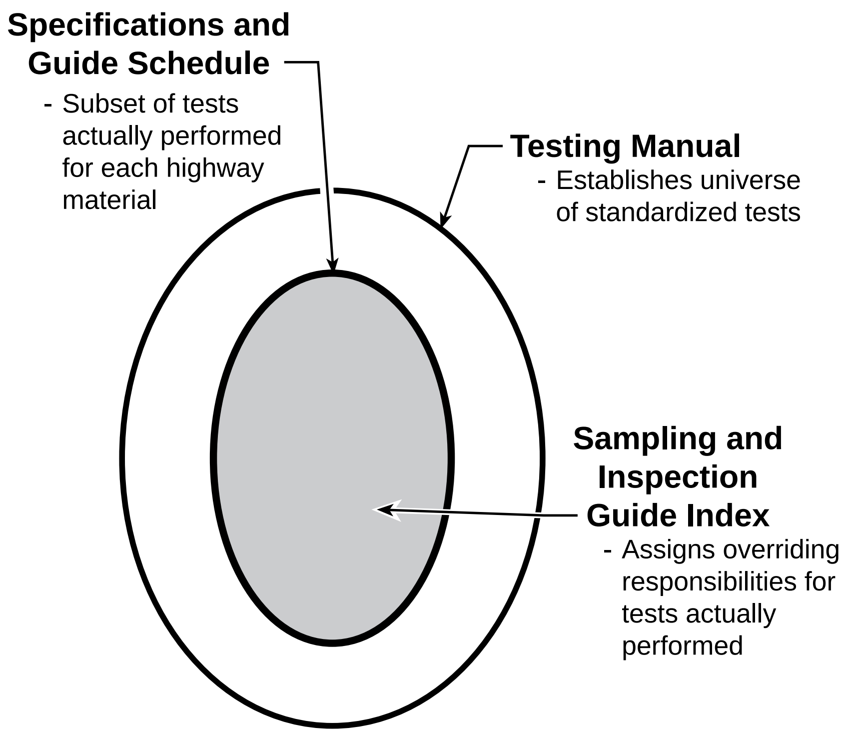


Figure 7.1: The Interrelationship of TxDOT Testing-Related References

7.3 BACKGROUND ON TESTING PROTOCOL

According to one TxDOT expert, material quality tests, such as the LA Abrasion test (Tex 410-A), the Magnesium and Sodium Sulfate tests (Tex 411-A), and the Aggregate Reactivity test, are generally performed at the division level within TxDOT. All other tests are performed at the district or area level. More specifically, the Guide Index outlines responsibilities for testing and sampling at both levels (district and division level) (TxDOT [3] 95). According to the Guide Index, for most materials, the project engineer (at the district level) is responsible for job control and quality tests as required by specifications for a given material. On the other hand, the division is responsible for administering the Aggregate Quality Monitoring Program and for running quality tests as required (TxDOT [3] 95). However, the Materials and Tests Division functions with regard to material testing are more inclined to vary material by material.

Generally, the Engineers' Handbook focuses on those tests applicable at the district level. However, the tests applicable at the district level fall into one of two categories: "Project tests" are performed at area offices, and "independent assurance tests" are carried out at the district laboratory.

Project tests are those used to confirm that a given material conforms to specifications (TxDOT 96). Within project tests, there are acceptance tests and monitoring tests. Acceptance tests "determine if the quality of the materials or the quality of the construction work produced conforms to the plans and specifications" (TxDOT 96). Normally, the area engineer is responsible for these tests, after which he or she can do one of three things: reject and remove the material, rework and retest the material, or accept and adjust the unit price of the material according to the specifications (TxDOT 96). Monitoring tests determine the need for adjustment of the contractor's operations, including material changes or adjustments (TxDOT 96). Normally, the area engineer is also responsible for monitoring tests. If a material fails the monitoring test, the contractor must adjust his or her operation to ensure that the monitoring tests are passed. The failing material is not rejected by the area engineer out of hand; rejection occurs only when the engineer "determines that it is clearly unacceptable for the purpose intended" (TxDOT 96). While both acceptance and performance tests are usually performed by the area engineer, they may also be performed in a district lab, in an outside lab, and, in the case of acceptance tests, at the Materials and Testing Division's lab.

On the other hand, independent assurance tests (previously referred to as Record Tests), are independent checks on the aforementioned project tests (TxDOT 96). One criterion for independent assurance tests is that they must be performed, either through testing or witnessing, by an individual who has no responsibility for the project testing (in order to assure independence). Furthermore, the testing equipment for independent assurance tests should generally be from a different laboratory (i.e., not from the same laboratory used for project testing). Data from independent assurance tests are compared with similar project tests by the area engineer in an effort to check (TxDOT 96):

1. the procedures and techniques of the actual project sampling and testing,
2. the equipment used by the project personnel, and
3. the project test results.

Consequently, while the project tests and independent assurance tests have different protocols and purposes, they are generally based on the same test specifications. For example, an independent assurance test and a project test for LA Abrasion would be required at different times and might be performed by different personnel and equipment, but the same testing procedure as stated in the Testing Manual would apply to both. On a side note, nearly all the testing on aggregates intended for base materials is performed at the district level, and most division-level aggregate testing is performed on aggregates intended for use in asphalt and portland cement concrete.

7.4 TEST DATA STORAGE

The individual interviewed about testing described how data from testing are stored within the TxDOT infrastructure. Different protocols exist for division and district tested data. Any test that is run at the division level on aggregates is stored in an internally accessible database within the Materials and Tests Division. An outside consulting firm recently developed this database, which stores 6 years' worth of test results catalogued by aggregate source. At the interview, it was revealed that this database will eventually export its data to SiteManager. According to the interviewee, nonaggregate test data obtained at the division level go into paper files and folders organized by laboratory number. These paper files are kept for 3 years (current year plus 2 previous years). Unfortunately, according to the interviewee, accessing these files can be very impractical. While the interviewee noted that material test results are not available on a computerized database, this individual added that some pass/fail-type test results are stored in the TxDOT mainframe for 3 years. The expert referred to this mainframe system as the Construction Information System (CIS), suggesting that we contact Floyd Inman for more information regarding CIS.

According to the interviewee, district-level testing data are not widely available, but rather are stored at that level, organized by source. These test results are actually stored as two separate copies: One copy is stored at the district level while the other is stored in a project folder retained by the area office in charge of inspection and audited by the construction office. Retention time of these test results varies by district. One interviewee suggested that Bunny Neible would be a contact regarding the storage of material testing data within the district level. According to the interviewee, the entire point of SiteManager is that it could be a reliable, user-friendly, current repository of the aforementioned types of material data.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

This report has outlined current TxDOT database and testing capacities, protocols, and procedures. It is clear that the material properties that may be required in a materials performance database are currently being tested for by TxDOT and are currently being stored in department-wide material and pavement databases. As the previous chapters have demonstrated, the PMIS, MMIS, RL, and TRM databases are currently in operation and store limited amounts of materials-related data. Additionally, the still-developing SiteManager database appears to be a wellspring of material testing data. All five of these databases have been described and detailed in this report.

This report has also made it clear that there is a large degree of overlap among the various databases used by TxDOT. For example, many of the databases import and export data to and from each other. TxDOT may want to consider the efficiency that would be increased by integrating these databases into a unified structure. This unification may require creating a position that would manage the databases, eliminate their redundancy, and streamline their operations. Such action (including merging databases) was discussed in the chapters focusing on Road Life and PMIS.

This background in database sources should provide some of the information necessary to identify important data "mines" for the proposed material performance database; at the same time, it should also facilitate reasonable decisions about the availability of important data. More specifically, the information provided by this report, coupled with the testing information provided in Report 1785-2, will assist in the prioritization procedures discussed in Chapter 6 of Report 1785-2. It is important to realize, however, that, as data sources for the proposed database, the precise role of these databases and TxDOT's testing program cannot yet be accurately defined. This definition will be clarified only when the data contents of the proposed database are more accurately defined (as discussed in Report 1785-2).

References

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(TxDOT – MMIS) TxDOT, ***Maintenance Management Information System (MMIS) Data Dictionary***.

(TxDOT – PMIS) TxDOT, ***Pavement Management Information System (PMIS) Data Dictionary.***

(TxDOT – RL) TxDOT, ***Road Life (RL) Data Dictionary***.

(TxDOT – TRM) TxDOT, ***Texas Reference Marker (TRM) Data Dictionary***.

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Appendix A:
Listing of Data Contents of TxDOT
Material and Pavement Databases

Appendix A: Listing of Data Contents of TxDOT Material and Pavement Databases

Following is an abbreviated summary of the main data elements stored on each of the four materials/pavements databases operated by TxDOT. These data were extracted from current data dictionaries received during interviews with TxDOT database experts, information gathered during those interviews and from past research performed for Project 0-1731. Details on these data elements concerning their exact function and format are available in the data dictionaries for these various databases (Victorine 98), (TxDOT – MMIS), (TxDOT – TRM), (TxDOT – RL), (TxDOT – PMIS), (AASHTO 98). The author has used discretion in selecting the data elements that appear here. That is, many data elements on these databases that are not related to materials or testing have been left off for the sake of brevity. These unrelated data elements include administrative data elements, user verification elements and approved user elements for examples. Furthermore, in some cases, data elements listed here actually represent multiple data elements in their respective databases, but have been listed as a single unified entry, again for brevity. When applicable, data elements are followed by a parenthetical modifier to indicate the other database from which they import those data elements.

1. PMIS

1.1 Location Data

District (from TRM)
County (from TRM)
Maintenance Section and ID (from TRM)
Highway Designation (from TRM)
PMIS Highway System
Beginning Reference Marker and Displacement (from TRM)
Ending Reference Marker and Displacement (from TRM)
Roadbed ID (from TRM)
Functional System (from TRM)
Urban/Rural Designation Standard (from RL)
Under Construction Flag (from RL)

1.2 Pavement Type and Characteristics Data

Roadbed Pavement Type: CRCP, JCP, ACP
Number of Through Lanes (from TRM)
Left Shoulder Type (from TRM)
Left Shoulder Width (from TRM)
Right Shoulder Type (from TRM)
Right Shoulder Width (from TRM)

Roadway Surface Width (from TRM)

1.3 Visual Distress Data (only for most heavily damaged lane in control section)

1.3.1 For Asphalt Concrete Pavement

Shallow Rutting % (both visual and measured)
Deep Rutting % (both visual and measured)
Patching %
Total Number of Failures
Alligator Cracking %
Block Cracking %
Length of Longitudinal Cracking
Number of Transverse Cracks
Raveling
Flushing

1.3.2 For Continuously Reinforced Concrete Pavement

Number of Spalled Cracks
Number of Punchouts
Number of Asphalt Concrete Pavement Patches
Number of Portland Cement Concrete Patches
Average Crack Spacing

1.3.3 For Jointed Concrete Pavement

Number of Failed Joints and Cracks
Number of Failures
Number of Shattered Slabs
Number of Slabs with Longitudinal Cracks
Number of Portland Cement Concrete Patches
Apparent Joint Spacing

1.4 Other Non-Visual Distress Data

Ride Quality Data
Various Rutting Data

1.5 Condition Scores

Ride Score
Distress Score
SSI Score
Condition Score
Skid Score

1.6 Maintenance Data

Amount Spent (from MMIS)

1.7 Climatic Data

Average Annual Rainfall (constant for all roads within a county)
Average Annual Number of FT Cycles (constant for all roads within a county)

1.8 Traffic Data

Average Daily Traffic (from TRM)
Estimated AADT Achieved @End of Design Year, Growth Rate/Factor %
Cumulative ADT Since Original Surface
Cumulative ADT Since Last Overlay
Truck Traffic (18k ESALs) (from TRM)
Current 18 k Measure, 20 Year Projected 18 kip ESAL (from TRM)
Cumulative 18 k ESAL Since Original Surface Date
Cumulative 18 k ESAL Since Last Overlay Date
% Trucks (from TRM)
Average Ten Heaviest Wheel Loads (from TRM)

1.9 Cross Section Data

1.9.1 Original Surface

Date (from RL)
Type (from RL)
Thickness (from RL)
Width (from RL)

1.9.2 Base

Type (from RL)
Thickness (from RL)
Width (from RL)

1.9.3 Subbase

Type (from RL)
Thickness (from RL)
Width (from RL)
Swelling Potent.(RL)

1.9.4 Subgrade

Type (from RL)
Stabilization Type (from RL)
Stabilization Thickness/Depth (from RL)
Triaxial Class (from RL)

1.9.5 Last Overlay

Type (from RL)
Date of Last Overlay (RL)
Tot. Overlay Thickness (RL)
Width of Last Overlay (RL)

1.9.6 Last Seal Coat

Type
Date of Last Coat (from RL)

2. Road Life

2.1 Location Data

District
County
Highway Designations (hwy syst., #, suffix)
Beginning Reference Marker and Displacement
Ending Reference Marker and Displacement
Roadbed ID
Control – Section – Job #
Urban Rural Designation
Under Construction Flag

2.2 Pavement Type and Characteristics Data

2.2.1 Roadbed Pavement Type

CRCP
JCP
ACP

2.3 Cross Section Data

Location of Layer Information
Layer Number

2.3.1 Original Surface

Date
Type
Thickness
Width
Aggregate Type
Aggregate Grade
Polish Value
Asphalt Binder Type
% Air Content
Date % Air Content Cores Taken
%RAP
% Air Voids
Date % Air Voids Cores Taken
Asphalt Viscosity
Date Asphalt Viscosity Cores Taken
% Passing #200 Sieve
Coarse Aggregate Grade
Cement Type
Fly Ash (0 – 99.9)
Pit I.D. #
Precoated (y or n)

2.3.2 Base

Type
Thickness
Width
Stabilization Type
Drainable
Pit I.D. #

2.3.3 Subbase

Type
Thickness
Width
Swelling Potential
Stabilization Type
Drainable
Pit I.D. #

2.3.4 Subgrade

Type
Stabilization Type
Stabil. Thickness/Depth
Triaxial Class

2.3.5 Last Overlay

Type
Date of Last Overlay
Thickness of Last Overlay
Total Overlay Thickness
Width of Last Overlay
Aggregate Type
Aggregate Grade
Polish Value
Asphalt Binder Type
% Air Content
Date % Air Content Cores Taken
% RAP
% Air Voids
Date % Air Voids Cores Taken
Asphalt Viscosity
Date Asphalt Viscosity Cores Taken
% Passing #200 Sieve
Coarse Aggregate Grade
Cement Type
Fly Ash (0-99.9)
Pit I.D. #
Precoated (y or n)

2.3.6 Last Seal Coat

Type
Date of Last
Aggregate Type
Aggregate Grade
Pit ID #
Precoated (y or n)
Polish Value

3. MMIS

3.1 Location Data

District
County
Responsible Maintenance Section
Highway Designation (hwy system, #, suffix)
Beginning Reference Marker and Displacement
Ending Reference Marker and Displacement
Actual Reference Marker
Contract Number
Fiscal Year

3.2 Maintenance Data

Date Work Performed
Amount Spent
Function Code
Month to Date Amounts
Month to Date Material Area
Type/Kind of Work

4. TRM

4.1 Location Data

District
County
Maintenance Section
Highway Designations (hwy syst., #, suffix)
Beginning Reference Marker and Displacement
Ending Reference Marker and Displacement
Roadbed ID
Elevation Measure
Latitude Measure
Longitude Measure
Functional System
Highway Status Code

4.2 Pavement Type and Characteristics Data

Number of Through Lanes
Left Shoulder Type
Left Shoulder Width
Right Shoulder Type
Right Shoulder Width
Curb Type
Median Type
Roadway Surface Width

4.3 Traffic Data

Average Daily Traffic
Cumulative ADT Since Original Surface
Design Hourly Volume
Current 18 kip Measure, 20 Year Projected 18 kip ESAL
% Trucks
Average Ten Heaviest Wheel Loads

4.4 Cross Section Data

4.4.1 Original Surface

Type

4.4.2 Base

Type

5. SiteManager

5.1 Location Data

County
Contract Number
Prime Contractor

5.2 Material Descriptions

Material Code
Material Short Name
Material Full Name
Material Category
Material Specification Reference
Material Status

5.3 Material Gradations

Gradation Sieve Size
Gradation Minimum Range
Gradation Maximum Range
Gradation Status

5.4 Mix Designs

Contract Mix
Aggregate Blend
Bituminous Concrete Mixes
- *Hveem*
- *SuperPave*
- *Marshall Mix Design*

Portland Cement Concrete Mix Design
Aggregate Mix Design
Pavement Structural Design Data

5.5 Hveem Mix Description

Hveem AC Type
Hveem Mix Type
Hveem Full Name
Hveem Producer/Supplier Name
Hveem Designer Name
Hveem Approved by I.D.

5.6 Hveem Mix Properties

HVEEM VFA %
HVEEM Optimum AC% Tot. Weight
HVEEM Stabilometer Value
HVEEM VMA %
HVEEM Bulk Density
HVEEM Average Film Thickness
HVEEM Bulk Dnsty Optim. AC Units Type
HVEEM Dust Asphalt Ratio
HVEEM Maximum Density
HVEEM Moisture Susceptibility
HVEEM Maximum Density Units Type
HVEEM Maximum Specific Gravity
HVEEM Air Void %
HVEEM Bulk Specific Gravity
HVEEM Mixing Temp. And Units
HVEEM Compaction Temp. Units Type
HVEEM Compaction Temperature

5.7 Marshall Mix Description

Marshall Designer Name
Marshall Mix ID
Marshall Mix Type
Marshall Material Code
Marshall Effective Date
Marshall Full Name
Marshall Termination Date
Marshall Producer/Supplier Code
Marshall Approved Date
Marshall Producer/Supplier Name
Marshall Approved By User ID

5.8 Marshall Mix Props

Marshall Asphalt Content %
Marshall Stability
Marshall Flow
Marshall Air Voids %
Marshall VMA%
Marshall Film Thickness
Marshall Filler/Bitumen Ratio
Marshall VFA%
Marshall Brick Height
Marshall Recycling Agent %
Marshall Anti-Strip Agent %
Marshall Asphalt Absorp. %
Marshall Weighted BSG
Marshall Max. Spec. Gravity
Marshall Virt. Spec Gravity
Marshall Effective Asphalt
Marshall Density/Unit Wt.
Marshall Number of Blows
Marshall Mixing Temp.
Marshall Compaction Temp.

5.9 SuperPave Mix Description

SuperPave AC Type
SuperPave Mix Type
SuperPave Full Name
SuperPave Producer/Supplier Name
SuperPave Approved By User ID
SuperPave Designer Name

5.10 SuperPave Mix Props

SuperPave N (Initial)
SuperPave N (Design)
SuperPave N (Maximum)
SuperPave % Gmm @ N (Initial)
SuperPave % Gmm @ N (Maximum)
SuperPave Opt. AC % by Total Wt
SuperPave Dust Proportion
SuperPave VMA %
SuperPave VFA %
SuperPave Lottman TSR
SuperPave Max. Specific Gravity
SuperPave Bulk Specific Gravity
SuperPave Mixing Temperature
SuperPave Compaction Temp.

5.11 Bituminous Materials

Bituminous Material Full Name
Bituminous Material Brand Name
Material %
Bituminous Material Sample ID
Bituminous Material Apparent Specific Gravity

5.12 Bitum. Gradations

Bit. Gradation Sieve Size
Bit. Gradation Sieve Value Bituminous
Master Grad. Limits Min.
Master Grad. Limits Max.
Production Tolerance Min.

Bituminous Material Producer/Supplier Name
Bituminous Material Bulk Specific Gravity
Production Tolerance Max.

5.13 PCC Description

PCC Mix ID
PCC Concrete Class Type
PCC Effective Date
PCC Full Name
PCC Termination Date
PCC Approved Date
PCC Producer/Supplier Name
PCC Approved by User ID
PCC Designer Name

5.14 PCC Properties

PCC Min. Avg. Strength Required
PCC Design Strength Required
PCC Air Content Measure
PCC Water to Cement Ratio
PCC Slump Measured
PCC Theoretical Unit Weight
PCC Unit Weight Measured

5.15 PCC Materials

PCC Materials Specific Gravity
PCC Materials Material Code
PCC Materials Bulk Specific Gravity
PCC Materials Brand Name
PCC Materials SSD Weight
PCC Materials Absorption %
PCC Materials %
PCC Materials Fineness Modulus
PCC Materials Sample ID
PCC Materials Mass

5.16 PCC Gradations

PCC Master Gradation Limits Max.
Grad. Production Tolerance Min.
PCC Gradation Sieve Size
Grad. Production Tolerance Max.
PCC Gradation Sieve Value
PCC Gradation Unit Types
PCC Master Gradation Limits Min.

5.17 Aggregate Mix Description

Aggregate Mix ID
Aggregate Mix Material Code
Aggregate Mix Full Name
Aggregate Mix Producer/Supplier Code
Aggregate Mix Producer/Supplier Name
Aggregate Mix Designer Name
Aggregate Mix Concrete Class Type
Aggregate Mix Effective Date
Aggregate Mix Termination Date
Aggregate Mix Approved Date
Aggregate Mix Approved by User ID
Aggregate Mix Raw Soil Max. Density
Aggregate Mix Units for Raw Soil Max. Density
Aggregate Mix Raw Soil Optimum Moisture %
Aggregate Mix Raw Soil Plus Cement Percent

5.18 Agg. Mix Comp. Str.

Aggregate Mix Age
Aggregate Mix Cement Percent
Aggregate Mix Compressive Str.

5.19 Aggregate Mix Materials

Aggregate Mix Material Code
Aggregate Mix Material Name
Material Producer/Supplier Code
Aggregate Mix Material Blend %
Aggregate Mix Material Sample ID

5.20 Agg. Mix Grad.

Master Grad. Limits Min.
Master Grad. Limits Max.

Aggregate Mix Soil Cement Maximum Density
Aggregate Mix Units of Soil Cement Max. Density
Aggregate Mix Soil Cement Optimum MC%
Aggregate Mix Recommended Cement Content by
Aggregate Mix Recommended Cement Content by
Aggregate Mix Maximum Volume Change %

Gradation Sieve Size
Production Tolerance Min.
Gradation Sieve Value
Production Tolerance Max.

5.21 Pavement Structural Design Data

Pavement Base
Pavement Subbase
Pavement Shoulder
Pavement Drainage Condition
Pavement Surface Thickness
Pavement Base Thickness
Pavement Subbase Thickness
Pavement Subgrade R-Value
Pavement Structural Capacity
Pavement Composite k-Value
Pavement Beginning Reference Point
Pavement Ending Reference Point
Pavement Milled Depth
Pavement Inside Shoulder
Pavement Lane 1
Pavement Lane 2
Pavement Lane 3
Pavement Lane 4
Pavement Lane 5
Pavement Lane 6
Pavement Lane 7
Pavement Lane 8
Pavement Lane 9
Pavement Lane 10
Pavement Outside Shoulder

5.22 Agg. Blend Data

Aggregate Blend Percent
Aggregate Blend Sample ID
Aggregate Blend Sieve Size
Agg. Blend Material Code
Aggregate Blend % Passing
Aggregate Blend Mat'l Name
Pavement Effective Thickness

5.23 Specifications

SiteManager also stores all the data elements required for the following three specifications:

Steel
Portland Cement
Emulsified Asphalt

5.24 Material Test Results

Sieve Analysis of Fine and Coarse Aggregates
Specific Gravity of Fine and Coarse Aggregates
Materials Finer Than No. 200 Sieve in Mineral Aggregates by Washing
Determining the Liquid Limit of Soils
Determining the Plastic Limit and Plasticity Index of Soils
The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
Compressive Strength of Cylindrical Concrete Specimens
Slump of Portland Cement Concrete

Weight Per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete
Air Content of Freshly Mixed Concrete by Pressure Method
Air Content of Freshly Mixed Concrete by the Volumetric Method
Mechanical Analysis of Extracted Aggregate
Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
Bulk Specific Gravity of Compacted Bituminous Mixtures Using SSD Specimens Maximum
Specific Gravity of Bituminous Paving Mixtures
Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
Asphaltic Cement Content of Asphalt Concrete Mixtures by the Nuclear Method
Particle Size Analysis of Soils
Specific Gravity of Soils
Resistance to Abrasion of Small Size Coarse Aggregate Using Los Angeles Machine
The Moisture-Density Relations of Soils Using a 5.5 lb. Rammer and a 12 in. Drop
Moisture-Density Relations of Soils Using a 10 lb. Rammer and an 18 in. Drop
Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
Penetration of Bituminous Materials
Effect of Heat and Air on Asphalt Materials (Thin-Film Oven Test)
Kinematic Viscosity of Asphalts
Viscosity of Asphalts by Vacuum Capillary Viscometer
Specific Gravity of Semi-Solid Bituminous Materials
Plastic Fines in Graded Aggregate and Soils by Use of the Sand Equivalent Test
Total Moisture Content of Aggregate by Drying
Laboratory Determination of Moisture Content of Soils
Unit Weight and Voids in Aggregate
Testing Emulsified Asphalt
Unconfined Compressive Strength of Cohesive Soil
Compressive Strength of Hydraulic Cement Mortar (Using 2 in. or 50 mm. Cube Spec.)
Air Content of Hydraulic Cement Mortar
Fineness of Portland Cement by Air Permeability Apparatus
Clay Lumps and Friable Particles in Aggregate
Water Retention by Concrete Curing Materials
Ductility of Bituminous Materials
Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth)
pH of Aqueous Solutions with the Glass Electrode
Determination of Organic Content in Soils by Loss on Ignition
Distillation of Cut-Back Asphaltic (Bituminous) Products
Mechanical Testing of Steel Products
Resistance of Concrete to Rapid Freezing and Thawing
Resistance R-Value and Expansion Pressure of Compacted Soils
Autoclave Expansion of Portland Cement
Normal Consistency of Hydraulic Cement
Time of Setting of Hydraulic Cement by Gillmore Needles
Free Form Test

To be specific, the following tests' results are provided for on the current version of SiteManager (they are represented by the above test names):

AASHTO *T11, T27, T84, T85, T89, T90, M145, T22, T119, T121, T152, T196, T30, T164, T166, T209, T269, T287, T88, T100, T96, T99, T180, T104, T49, T179, T201, T202, T228, T176, T255, T265, T19, T59, T208, T106, T137, T153, T112, T155, T51, T238, T200, T267, T78, T244, T161, T190, T107, T129, T154, Free Form*

ASTM *D2487, D4867*