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<tr><td colspan="4">16. Abstract
Research Project 0-4381, entitled "Develop an Automated System for Updating Pavement Layer Data," is intended to develop the appropriate mechanism and the corresponding algorithms that can be used to build an automated relationship between the pavement structure of the layer database and other potential source(s) of pavement layer information at TxDOT. As a result, this research presents the structure of the Automated Updating System designed to achieve a live and accurate pavement layer database.
In this study, a thorough literature review on the potential data sources for the Automated Updating System has been performed, followed by a careful consideration of what pavement layer data items are essential for inclusion in the database. The essential data items that are not currently available within the current GEOPAK design processes are identified, and recommendations for making those data items available have been introduced. Based on the system design concept defined in this study, the proof of concept of the Automated Updating System has been developed. The recommendations for statewide implementation of the system have also been given.</td></tr>
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AN AUTOMATED SYSTEM FOR UPDATING PAVEMENT LAYER DATA

Zhanmin Zhang, Pithon Vithayasricharoen, and Terry E. Dossey

Research Report Number 0-4381-1

Research Project 0-4381
Develop an Automated System for Updating Pavement Layer Data

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

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DISCLAIMERS

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CHAPTER 1 INTRODUCTION

1.1 Background

Up-to-date pavement layer data is one of the most critical issues in Pavement Management Systems. With the availability of accurate and up-to-date pavement layer data, more effective management and engineering of highway pavements in Texas can be achieved. Pavement layer data is important in many aspects of pavement engineering and management. Pavement performance models and pavement structural indexes require pavement layer data as input. In addition, the layer thickness and material types represent an important element of a Pavement Management System (PMS) database; they are needed for pavement load rating, overlay design, and maintenance and rehabilitation prioritization. The importance of layer data is obvious. As a result, various efforts have been made at the Texas Department of Transportation (TxDOT) to develop the layer data and layer database in the past. However, none of the efforts was sustainable because of the manpower and resources required to keep the pavement layer data updated.

Due to historical reasons, most of the layer data was recorded in hard-copy format; therefore, accessing such data is usually a time-consuming process. Because of such limitations, at the present time TxDOT does not have an accurate pavement layer database. Some efforts have been made to develop pavement layer information under ongoing research projects, but it is being developed using the road-life files and typical sections in the construction plan files. This is a labor-intensive process and does not lend itself to keeping the pavement layer database up-to-date. Furthermore, even if a computerized database can be developed and populated with available accurate layer data, it will soon become inaccurate again if there is not a contingent procedure or system to update the database.

Examining past efforts in developing the pavement layer data reveals that the effectiveness of a pavement layer database depends not only on the database development, but rather on a procedure or system that can be used to automatically and continuously update the developed pavement layer database. Therefore, a process that can automatically update the pavement layer database to instantly reflect any change made to a pavement structure is critical for keeping the pavement layer data valid and up-to-date.

1.2 Objective and Scope of Report

This report aims at developing a system with the appropriate mechanism and corresponding algorithms that can be used to build the automated relationships between the pavement layer database and other potential sources of pavement layer information at TxDOT. The proposed system would automatically capture the layer information from one or more potential data sources and update the pavement layer database whenever needed. With these relationships, the data in the pavement layer database will be updated automatically when any change is made to a pavement structure in the network. As a result, the automated system can help ensure not only that the pavement layer data reflects the current structural condition of the pavements, but also that the resources needed to maintain the database are significantly reduced.

Since developing a pavement layer database is a time-consuming and resource-demanding process, the key to an accurate and up-to-date pavement layer database is an automated system for updating pavement layer data. It is therefore critical to develop an automated updating system before any effort is made to develop a database. This study is intended to develop the automated system for updating pavement layer data so that TxDOT can always have a live and accurate pavement layer database.

To achieve this goal, the following steps have been undertaken in the study:

1. Analyze the potential sources for pavement layer data at TxDOT. This is to determine which required pavement layer data is currently available at TxDOT, where it is stored, and whether it is in an electronic format. Each data source is carefully analyzed with regard to its potential usefulness for pavement layer data. Special attention is given to the feasibility of automated procedures for each of the potential data sources.

2. Determine the data items to be included in the pavement layer database. Careful consideration must be given to what data should be included in the pavement layer database and in what format. Since each data item to be included in the pavement layer database has a direct impact on the automation procedure, it is

critical that the data items be kept at a minimal level while not losing the information intended for the pavement layer database.

3. Determine the missing data items. This task would determine which required pavement layer data is not being currently recorded within the current TxDOT operations. If there is such data, a recommendation will be made with regard to how best to capture this data.

4. Define the automated procedures. This task is critical to the success of this study. The primary objective of this task is to define an effective procedure in such a way that any change to the pavement layer structure can be automatically reflected in the pavement layer database in a timely manner. The process involves two key steps: (1) to automatically capture the information about any change made to a pavement layer structure and (2) to update the pavement layer database automatically with the captured change(s).

5. Develop the automated system for updating pavement layer data. This task would implement the framework and procedures defined under Step 4. Once the automated system is developed, the pavement layer database should be electronically and automatically updated whenever there is a change made to the pavement layer structure. The key to this automated system is to automate all the transactions for the database updating process so that the manpower required from the District and Division offices of TxDOT to maintain the layer database is minimized.

1.3 Report Organization

This report summarizes the work accomplished under the study and discusses the implementation of the automated system for updating pavement layer data.

The report is composed of seven chapters. Chapter 1 provides the background, the objective and scope of the research project, and the organization of the report.

Chapter 2 discusses potential data sources for the automated updating procedures. It presents five potential data sources that are currently available within TxDOT: the construction plans, the R-log files, core sampling, ground penetrating radar (GPR), and the existing pavement-related databases at TxDOT. Chapter 2 also emphasizes the feasibility of the automated procedures for each of the available data sources.

Chapter 3 focuses on the data items needed in the database. Careful consideration is given to what data items should be included in the pavement layer data and in what format. Chapter 3 also discusses the missing required pavement layer data items that are not currently available within TxDOT operations and the corresponding processes for making such data items available to the automated system.

Chapter 4 describes the framework of the automated system for updating pavement layer data. The procedures for capturing and recording the required data items are also presented.

Chapter 5 discusses components of the automated updating system and their functions. It also provides guidelines for using the automated updating system software. It can serve as the user manual for this software.

Finally, Chapter 6 summarizes the major research efforts and gives the conclusions of this study.

CHAPTER 2 REVIEW OF POTENTIAL DATA SOURCES

This chapter summarizes potential data sources for updating pavement layer data. The source of the pavement layer data has an immediate impact on how the pavement layer database can be updated automatically. As a result, a thorough analysis of all potential data sources for pavement layer data is conducted to determine which required pavement layer data is currently available at TxDOT, where it is stored, and whether it is in an electronic format. Special attention is given to the feasibility of automated procedures for each of the potential data sources.

In general, the data sources available at TxDOT can be divided into three categories: historical documents, field tests, and existing pavement-related databases. These three types of data sources are discussed in detail further in this chapter.

2.1 Historical Documents

Historical documents are the cheapest sources of information, since the only effort required is the time to locate the document and to review it. No equipment is necessary, no trip to the field is required, and no other expenses are associated. Of course, the drawback of this method is that the accuracy of the data is completely dependent on the original information in the documents. Also, the data in the documents is sometimes not complete. Two sources of data are available in this category: the construction plans and the R-log files.

2.1.1 Construction Plans

The construction plans show the as-designed specifications for particular work performed on a section of highway. The construction plans have several levels of detail according to the kind of work they show. For major rehabilitation, upgrading of the sections, or reconstruction, they always give more detailed information in addition to the thickness for all layers. The construction plans also show the materials to be used for the work, as well as slopes, widths, and other geometric characteristics. The main problem with this source of information is that it takes a considerable amount of time to get the specific information from the plans since each set of construction plans contains several pages. In order to determine the layer thickness of a complete section, many sets of plans have to be examined. Another consideration is that certain changes made in the field may not be recorded on the construction plan, producing discrepancies between the as-designed and as-built information.

At TxDOT, all the construction plans are currently produced using two computer programs, MicroStation and GEOPAK.

2.1.1.1 MicroStation

MicroStation is an engineering computer-aided drafting (CAD) software product developed by Bentley Systems, Inc. It is widely used in both the public and private sectors to create engineering design drawings. It is the CAD standard currently implemented by TxDOT. All the construction plans at TxDOT are produced and stored in MicroStation CAD design files. These design files, which have the .DGN extension that is specific to MicroStation, are recorded in the Intergraph Standard File Format (ISFF) [Leavy 1996].

Intergraph design files are sequential, variable-length files with variable-length records for the Design File Header, file set-up information, graphical elements, and non-graphical data [Leavy 1996]. Design files begin with the Design File Header, followed by a series of graphical elements [Safe 2003]. The Design File Header contains global information, including the transformation equation from design units to user coordinates, as well as the dimension of the elements in the file. Each element contains a standard element header, including the element type, level, size of element, and coordinate range information, and standard display information, such as its color, level, class, and style, as well as a number of attributes specific to its element type [Safe 2003]. For example, a text element has fields for font, size, and the text string in addition to the standard display attributes.

Any pavement section, whether it is a flexible or rigid pavement, is constructed of a set of layers consisting of the surface course, base course, subbase course, compacted subgrade, and natural subgrade [Huang 1993]. Within the cross-sectional drawings of the construction plans produced with MicroStation, different types of layers are separated by a set of line elements, as illustrated in Figure 2.1.

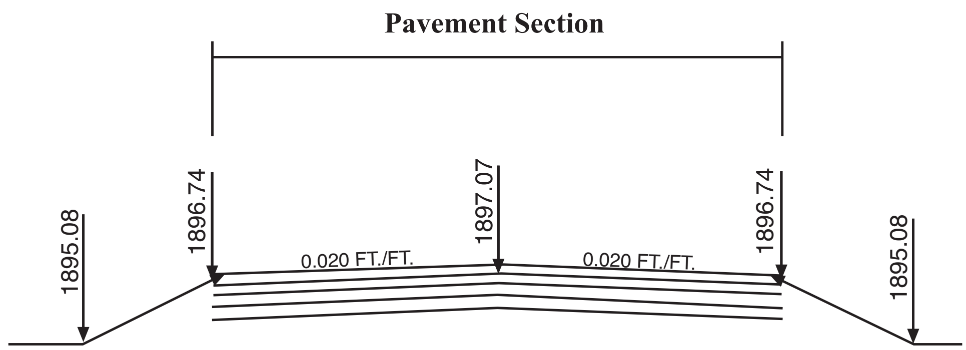


Figure 2.1 Cross Section of a Pavement Section Consisting of a Set of Layers

With the availability of the information regarding the design units of the design file and the coordinate range information of each element, the thickness information of each layer could be retrieved from the distances between each pair of line elements. Moreover, in a set of construction plans, text elements are also used to specify the location of work, type of work, material to be used for the work, and other detailed information in addition to the thickness of all layers. As a result, one would be able to extract the required pavement layer information in addition to the layer thickness from the text string available in the standard display information of each text element.

However, it is important to note that the required pavement layer information available in the design files (.DGN) is stored in binary format; thus, those design files must be decoded in order to get the specific information from the construction plans. In addition, as stated earlier, the design files are sequential, variable-length files with variable-length records; this means that the order of elements in a design file does not depend on the graphical location of such elements but rather on the sequence in which such elements were added to the design file. These drawbacks lead to a significant complexity in developing a system to track and capture the required pavement layer data stored in binary format from the design files.

2.1.1.2 GEOPAK

GEOPAK is an automated design software package used specifically for roadway design in the MicroStation graphic environment. It is a comprehensive software package that covers every project phase from the design to the production of roadway plans [TxDOT 2003a]. It is used to accomplish the following: Coordinate Geometry, Horizontal Alignment, Vertical Alignment, Existing Ground Profile, Existing Ground Cross Sections, Superelevation, Proposed Cross Sections, Drafting, Digital Terrain Modeling, and Sheet Generation. It is also used to compute the excavation quantities, draw the mass diagram, and determine the overhaul quantities in the Earthwork process. Finally, GEOPAK can create various cross-section reports to provide information about plan use (design elements and quantities) to contractors [TxDOT 2003a].

The software is fully integrated with the MicroStation CAD system to provide true interactive design. For example, a horizontal alignment can be created graphically by either the coordinate geometry component of GEOPAK or some interactive combination of MicroStation and GEOPAK. Dynamic on-screen design provides immediate interpretation of the plan view geometrics for making design choices through visualization.

GEOPAK uses script language to develop input files where the parameters for engineering drawings are defined. These input files are created and used for running various GEOPAK processes described earlier. The pavement layer data is part of the parameters that are defined in the input files created during the Proposed Cross Sections process [TxDOT 2003b]. Since the input files are created automatically during the GEOPAK design processes, high priority should be given to the feasibility of using the input files created in the GEOPAK processes as the source of the pavement layer data for the Automated Updating System.

It should be noted that the script-input information in the input files is stored in ASCII-text format, so it is easier to extract required information from the script-input files than the graphical design files generated by MicroStation. This provides the ideal opportunity to automate the updating of the pavement layer database. In other words, with well-designed computer software, the parameters related to the pavement layer can be tracked and captured from the script-input files. Once the information on the pavement layer is tracked and captured, another subroutine of the software can be developed to update the pavement layer database automatically.

2.1.2 The R-log Files

The R-log files contain the road life history of each pavement section according to control-section-job (CSJ) numbers. Most of the information in the R-log files was obtained from the construction plans. It summarizes all the work done to a particular segment of highway, including construction, rehabilitation, improvements, and reconstruction. The R-log files show the dates for each job, a brief description of the materials used, a brief description of the type of work that was done, and in some cases, an approximate cost.

The main problem with the R-log files is that the update of the files stopped several years ago (some in 1992 and the latest in 1995); therefore, the information in the files does not reflect the up-to-date pavement layer structure. Efforts were also made at TxDOT to develop the Road Life database, but the database is populated with only a very limited amount of data. Collection of data from the R-log files would be considerably less time-consuming than from the construction plans, but the cost is that the accuracy is compromised slightly. Therefore, the R-log files can be a good data source for developing the initial layer data, but it is certainly not a good source of information for the Automated Updating System.

2.2 Field Tests

In contrast to historical documents, field tests are methods that measure the in-situ pavement thickness. There are various field tests that can be used to obtain pavement thickness information. However, the field tests available at TxDOT are core sampling and ground penetrating radar (GPR). While field tests can give more accurate layer thickness information, the primary limitation for field tests is that they require many more resources compared to using historical documents, which makes it very hard to implement the method in a practical way for statewide applications. In addition, GPR can give good information on surface layer thickness, but it cannot provide information on the thickness of base or subbase layers and the material type of the layers.

2.2.1 Core Sampling

Core sampling, also known as coring, is the process of taking a cylindrical sample of the pavement from which the thickness and material of the layers can be determined. Core samples are usually 6 inches in diameter. However, their depth can vary according to the purpose of the sample taken. A coring can go as deep as necessary to get the whole structure of the pavement, including part of the subgrade or natural soil underneath the pavement structure. On the other hand, it can be as shallow as taking a sample of the surface layer only. A typical core sample from a flexible pavement is illustrated in Figure 2.2.

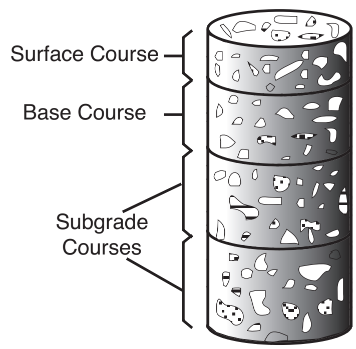


Figure 2.2 Typical Core Sample from a Flexible Pavement

The main advantage of this method is its accuracy, which is normally considered to be at 100 percent where the sample is taken. The measurement of the thickness of the layers is straightforward since it can be done using simple measurement devices such as ruler, measuring tape, and so on. Core sampling requires special equipment, but the equipment is fairly inexpensive.

However, one of the disadvantages of core sampling is the high cost due to the length of time required to extract the sample and patch the hole. In addition, the lane has to remain closed during the coring operations, causing delays and increasing user costs. The other major disadvantage of the core sampling process is the manpower required to perform all the tasks; thus, coring is not a practical source of information for automatically updating the pavement layer data.

2.2.2 Ground Penetrating Radar (GPR)

The ground penetrating radar (GPR) system has evolved as the most promising Non-Destructive Testing (NDT) method widely used to obtain high-resolution images of subsurface conditions. It can be employed to collect information about underlying highway pavement layers without incurring the time, labor costs, and traffic delays that come with the traditional method of drilling through the pavement to take core samples. In contrast, the GPR system collects pavement layer data quickly, unobtrusively, and inexpensively.

The GPR system uses a series of electromagnetic pulses to measure pavement layer thickness and other properties [Lenngren 2000]. It works similar to a fish finder or sonar. The difference is that the GPR uses electromagnetic waves rather than sound waves to penetrate the pavement, as illustrated in Figure 2.3.

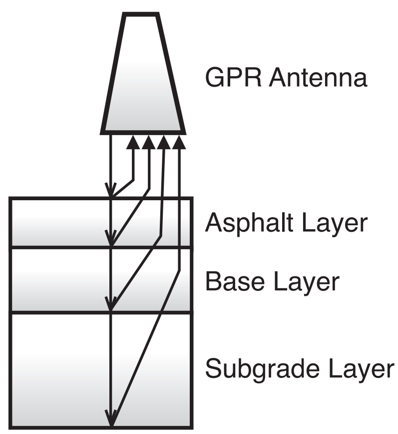


Figure 2.3 Concept of Measuring Pavement Layer Thickness with GPR

A series of short pulses of electromagnetic wave energy is transmitted into the pavement surface by an antenna mounted on a moving vehicle, as illustrated in Figure 2.4.

Figure 2.4 Ground Penetrating Radar Equipment Mounted on a Vehicle

As the energy travels down through the pavement structure, a transmitted wave is reflected at each layer interface. The arrival time and amount of the reflected energy can be used to calculate pavement layer thickness and other properties, such as moisture content and density.

The most important advantage of a GPR system is that it yields accurate data in a form ready for management consideration. The system surveys pavement quickly, cost-effectively, and with minimal traffic disruption and safety risks.

However, GPR also has several disadvantages, including the price of acquiring the equipment. One of the limitations of GPR is that it may not be able to detect the interface between concrete pavement and base layer or between base and subbase layers if there is insufficient contrast between the two layers. Secondly, GPR cannot provide the layer material information needed for the pavement layer database.

2.3 Current Pavement-Related Database at TxDOT

Another potential source of pavement layer data is the existing pavement-related databases at TxDOT. Currently, there are five major databases at TxDOT that are closely related to the engineering and management of pavements: 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). The information about the databases and the data elements contained within the databases was obtained from Victorine [1998]. This review also gives the background and the pavement-related data categories of the databases, in addition to their responsible division, control section size, data updating party, data collection party, frequency of data updating, degree of population, etc. Critical information regarding these five databases is summarized in Table 2.1

Table 2.1 Critical Information of Five Pavement-Related Databases [after Victorine 1998]

	PMIS	**Road Life**	**MMIS**	**TRM**	**SiteManager**
Section/ Division Responsible	Construction Division (CST)	Construction Division (CST)	Maintenance Division (MNT)	Transportation Planning and Programming Division (TPP)	Construction Division (CST)
Control Section Size	0.5 Mile	Homogeneous Sections	Distance Between TRMs	Continuous	Not Applicable
Data Updating Party	District PMIS Coordinator	Ad Lib	Maintenanace Crew Chief	District TRM Coordinator /TPP	Varies
Data Colletion Party	District Level	Ad Lib	District Level	District Level and TPP	Varies
Frequency of Data Updating	Annually/ Bi-Annually	Ad Lib	As Needed	As Needed	Varies
Degree of Population	Complete	Sparse	Complete	Complete	Not Applicable
Imports from	TRM, RL, MMIS	TRM	Not Applicable	Traffic Database	Unknown
Exports to	Not Applicable	PMIS	PMIS	PMIS, RL	Unknown

2.3.1 Pavement Management Information System (PMIS)

The Pavement Management Information System (PMIS) is an automated system used by TxDOT for "storing, retrieving, analyzing, and reporting information to help with pavement-related decision making process" [TxDOT 1994]. It is an analysis tool to support pavement management, the process of "providing, evaluating, and maintaining pavements in a serviceable condition according to the most cost effective strategy" [TxDOT 1994]. PMIS supports a wide range of activities, including planning, highway design, in-service evaluations, maintenance, rehabilitation, research, and extensive detailed reporting to a variety of decision makers. The PMIS database has been in use since its inception in May 1993 to satisfy the requirement of Federal Highway Administration for all states to initiate 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 needed funds to improve the highway system [Victorine 1998]. Therefore, the current PMIS carries data collected from 1983 to the present [Victorine 1998].

As shown in Table 2.1, the Construction Division is now responsible for PMIS. Data stored in the PMIS database are generally collected for and assigned to unique roadway sections. These sections are usually defined in half-mile increments and are identified by TxDOT district, county, and responsible maintenance section among other variables. More specifically, however, these half-mile sections are identified and isolated by their location within the Texas Reference Marker System (TRM), which is discussed in more detail later in this chapter. Consequently, sections are uniquely identified by the roadway designation, beginning and ending reference markers, and the corresponding displacements from each reference marker. These reference markers and displacements are actually maintained on the TRM database and are annually imported into the PMIS database in order to update section location information.

Data collection for PMIS has always been performed at the district level. The data is updated either annually or bi-annually by the district PMIS coordinator. PMIS is extremely well populated, despite the fact that, because PMIS receives its section location parameters from TRM, it only stores data on roadway sections currently on the TRM system. However, data population for those roadway sections on PMIS is complete. Some of the data items in addition to location information are imported from other databases such as RL and MMIS. It should be noted that PMIS only imports data from other databases, but it does not export data to others. PMIS contains nine pavement-related data categories listed as follows:

- Location Information
- Pavement Type and Characteristics
- Visual Distress Data
- Other non-Visual Distress Data
- Condition Scores
- Maintenance Data
- Climatic Data
- Traffic Data
- Cross Section Data

PMIS data is stored on the TxDOT mainframe computer in two ADABAS-type files. It may be accessed remotely through two kinds of software: Customer Information and Control System (CICS) and Remote Operating Systems Conversational On-Line Environment (ROSCOE). Therefore, theoretically it is accessible from any personal computer properly connected to the TxDOT network. "CICS provides a direct access environment with easy to use menus for accessing" [TxDOT 1994]. With CICS, preliminary database manipulations and inquiries can be performed directly. "ROSCOE provides a batch job environment for reviewing jobs submitted from the PMIS/CICS environment" [TxDOT 1994]. More complex functions are handled by submitting batch jobs from the menus.

2.3.2 Road Life Database

The Road Life Database (RL) was designed to support four functional areas: (1) performance of pavements, (2) rehabilitation design, (3) life-cycle costs, and (4) preventive maintenance [Victorine 1998]. It was created to offer an immediate solution for the data collection needs of TxDOT. The Road Life Database was initially developed by the Transportation Planning and Programming Division (TPP) of TxDOT in the early 1990s before the Design Division (DES) adopted its maintenance in November 1995. Road Life was finally completed in June 1996 [Victorine 1998].

As shown in Table 2.1, Road Life is now maintained by the Construction Division. The length of control section in Road Life depends on the homogeneity of the section. This means that Road Life data is stored in whatever lengths are convenient to yield homogeneously constructed pavement sections, such as intersection to intersection. Consequently, while generally homogeneous, the sections used in Road Life are incompatible with those in databases to which it 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 Road Life Database is inadequately populated given that it has been used on an optional basis by only some of the districts. Since the use of Road Life is optional, individual districts are entirely free to update the Road Life Database at their own leisure. Thus, theoretically, the parties responsible for data collection and updating as well as the frequency of data updating are varied among districts. The degree to which a district populates the Road Life Database has an influence on what effort is involved in updating it. For instance, some districts may want to enter data on roadways only as new construction and maintenance occurs while others may want to enter data on preexisting, unaltered roadways. The Road Life Database has three pavement-related data categories:

- Location Information
- Pavement Type and Characteristics
- Cross Section Information

Road Life data is stored on the TxDOT mainframe computer and can be accessed through CICS and ROSCOE from a properly networked personal computer.

2.3.3 Maintenance Management Information System (MMIS)

The Maintenance Management Information System (MMIS) is a TxDOT database system operated by the Maintenance Division (MNT). MMIS is designed to keep track of all maintenance activities performed on all roadways that fall under the jurisdiction of TxDOT [Victorine 1998]. Full data collection for MMIS began on September 1, 1989. It is the only

TxDOT database that stores extensive maintenance data on every Texas Reference Marker. In fact, other databases, such as PMIS and RL, import maintenance data from MMIS.

As shown in Table 2.1, MMIS is extremely well populated. Currently, MMIS stores records on every Texas highway reference marker according to the Texas Reference Marker System. The MMIS database is mainly updated at the district level by a maintenance crew chief to reflect new maintenance jobs performed on TxDOT-managed roads; thus, no data is imported from other databases. It is important to note that only maintenance activities are recorded in MMIS database; therefore, new construction is not a part of the scope of this database. There are two pavement-related data categories in MMIS:

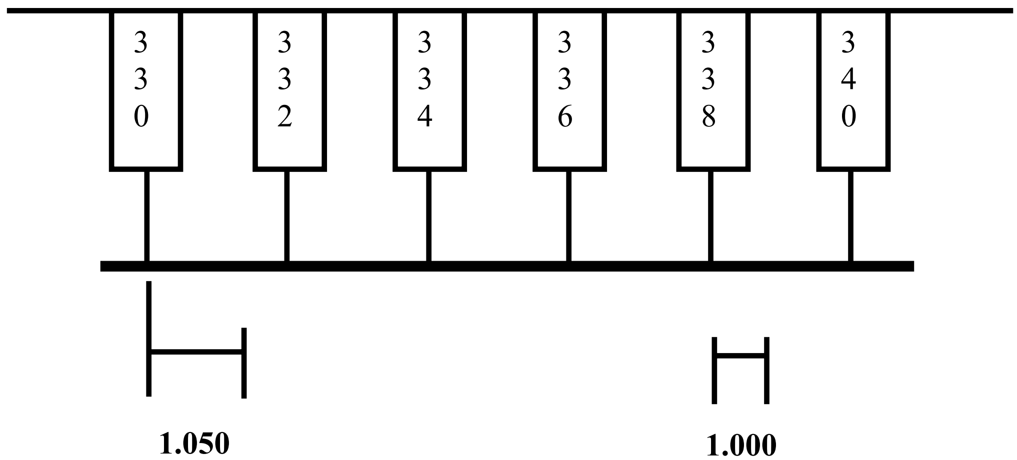
- Location Information
- Maintenance Data (such as type of work performed, type of maintenance materials, date of work performed, cost, material usage amounts, etc.)

MMIS data is stored on the TxDOT mainframe computer in four files: Audit, Master, Transaction, and FIMS-ENC41 files. MMIS data can be accessed remotely through CICS and ROSCOE.

2.3.4 Texas Reference Marker Database (TRM)

The Texas Reference Marker Database (TRM), taking its name from the roadway identification system used to organize TRM data, is designed to be a control location-based inventory of current roadway conditions within the TxDOT road network [Victorine 1998]. TxDOT created the TRM system to develop a statewide location system for the on-system routes in Texas, based on the physical markers located in the field. The TRM database was successfully implemented in May 1995. The TRM system 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, it stores data on the on-system roads, while the RI stores both on-system and off-system data.

Within the TRM database, data is tied to discrete, physical locations, accurate to one one-thousandth of a 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 are unique when their name is combined with the route designation on which they reside. For each Reference Marker, a distance from the origin of a roadway along the centerline of the roadway is assigned as its Distance from Origin (DFO) and is stored in the TRM master file. A specific feature or location on any roadway section can be simply identified by the DFO of the Reference Marker, the Reference Marker Sign, and the Reference Marker Displacement. The Reference Marker Sign is the symbol indicating the ascending or descending direction to a specific feature from the Reference Marker. The positive sign (+) indicates the displacement in an ascending reference marker direction, while the negative sign (−) indicates the displacement in a descending reference marker direction. The Reference Marker Displacement is the distance in miles from the specified Reference Marker on the highway to the specific feature. Thus, all feature locations are listed in relation to their distance from reference markers rather than their distance from the origin of the entire route. An example of a roadway section identified using the Texas Reference Marker System is illustrated in Figure 2.5.



Beginning Location	***Ending Location***
Highway System : **US**	Highway System : **US**
Highway Number: **0059**	Highway Number: **0059**
Reference Marker: **330**	Reference Marker: **338**
Displacement Sign: +	Displacement Sign: +
Displacement : **1.050**	Displacement : **1.000**

Figure 2.5 Definition of Sections and Discrete Locations Using the TRM System [TxDOT 1990]

As shown in Table 2.1, the TRM database is maintained by the Transportation Planning and Programming Division (TPP). TRM is not organized into control sections of discrete length, but rather in a continuous fashion. TxDOT districts and TPP are responsible for collecting TRM data, which is updated as needed by district TRM coordinators and TPP analysts. The TRM database is not only well organized but also extremely well populated. Some of the TRM data is exported to the PMIS and RL databases. On the other hand, the TRM database imports traffic data from the Traffic Database. TRM data is stored on the TxDOT mainframe computer in nine files: transaction, administration, feature, geometric, link, master, pavement, tracking, and traffic. TRM data can be accessed remotely through CICS.

There are four pavement-related data categories in the TRM database:

- Location Information
- Pavement Type and Characteristics
- Traffic Data
- Cross Sectional Data

2.3.5 SiteManager Database

The SiteManager development project officially started in October 1995 when MCI Systemhouse was awarded the contract for its creation. As it was envisioned, SiteManager is a comprehensive, state-of-the-art, and jointly developed construction management system sponsored by the American Association of State Highway and Transportation Officials (AASHTO), eighteen state Departments of Transportation (DOTs), one Canadian province, and the Federal Highway Administration (FHWA). It is intended to automate five major functional areas: (1) daily work reports and project records, (2) materials management, (3) contractor payments and progress monitoring, (4) civil rights requirements, and (5) administrative support [Victorine 1998].

As shown in Table 2.1, the responsible division for SiteManager is the Construction Division (CST). SiteManager does not have control sections like other pavement-related databases. SiteManager data is stored in a relational database. It should be noted that the other information from Table 2.1, such as the parties responsible for data collection and updating, the frequency of data updating, the degree of data population, etc., may not be up-to-date anymore because of the evolving nature of SiteManager. SiteManager is capable of running on Microsoft Windows 95, Microsoft Windows for Workgroups, Microsoft Windows NT, and IBM's OS/2 platform [AASHTO 1998]. SiteManager works in a client-server, local, or wide area network environment. There are 24 pavement-related data categories in SiteManager:

- Location Information
- Material Gradations
- Hveem Mix Description
- Material Descriptions
- Mix Designs
- Hveem Mix Properties

- Marshall Mix Description
- Marshall Mix Properties
- Superpave Mix Description
- Superpave Mix Properties
- Bituminous Material
- Bituminous Gradations
- PCC Description
- PCC Properties
- PCC Materials
- PCC Gradations
- Aggregate Mix Description
- Aggregate Mix Materials
- Aggregate Mix Compressive Strength
- Aggregate Mix Gradation
- Pavement Structural Design Data
- Aggregate Blend Data
- Specifications
- Material Test Results

After a comprehensive review of these five pavement-related databases with regard to their capability in providing pavement layer data for an automated updating system, it can be concluded that none of them has a mechanism for any pavement layer data to be updated systematically. Based on the review conducted in this chapter, the highest priority should be given to investigating the feasibility of using input files created in the GEOPAK processes as a primary source of pavement layer data for the automated updating system.

CHAPTER 3 PAVEMENT LAYER DATABASE

The pavement layer database is intended to provide pavement layer information essential to various management activities involved in providing and maintaining pavements at a level of service acceptable to the public. However, since each data item to be included in the pavement layer database has a direct impact on the automation procedure, the data items must be kept at a minimal but useful level that will not lose the important information intended for the database.

3.1 Essential Data Items

To meet the requirements of the pavement layer database, both the general pavement layer information and the location information of each highway section must be included in the database. To determine the data items essential to the pavement layer database, previous pavement-related databases have been reviewed, and meetings with TxDOT engineers as experts have been held.

The data items that are considered to be essential for inclusion in the pavement layer database are described as follows.

3.1.1 Section Description Data

The general pavement layer data in the pavement layer database is organized according to pavement sections. The section description data describes the location of the pavement section. Therefore, this information should be unique to each pavement section so that it can be used to identify the exact location of each particular pavement section. In the pavement layer database, the pavement section description method, also known as the location reference system, is similar to the location description method used in the Road Life Database, which was intended to aid investigations of pavement performance, rehabilitation design, life-cycle costs, and preventive maintenance of pavement sections. The aforementioned database uses Control-Section-Job (CSJ) numbers as the location description method. This location reference method is used in the pavement layer database because it is widely used by TxDOT to organize the construction plans produced for each of the construction projects.

The following is a list of the section description data items that should be included in the pavement layer database.

1. **Control-Section-Job Number (CSJ Number)**

   Most of the construction plans at TxDOT are organized by the control, section, and job numbers of a particular project. Control-Section-Job (CSJ) numbers are numbers assigned to all on-system public highways in Texas. The control number is assigned to a stretch of highway that often breaks at a county line, a major highway intersection, a river, or a stream. However, it can also break at any convenient location. The section number is a number within a specific control and is usually assigned sequentially from the beginning of the control number.The job number is the sequential number for any type of construction project (bridge, paving, etc.) that may have ever occurred on that section of highway. Thus, the CSJ number is a unique, identifying nine-digit number of a project done on a pavement section.

2. **District Name**

   This data item indicates which district is responsible for each construction project. The state of Texas is geographically divided into 25 highway districts. The area of each of the districts is an aggregation of traffic serial zones used in travel demand modeling for analysis and reporting. It should be noted that each district in which the Texas Department of Transportation conducts its primary work activities is managed by a district engineer.

3. **Highway Name**

   The highway name is composed of two parts, namely the route description and the number. The route description describes the ranking of the route. There are nine possible route descriptions: IH (Interstate Highway), US (US Highway), SH (State Highway), BI (Business Interstate), BU (Business US Highway), BS (Business State Highway), FM (Farm to Market), BF (Business Farm to Market) and PR (Park Road). The number distinguishes each highway from other highways with the same route description.

4. **Beginning Reference Marker and Ending Reference Marker**

   The district name and highway name information identifies the location of a specific highway. The CSJ number is then used as the location identification. Under this format, a control-section number represents each particular section of highway and a job number reflects the serial number of work performed on the specific section of highway. However, this location reference method does not provide the exact boundaries of each construction project performed on the highway. Therefore, the Texas Reference Marker system, in addition to the CSJ number, is used to identify the exact boundaries of construction work performed on a specific highway section. Such boundaries are defined by the beginning reference marker and the ending reference marker of each work activity. It should be noted that the first marker number represents the beginning of the route. It is the same as the nearest grid location that is derived by imposing a grid on the Texas state map. The following marker number is generally increased by 2, subsequently, until the end of the route is reached. In general, the reference marker increment direction is from west to east or from south to north for straight routes and clockwise for circular loops.

5. **Beginning Reference Marker Displacement and Ending Reference Marker Displacement**

   Because the real construction section or the maintenance section does not exactly match the sections divided by the road reference markers, the beginning reference marker displacement and the ending reference marker displacement are therefore needed to provide information about the difference in location of section boundaries from the specified beginning and ending reference markers. For example, a beginning reference marker displacement of 0.5 means that the beginning of the construction section is located 0.5 miles away from the nearest reference marker. These reference marker displacements are used in combination with the beginning and ending reference marker signs in order to identify the direction of the displacements to the boundaries of the construction project from the beginning and ending reference markers.

6. **Beginning Reference Marker Sign and Ending Reference Marker Sign**

   The beginning and ending reference marker signs are the symbols indicating the ascending or descending direction of the displacement from the beginning and ending reference markers to the exact boundaries of the construction project. The positive sign indicates the displacement in ascending direction from the reference marker, while the negative sign indicates the displacement in descending direction from the reference marker.

   With these five data items, the location of a pavement section can be fully determined. Table 3.1 is an example of the location reference data from the pavement layer database.

Table 3.1 Sample Location Reference Data in the Pavement Layer Database

DISTRICT	CONTROL	SECTION	JOB	HIGHWAY	Beg Ref Marker	Beg Sign	Beg Disp	End Ref Marker	End Sign	End Disp
LAREDO	0412	05	026	SH0163	0396	-	0.629	0398	+	1.847

As the table shows, the highway in the example is a state highway in the Laredo district. The construction project is the project 026 performed on control section 0412-05 of SH0163. This construction work begins at a point 0.629 mile in descending direction from the 0396 marker and ends at a point 1.847 miles away in ascending direction from the 0398 marker.

3.1.2 Pavement Layer Data

Data items in this category describe the properties and characteristics of each pavement section. Such data items are listed as follows:

1. Pavement Surface Thickness
2. Base Thickness
3. Subgrade Thickness
4. Pavement Width

5. Pavement Type, such as joint concrete pavement (JCP), flexible asphalt concrete pavement (ACP), continuous reinforced concrete pavement (CRCP), jointed reinforced concrete pavement (JRCP), joint plain concrete pavement (JPCP), prestressed concrete pavement (PCP), etc.
6. Material Type of Each Layer
7. Construction Year
8. Activity Type, such as overlay, new construction, etc.

3.2 Data Items Available from Construction Plans Produced by GEOPAK

A thorough analysis of the GEOPAK design procedure has been conducted in order to determine what kind of pavement layer information is available from the GEOPAK design process and where such information is stored.

It has been found that TxDOT is now accessing GEOPAK dialogs from Project Manager. Project Manager is a GEOPAK tool that associates a project with its respective gpk job number, users, working directories, and project files. It is also an excellent work flow system that records processes run throughout the design of a project. The working directory along with many other settings can be defined within Project Manager. Once Project Manager is setup, all the design files, output files, and input files created during the GEOPAK design process will be kept in the same working directory for each project. As a result, all the essential pavement layer information of each project can be captured from the same location.

A concentrated analysis has been given to the Proposed Cross Sections design process because it is the only design process of GEOPAK in which the pavement layer data are specified. Essential inputs required in this process are existing ground cross-section design files, pattern design files, existing ground profile design files, shape design files, and criteria files. All of those design files are generated in other design processes of GEOPAK, while the criteria files are tools used for creating proposed cross-section drawings at the end of this process.

Criteria files are free-format ASCII text files that evaluate conditions that GEOPAK uses to make design decisions. For example, criteria files will check the maximum slope intercept for a ditch section, then select the proper slope to tie to existing ground. Criteria files will consider each cross section individually, making this a very helpful and flexible tool. Criteria files are also used to place structures on the design cross sections, such as curb and gutters, concrete traffic barriers, and retaining walls. Using criteria files, the designer is able to input values for design options (DEFINE Variables) and use MicroStation elements to identify specific design features (DEFINE_DGN Variables). Following are descriptions and examples of elements that may be included in a criteria file.

DEFINE Variables text string keyed-in by the user to define a design option, e.g., **define "BASE DEPTH" 0.5**

This defines the proposed depth of a base layer using value of 0.5 ft.

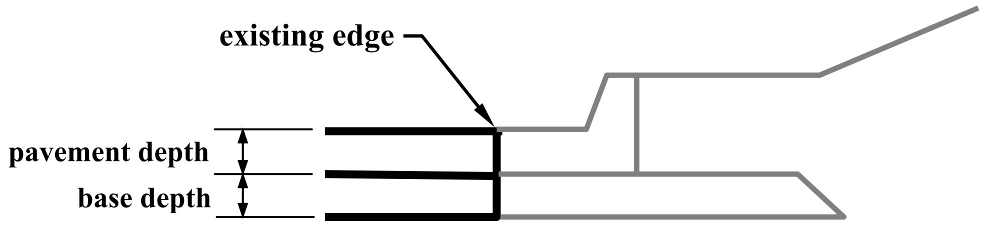
DEFINE_DGN Variables a series of text strings used to describe a design option or feature stored in a MicroStation graphics file as a MicroStation Element,

e.g.,

```
define_dgn  "ROW" \
dgn = plan.dgn \
lv =17 \
co = 6 \
lc = 0 \
```

This example points to the dgn variable "ROW" and indicates where the feature is referenced in the specified design file by level, color, and line code.

Some of the pavement layer data is also considered as design variables, such as pavement depth, base depth, and so on. An example of how a criteria file works is illustrated in Figure 3.1. This criteria file is used to place a surface and base layer in the proposed cross section plans for a rehabilitation job.



DEFINE Variables	**Existing Edge**
	Plan view graphical representation of existing edge.
DEFINE_DGN Variables	**Pavement Depth**
	Depth of proposed pavement
	Base Depth
	Depth of proposed base

Figure 3.1 Example of a Criteria File Used for a Rehabilitation Job [TxDOT 2003b]

At the end of the Proposed Cross Sections design process, an input file, pxsprj.inp, will be generated automatically by GEOPAK in the current working directory. This input file contains all of the essential information required for generating the proposed cross-section drawings, including those pavement layer variables defined in the criteria files. Values for the DEFINE Variables design option are available in the ASCII text format, as illustrated in Figure 3.2.

```
define_dgn "ROW" \
        dgn = D:\GEOPAK\LAREDO\0412-05\026\200110163g.dgn \
        lv = 18 \
        lc = 4 \
        wt = 4 \
        co = 6 \
        type = line, line_string, arc, curve, cmp_string

define_dgn "BASELINE" \
        dgn = D:\GEOPAK\LAREDO\0412-05\026\200110163g.dgn \
        lv = 1,18 \
        lc = 4 \
        wt = 2 \
        co = 0 \
        type = line, line_string, arc, curve, cmp_string

define "SLOPE TEXT SIZE" 0.6

define "ROW BERM DIST" 4

define "BASE DEPTH" 0.5

define "PAVEMENT DEPTH" 0.6

define "SCALE" 2

define "BASE TAPER WIDTH" 0.5

define "FORESLOPE USUAL" 6:-1

define "FORESLOPE WIDTH" 8

define "FILL SLOPE 6" 3:1

define "FORESLOPE MAX" 6:-1
```

Figure 3.2 Proposed Cross Section Input File Created by GEOPAK

Figure 3.2 shows that essential pavement layer data, pavement depth and base depth, can be obtained from this input file. Base depth of this roadway section is equal to 0.5 ft while pavement surface thickness is 0.6 ft. As a result, the input file generated during the Proposed Cross Sections design process by GEOPAK is the major source of information for the pavement layer database. Moreover, another major source of useful information is the input file generated during the Superelevation design process. Data items that can be extracted from these two input files are listed below:

- Pavement Surface Thickness
- Base Depth
- Subgrade Depth
- Pavement Width
- Construction Year

3.3 Missing Data Items

Several essential data items, especially section description data, cannot be captured from the input files generated during the GEOPAK design processes. The required pavement layer data that are not currently available within the design processes of GEOPAK are listed below:

- Cross-Section-Job Number (CSJ Number)
- District Name
- Highway Name
- Beginning Reference Marker and Ending Reference Marker
- Beginning Reference Marker Displacement and Ending Reference Marker Displacement
- Beginning Reference Marker Sign and Ending Reference Marker Sign
- Pavement Type
- Material Type of Each Layer
- Activity Type

These missing data items are very important information needed for inclusion in the pavement layer database. As a result, the best procedure for incorporating each of the missing data items into the GEOPAK design processes is carefully determined in order to ensure that those missing data items are automatically and systematically captured by the automated updating system. Such a procedure is described in the next section of this chapter as a recommendation for making those missing data items available to the automated updating system developed under this study.

3.4 Recommendations for Making the Missing Data Items Available

To capture the missing pavement layer data items stated in the earlier section, a procedure for making those data available to the automated updating system is needed for each of the missing data items. Those procedures are discussed in detail in the following sections.

3.4.1 Control-Section-Job Number (CSJ Number)

As stated earlier, most of the construction plans at TxDOT are organized by the construction project control, section, and job number (CSJ). The automated updating system will systematically capture the CSJ number if the CSJ number itself is set as the name of the working directory for each GEOPAK design project. It is recommended that the job number be set as the current working directory and the control-section number be set as the name of the parent directory where the working directory is located. An example of this directory hierarchy is as follows.

D:\geopak\LAREDO**0412-05****026**

Where: The control number is 0412
The section number is 05
The job number is 026

3.4.2 District Name

This data item, which indicates what district is responsible for each particular construction project, should be included in the pavement layer database. In order to capture the district name information, the district name should be set as the parent directory of the Control-Section directory. An example is shown below.

D:\geopak**LAREDO**\0412-05\026

Where: The district name is LAREDO
The control number is 0412
The section number is 05
The job number is 026

3.4.3 Highway Name

This information will allow easier identification of the location of each construction project. In order to capture this data, the highway name should be set as a project name in Project Manager, which, as stated earlier, is a tool GEOPAK uses to manage all processes run throughout the design of a project. Project Manager associates a project with its respective gpk job number, users, working directories, and project files. After the creation of a new design project, a project file (*projectname.prj*) will be created in the current working directory. If the highway name is set as the project name within the Project Manager dialog box, the automated updating system will capture the highway name automatically. An example of the project file is shown below.

sh163.prj

Where: The route description is SH (State Highway)

The highway number is 163

Figure 3.3 shows an example of the highway name being set as the project name in the Project Manager dialog box.

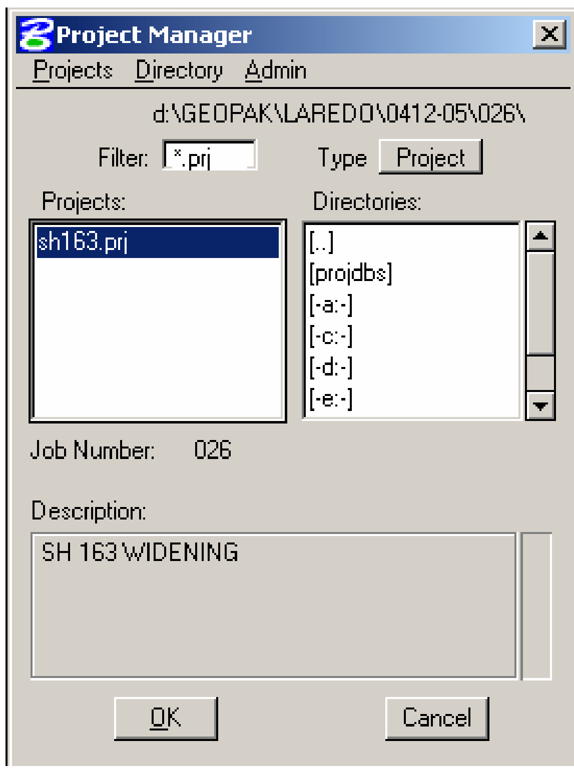


Figure 3.3 Example of the Highway Name Being Set as the Project Name

3.4.4 Pavement Type

This is important pavement layer information that must be maintained in the pavement layer database. To make this information available, a dummy criteria file can be created having "PAVEMENT TYPE" as a variable. If this dummy criteria file is added to the

Proposed Cross Sections design process, the Pavement Type variable will become an essential input for the design process. Such information will then be available in the input file generated by GEOPAK at the end of the Proposed Cross Sections design process. It should be noted that this dummy criteria file will not have any effect on the proposed cross-section drawings since it does not contain any drawing commands but only the "PAVEMENT TYPE" variable.

3.4.5 Material Type of Each Layer

Since material type is one of the factors used to evaluate the condition of a pavement structure, material information should be included in the pavement layer database. However, material information is not currently recorded in the GEOPAK design processes performed at TxDOT. Material information can also be made available to the automated updating system using the same procedure as for the Pavement Type information. Adding "BASE MATERIAL" and "SUBGRADE MATERIAL" variables to the dummy criteria file will allow such data to be captured in the input file generated by GEOPAK.

3.4.6. Beginning Reference Marker, Beginning Reference Marker Sign, and Beginning Reference Marker Displacement

Beginning Reference Marker, Beginning Reference Marker Sign, and Beginning Reference Marker Displacement values represent the beginning boundary of a construction project. Therefore, these three data items should be maintained in the pavement layer database. Without the exact location information, the full benefits of the pavement layer database cannot be achieved. The automated updating system can capture these three data items by adding "BEGINNING REFERENCE MARKER" and "BEGINNING REFERENCE MARKER OFFSET" variables to the dummy criteria file. It is important to note that the Beginning Reference Marker Sign and the Beginning Reference Marker Displacement can be combined jointly into the "BEGINNING REFERENCE MARKER OFFSET" variable. The automated updating system is arranged to split the input information into two data items and store them separately in the pavement layer database.

3.4.7 Ending Reference Marker, Ending Reference Marker Sign, and Ending Reference Marker Displacement

Ending Reference Marker, Ending Reference Sign, and Ending Reference Marker Displacement values represent the ending boundary of a construction project. They can also be made available to the automated updating system using the same procedure as for the beginning boundary of the construction project by adding "ENDING REFERENCE MARKER" and "ENDING REFERENCE MARKER OFFSET" variables to the dummy criteria file.

3.4.8 Activity Type

Activity type of a project is one of the essential elements of information to be included in the pavement layer database. This data item indicates what activities have been applied to each highway section. To capture this information, the "ACTIVITY" variable is added to the dummy criteria file. With this criteria file, the activity information is obtainable in the input file generated at the end of the Proposed Cross Sections design process.

The dummy criteria file containing variables for all missing pavement layer data, namely layerdata.e, is created and used in the Proposed Cross Sections design process to verify the effectiveness of the proposed procedures for capturing those missing data items. An example of such a dummy criteria file is illustrated in Figure 3.4.

```
/*---------------------------------------------------------------------------*/
_s_message1 = ^PAVEMENT TYPE^
_s_message2 = ^BASE MATERIAL^
_s_message3 = ^SUBGRADE MATERIAL^
_s_message4 = ^BEGINNING REFERENCE MARKER^
_s_message5 = ^BEGINNING REFERENCE MARKER OFFSET^
_s_message6 = ^ENDING REFERENCE MARKER^
_s_message7 = ^ENDING REFERENCE MARKER OFFSET^
_s_message8 = ^ACTIVITY^


if pavement slope < 100 then
{
        if _s_message1 = "PAVEMENT TYPE" then
        draw dx = 0 dy = 0
        if _s_message2 = "BASE MATERIAL" then
        draw dx = 0 dy = 0
        if _s_message3 = "SUBGRADE MATERIAL" then
        draw dx = 0 dy = 0
        if _s_message4 = "BEGINNING REFERENCE MARKER" then
        draw dx = 0 dy = 0
        If _s_message5 = "BEGINNING REFERENCE MARKER OFFSET" then
        draw dx = 0 dy = 0
        if _s_message6 = "ENDING REFERENCE MARKER" then
        draw dx = 0 dy = 0
        if _s_message7 = "ENDING REFERENCE MARKER OFFSET" then
        draw dx = 0 dy = 0
        if _s_message8 = "ACTIVITY" then
        draw dx = 0 dy = 0
}
else
{
        if _s_message1 = "PAVEMENT TYPE" then
        draw dx = 0 dy = 0
        if _s_message2 = "BASE MATERIAL" then
        draw dx = 0 dy = 0
        if _s_message3 = "SUBGRADE MATERIAL" then
        draw dx = 0 dy = 0
        if _s_message4 = "BEGINNING REFERENCE MARKER" then
        draw dx = 0 dy = 0
        If _s_message5 = "BEGINNING REFERENCE MARKER OFFSET" then
        draw dx = 0 dy = 0
        if _s_message6 = "ENDING REFERENCE MARKER" then
        draw dx = 0 dy = 0
        if _s_message7 = "ENDING REFERENCE MARKER OFFSET" then
        draw dx = 0 dy = 0
        if _s_message8 = "ACTIVITY" then
        draw dx = 0 dy = 0
}
```

Figure 3.4 Dummy Criteria File Containing Variables for the Missing Data Items

The dummy criteria file, layerdata.e, is then added to the Shape Clusters dialog box during the Proposed Cross Sections design process, as illustrated in Figure 3.5.

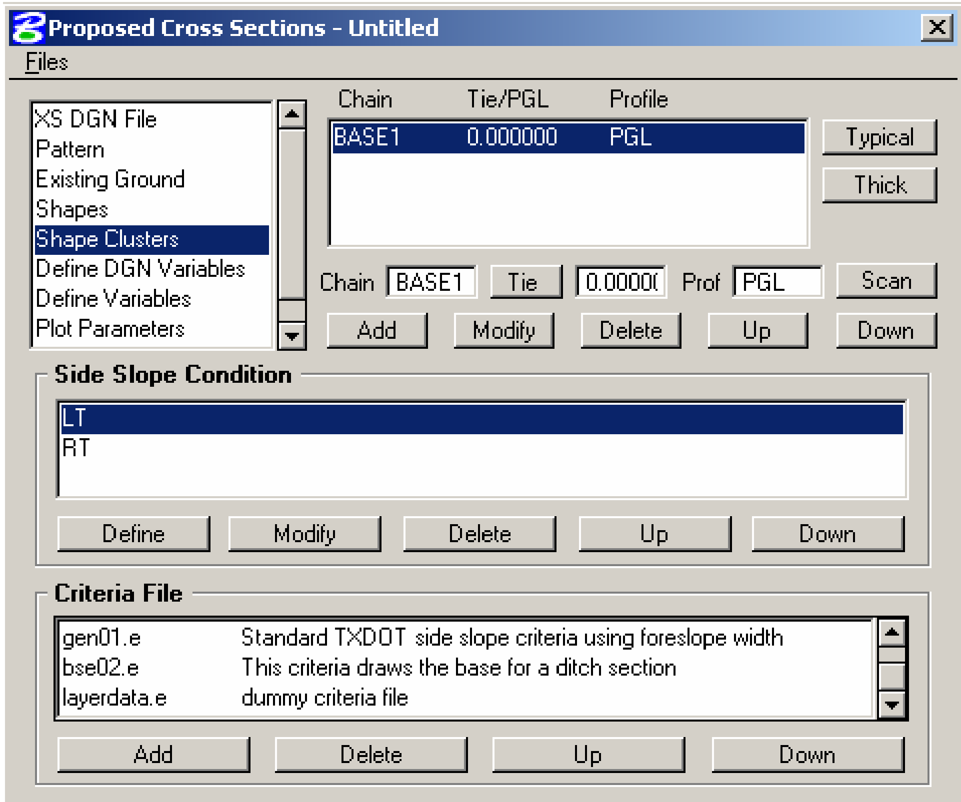


Figure 3.5 Shape Cluster Dialog Box Containing layerdata.e

With the dummy criteria file added to the Shape Clusters dialog box in the Proposed Cross Sections design process, in the Define Variables dialog box, the variables for the missing pavement layer data are available to be included in the Proposed Cross Sections design process, as depicted in Figure 3.6.

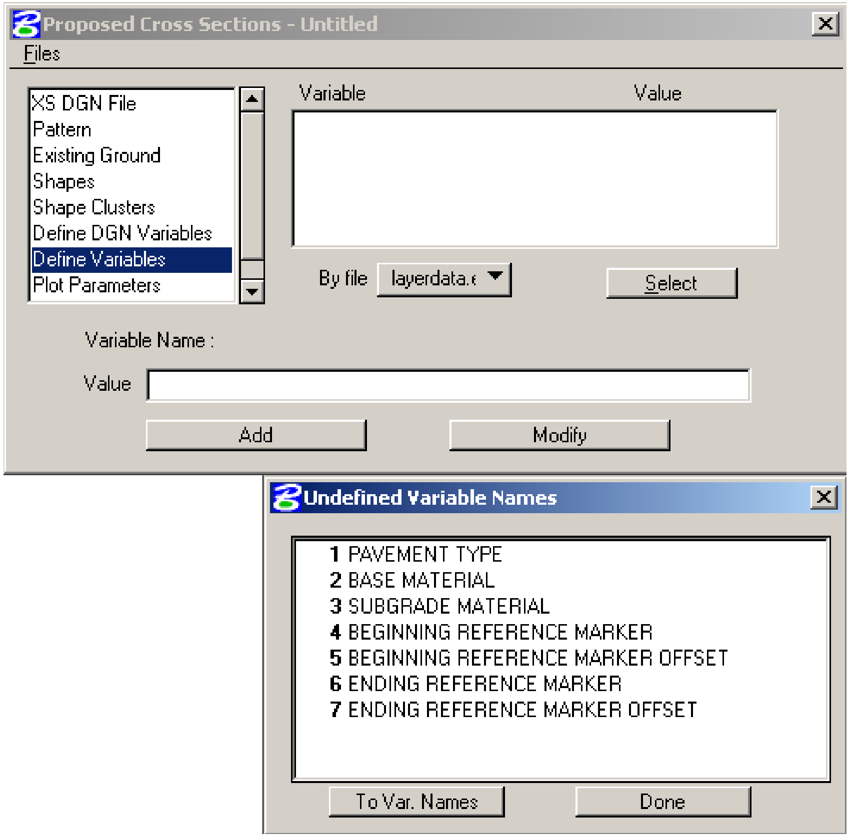


Figure 3.6 Pavement Layer Variables Defined in layerdata.e

Eventually, the value entered in the Define Variables dialog box for each of the variables and the variable name are stored in the input file produced by GEOPAK at the end of the Proposed Cross Sections design process. This input file is used by GEOPAK to draw all the cross-section drawings within the specified roadway section.

In summary, the procedures proposed in this chapter provide means by which all missing pavement layer data important to the pavement layer database can be effectively and efficiently captured and processed by the automated updating system. The framework and system design concept of the automated updating system are discussed in Chapter 4.

CHAPTER 4 THE CONCEPT OF SYSTEM DESIGN OF THE AUTOMATED UPDATING SYSTEM

The purpose of developing an automated system for updating pavement layer data is to have the appropriate mechanism and the corresponding algorithms that can be used to build an automated relationship between the pavement layer database and the input files, pxsprj.inp, generated by GEOPAK at the end of the Proposed Cross Sections design process. The automated system is developed in such a way that any change made to the pavement layer structure in the Texas road network can be systematically and automatically reflected in the pavement layer database in a timely manner. The process involves two key steps. One step is to automatically capture the layer information on any change made to the pavement layer structure from the input files produced by GEOPAK; the other step is to update the pavement layer database automatically with the captured information. As a result, the automated updating system can help ensure that the pavement layer data in the pavement layer database completely reflects the current structural condition of the pavement sections.

The following two chapters discuss important issues related to the design and pilot implementation of the automated updating system. This chapter focuses on the concept of system design issues; Chapter 5 introduces functions and the Graphical User Interface (GUI) of the Automated Supporting Software.

System design of the automated updating system concentrates on two important tasks, as stated earlier. The first task is to electronically capture the pavement layer information from the input files created by GEOPAK at the end of the Proposed Cross Sections design process; the other task is to automatically update the pavement layer database with the captured information. With the automated updating system, the resources required from the District and Division offices of TxDOT to maintain the layer database would be minimized.

4.1 Introduction to the Development Environment

Microsoft Visual Basic 6.0 is used to develop the automated updating system. Microsoft Visual Basic is one of the components of the Microsoft Visual Studio Package, which is a product from Microsoft Corporation. It is a powerful object-oriented, event-driven Graphical User Interface (GUI) programming language that provides a very user-friendly environment for software designers to develop Windows-based applications [Microsoft 1998].

Microsoft Visual Basic has the following characteristics that make it a useful programming development tool:

1. Microsoft Visual Basic operates in a Graphical User Interface (GUI) environment, which means that it provides the software developer such user interfaces as menus, windows, and window controls. It also contains various user interface design objects, such as label object, command button object, scroll bar object, text box object, etc, which can be placed directly on the design window without any code required [Microsoft 1998].

2. Microsoft Visual Basic adopts an event-driven mechanism [Microsoft 1998]. The application responds to user actions, such as clicking the mouse button, moving down the scroll bar, changing the position of the cursor or clicking the function button. This mechanism makes it possible for the user to control the next step after the software begins to run.

3. Microsoft Visual Basic provides a data control object that can be used to access the data stored in databases [Microsoft 1998]. It also provides bound controls, which allow the user to manipulate several data records simultaneously [Microsoft 1998].

4. Microsoft Visual Basic provides a data window object that can be utilized to connect databases with the window interface. With the data window object, the pavement layer data stored in the database can be displayed in the window interface.

5. Microsoft Visual Basic provides easy access to data stored in various kinds of relational databases. This characteristic makes it possible for the pavement layer database to be manipulated with various kinds of functions.

While the automated updating system is developed using Microsoft Visual Basic, the pavement layer database is developed within the Microsoft Access Environment. Microsoft

Access is one of the most popular database applications, and it is most compatible with the automated updating system developed in the Microsoft Visual Basic Environment.

4.2 Framework of the Automated Updating System

The automated system for updating pavement layer data is developed based on the framework illustrated in Figure 4.1.

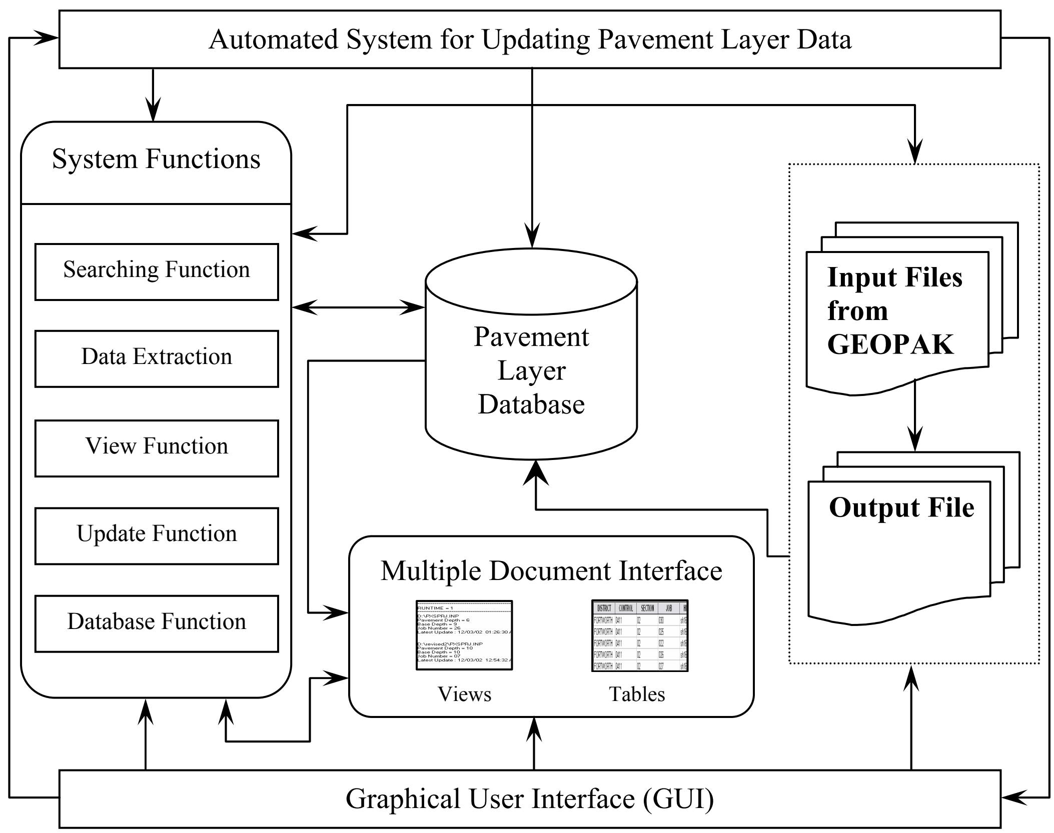


Figure 4.1 Framework of the Automated Updating System

As shown in Figure 4.1, the automated updating system is the central component for updating pavement layer data. The automated updating system performs the data extraction functions as well as the data storage functions. The major data of the automated updating system is acquired from the input files produced by GEOPAK at the end of the Proposed Cross Sections design process. The output of the automated updating system can be displayed in two formats: the ASCII text format and the tabular format.

This automated system has the capability to search through each active hard drive for the input files generated by GEOPAK, and consequently can electronically capture all required pavement layer information from those input files in a timely manner. Such information is then used to update the pavement layer database automatically. This automated updating system is capable of displaying the information within the pavement layer database to the user within the same Graphical User Interface (GUI). Because all these tasks can be done within the same user environment, the manpower required to maintain the developed pavement layer database will be minimized.

4.3 Operational Requirements of the Automated Updating System

The automated updating of pavement layer data consists of two key steps:

- The automated system automatically captures the information on any change made to a pavement layer structure.
- The automated system systematically updates the pavement layer database within the captured pavement layer information.

Once the automated updating system is first executed, users are required not only to designate the hard drive(s) used to keep the design projects created by GEOPAK, but also to specify the output file name and location. This output file works as a buffer zone of the pavement layer information captured from the input files produced by GEOPAK at the end of the Proposed Cross Sections design process.

When the required setup information is defined, the automated updating system utilizes the acquired information to search the specified hard drive(s) for the input files created by GEOPAK. The automated updating system then accesses each of the input files to capture the essential pavement layer information stored in those input files. Once the pavement layer information of each GEOPAK project is extracted, the automated system stores such information in the output file automatically.

After the first-time execution of the automated updating system software, it is unnecessary to provide the setup information unless the required setup information is changed. The system is designed to perform all tasks using the setup information specified in the first execution. All the pavement layer information of every pavement section acquired from the input files will be appended to the output file each time the automated system is executed.

Since the automated updating system is designed to search the specified hard drive(s) for the input files produced by GEOPAK every time it is executed, all the input files found in the current execution will also be found in the next execution. As a result, the pavement layer information of the same pavement section will be stored in the output file over and over again. In order to avoid the redundancy of storing the pavement sections in the output file, the date and time of the most recent execution of the automated system are taken into account for the current operation of the automated system. The date and time of the latest execution of the automated updating system are compared with the date and time of each input file. The automated updating system will search for and detect only the input files created after the previous execution. This process ensures that the input files that were once accessed to extract the pavement layer information will not be detected again. The complete data extraction process is shown in Figure 4.2.

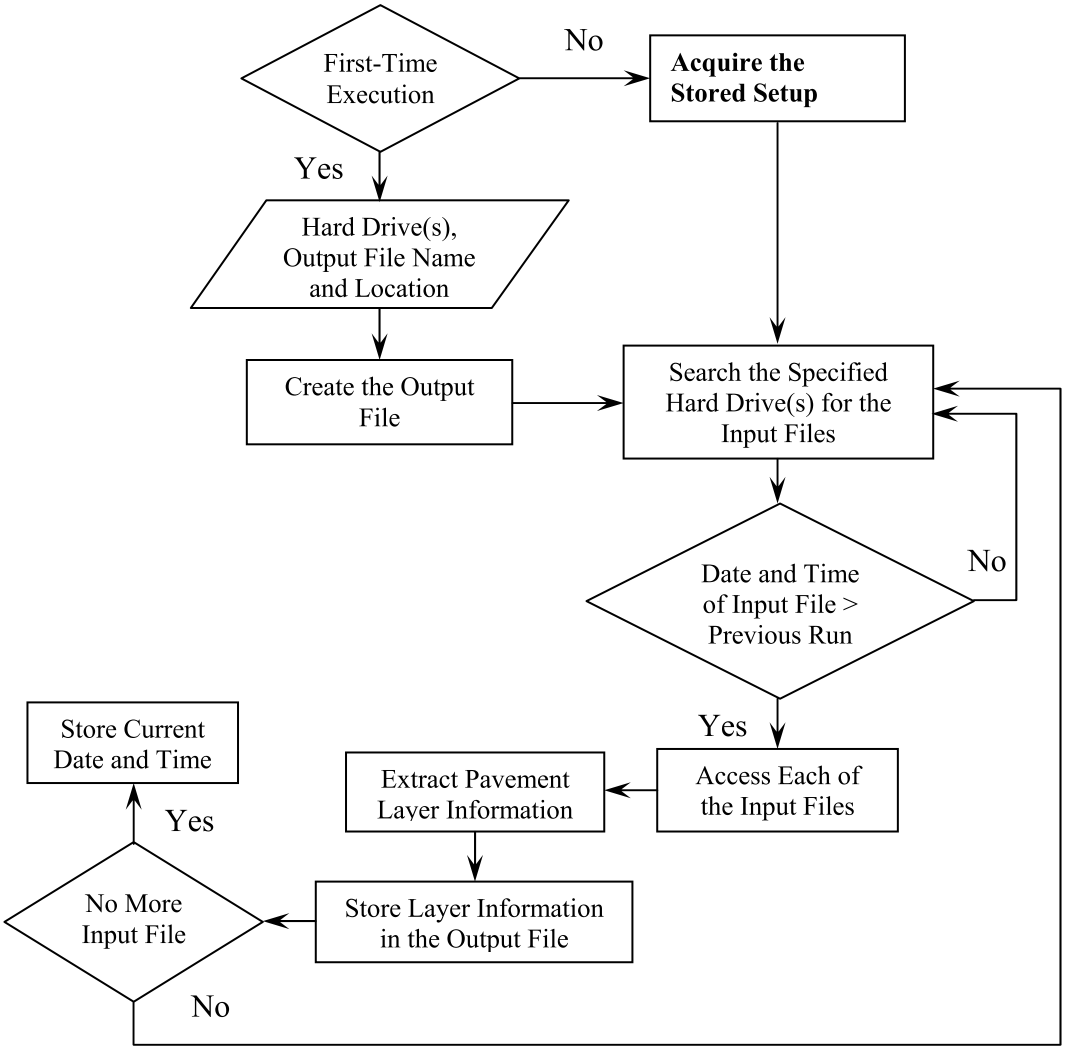


Figure 4.2 Data Extraction Process of the Automated Updating System

The automated system provides users the feature to view the pavement layer information stored in the output file. It also provides the tools for managing and manipulating the pavement layer information of the pavement sections existing in the output file. With the tools provided in the automated updating system, it is possible to insert a new pavement section based on the CSJ number along with the pavement layer information, modify the pavement layer information of the existing pavement sections, and clear all layer information of an existing pavement section.

Furthermore, the automated system is intended to export the pavement layer information of a set of selected pavement sections from the output file to the pavement layer database. To provide user-friendly support, the automated system is designed to provide the visualization of the information stored in the pavement layer database through a data window object. The system is also capable of determining and displaying the current pavement layer information of a selected pavement section based on the Texas Reference Marker System.

It is important to note that to get the automated updating system automatically executed in a timely manner, this automated updating system software must be added to the Scheduled Tasks utility in the Control Panel under the Windows environment. This Scheduled Tasks utility will execute the automated updating system at the date and time specified. Users are able to schedule this automated system to run daily, weekly, monthly, or at certain times as needed.

4.4 Operational Issues of the Automated Updating System Design

The system design considers these operational issues: (1) what operations should be applied to the data, (2) what functions should the automated system provide, and (3) how should the user interface be designed. This section describes the general operation design procedure. The software functions will be introduced in detail in Chapter 5.

In order to determine the desired functions of the automated system for updating pavement layer data, the tasks that the automated system is required to perform should be identified first. Table 4.1 shows the required tasks for the automated updating system.

Table 4.1 Application Tasks for the Automated Updating System

Task Number	Task Description
1	Capture the pavement layer information.
2	Visually display the pavement layer information.
3	Manage the pavement layer information of the pavement sections.
4	Update the pavement layer database.
5	Visually display the pavement section information.

Each general task of the system can be split into specific functions, as described in Table 4.2.

Table 4.2 Desired Functions for the Automated Updating System

Application Tasks	Desired Functions
Capture the pavement layer information	1. Select the hard drive(s) to be searched. 2. Specify the name of the output file. 3. Specify the location of the output file. 4. Search the specified hard drive(s) for the input files produced by GEOPAK. 5. Capture the required pavement layer information from the input files. 6. Create the output file. 7. Store the captured information in the output file.
Visually display the pavement layer information	1. Link the data window object with the output file. 2. View the pavement layer information of each pavement section based on the CSJ number stored in the output file.
Manage the pavement layer information	1. Import the pavement layer information from the output file. 2. Sort the existing pavement sections based on the CSJ number. 3. Insert new pavement section. 4. Insert pavement layer information of the new pavement section. 5. Delete all pavement layer information from an existing pavement section. 6. For each existing pavement section record: 6.1 View the pavement layer information. 6.2 Edit the pavement layer information. 6.3 Update the pavement layer information of the selected pavement section. 7. Update the output file.

Table 4.2 Desired Functions for the Automated Updating System (Cont.)

Application Tasks	Desired Functions
Update the pavement layer database	1. Connect to the pavement layer database. 2. List all existing pavement sections from the output file. 3. Export the pavement layer information of the selected pavement sections to the pavement layer database. 4. Remove the pavement sections exported to the pavement layer database from the output file.
Visually display the pavement section information	1. Search the whole database for the specified pavement section. 2. View the latest pavement layer information based on the Texas Reference Marker System.

Another important operational issue of the system design is the Graphical User Interface (GUI). The Graphical User Interface of the automated updating system software serves as the linkage between the software user and the functions that the automated updating system application provides; therefore, the user interface is designed to be friendly, intuitive, and self-explanatory enough so that the learning curve of the automated supporting software will not be so high as to impede the implementation of the automated system.

Based on the system design concept defined in this chapter, the Automated Updating System software has been developed. The software functions and the Graphical User Interface of the Automated Supporting Software are introduced in detail in Chapter 5.

CHAPTER 5 AUTOMATED UPDATING SYSTEM SOFTWARE

The automated updating system is designed to produce a live and accurate pavement layer database. With the automated updating system software, the pavement layer information of any construction activity made to a pavement layer structure can be automatically captured and the pavement layer database can be systematically updated with the captured pavement layer information. The software provides a user-friendly graphical user interface (GUI) used not only to store, modify, delete, and display the pavement layer information, but also to update the pavement layer database with the captured layer information. The final product of the automated updating system software is an executable computer program running under the Windows environment.

Software components and their functions are comprehensively described in this chapter. Step-by-step guidelines for using the automated software are also provided.

5.1 System Components and Menu Structure

The automated system for updating pavement layer data consists of two major components: system setup and database management. The system setup component launches the input and output information used for the data extraction process, while the database management component stores, updates, displays, and visually displays the pavement layer data in both the pavement layer database and the output file used to store the captured pavement layer information.

The primary menu of the automated updating system consists of six parts: File, Run, View, Modify, Database, and Layer. Each part has its own submenu items that perform various functions. The software also provides shortcut command buttons for all frequently used menu items to make those functions easily accessible. These shortcut command buttons are docked on the mainframe of the automated updating system software. Figure 5.1 illustrates the main menu structure of the automated updating system software.

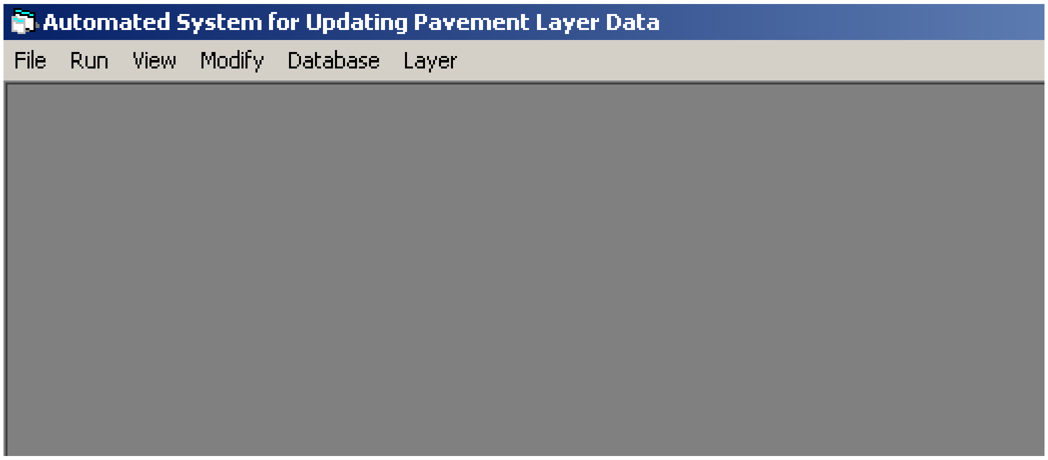


Figure 5.1 Main Menu Structure of the Automated Updating System

The submenu structure of each primary menu item is shown in Table 5.1.

Table 5.1 Submenu Structure of the Automated Updating System

Primary Menu	Submenu Structure
File	New Search Ctrl+N Input Ctrl+I Output Ctrl+O Exit Ctrl+X
Run	Start Shift+F5
View	View Output File Ctrl+V
Modify	Modify Layer Information Ctrl+M
Database	Update Database Ctrl+U
Layer	Current Layer Information Ctrl+C

Table 5.2 shows the shortcut buttons and the functions they represent.

Table 5.2 Shortcut Command Buttons and the Corresponding Functions

Shortcut Command Button	Corresponding Function
Input	Input Setup
Output	Output Setup
Start	Start the Data Extraction Process
View	Display the Captured Information
Modify	Edit the Pavement Layer Information
Update Database	Update the Pavement Layer Database
Update Layer	Display the Pavement Section Information

5.2 Operation of the Automated Updating System

5.2.1 Getting Started

To start the Automated Updating System software, the user uses the "Start" button on the Windows task bar and selects "All Programs." The user then selects the "Automated Updating System" program group and clicks on the "Automated Updating System" icon. When the program is launched, the Automated System startup splash screen will appear to notify the user that the software is being loaded. The startup splash screen is illustrated in Figure 5.2.

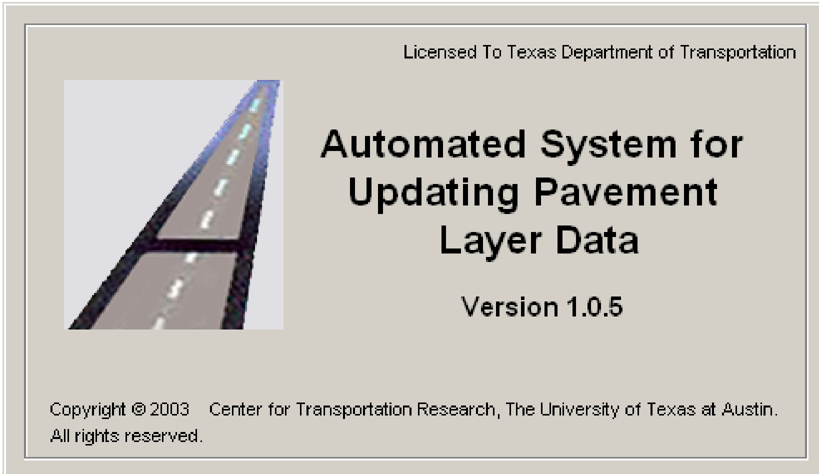


Figure 5.2 Automated Updating System Startup Splash Screen

When using the automated system for the first time, the user must go to the File menu and select New Search. At this point, the Main Menu window of the automated software will appear, as shown in Figure 5.3.

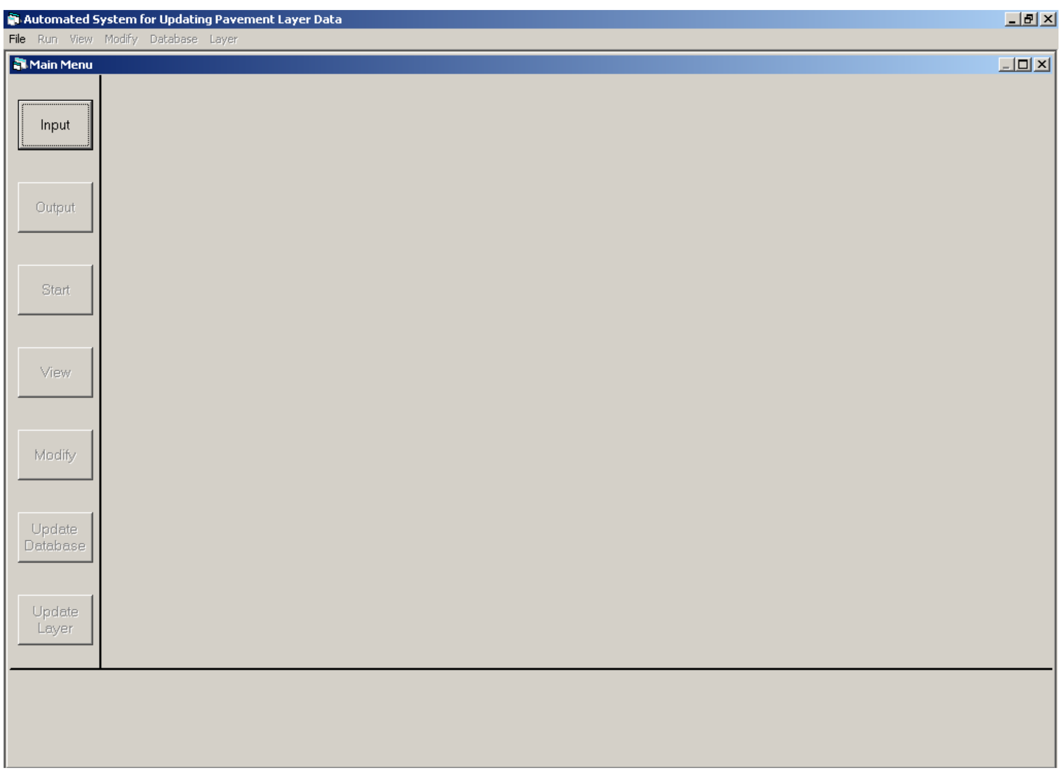


Figure 5.3 Main Menu Window of the Automated Updating System

5.2.2 File Menu

The File menu is used to open the Main Menu window of the Automated Updating System as well as to terminate the operation of the software. Moreover, it is also used to set up both the input and output information. It includes four submenu items: New Search, Input, Output, and Exit.

5.2.2.1 New Search

The first item in the File menu is "New Search." This is the only item that is enabled when the automated software is executed for the first time. It opens the Main Menu window of the Automated Updating System, as illustrated in Figure 5.3. At this point, the system is ready to be operated.

5.2.2.2 Input

The second item on the File menu is "Input," which is the only menu item that is accessible after the Main Menu window of the software is opened since the user has to specify the hard drive(s) to be searched before anything can be done. This menu item opens the Input dialog box, which allows the user to select the active hard drive(s) in which the design projects as well as the input files created by GEOPAK are kept. The hard drives that are shown in the Input dialog box are the hard drives that are currently in use. Any inactive hard drive will not appear in the Input dialog box. This prevents an unexpected error in case the user selects an inactive hard drive unintentionally. The input file name that is searched by the Automated Updating System is *pxsprj.inp*, generated by the Proposed Cross Sections process of GEOPAK. The Input dialog box is shown in Figure 5.4.

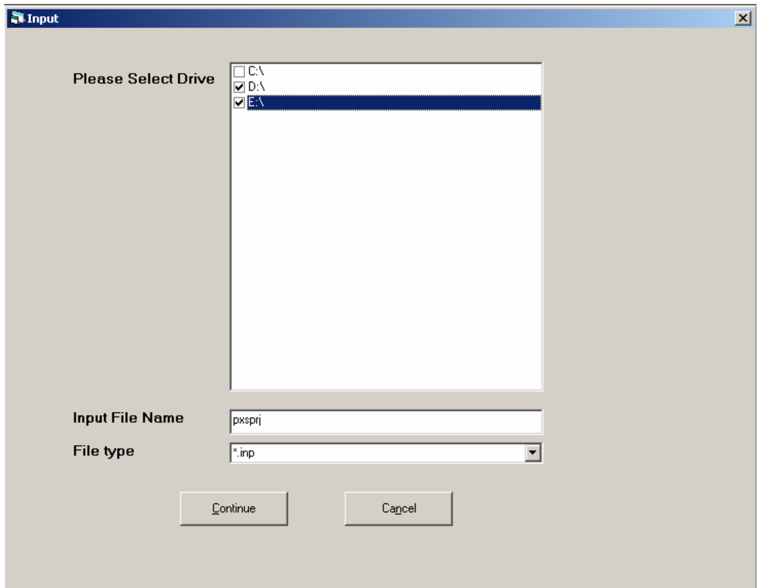


Figure 5.4 Input Dialog Box

The user can proceed to the next step by clicking the "Continue" button to make the Output menu item accessible. On the other hand, the user can click the "Cancel" button to close the Input dialog box and return to the Main Menu window. If no hard drive is selected, the user will be unable to proceed to the next task because the "Continue" button will remain unavailable until a hard drive is chosen.

5.2.2.3 Output

The third menu item on the File menu is "Output," which is used to set up the name and location of the output file used to store the pavement layer information captured from the input files produced by GEOPAK at the end of the Proposed Cross Sections design process. Clicking the "Output" menu item opens the Output dialog box, illustrated in Figure 5.5.

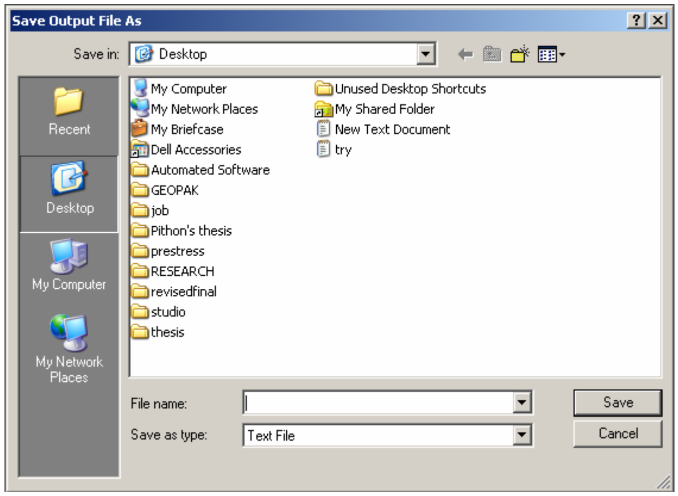


Figure 5.5 Output Dialog Box

After specifying both the name and location of the output file, the user can proceed to the next step by clicking the "Save" button. Alternatively, the user can click the "Cancel" button to close the Output dialog box and return to the Main Menu window without providing output file information. However, again, the user is not able to proceed to the next step unless the output file information is provided to the system.

5.2.2.4 Exit

The final item provided on the File menu is "Exit." This function is used to terminate the operation of the Automated Updating System software.

5.2.3 Run Menu

The Run menu is used to start the layer information extraction process. It has only one submenu item, which is the "Start" menu. In this process, the input and output information specified by the user in the previous steps are utilized. The Automated Updating System will search the hard drive(s) selected in the Input dialog box for the input files created by GEOPAK. The software will then access each of the input files to capture the essential pavement layer information stored in those input files. Once the pavement layer information of each GEOPAK project is extracted, the Automated Updating System can automatically store such information in a text file named and located as indicated by the user.

It is important to note that, in the initial execution, the Automated Updating System will extract the pavement layer information from all the input files existing in the specified hard drive(s). However, apart from the initial execution, the Automated Updating System will search for and detect only input files created after the prior execution to avoid redundancy of the pavement sections stored in the output file. This ensures that input files that were once accessed to extract the pavement layer information will not be detected again.

The “Start” menu item opens the Scanning Process dialog box. In this dialog box, the hard drive(s) specified by the user and the input file name, pxsprj.inp, will be shown so that all the information given by the user can be verified. When the user is satisfied with the specified information, the data extraction process can be launched by clicking the “Start” command button. Alternatively, the user is allowed to modify the setup information by clicking the “Back” button. With a click on the “Back” button, the Scanning Process dialog box will be closed, while the Input dialog box will pop up instead. As a result, the user is able to change both the input and output information as needed. The Scanning Process dialog box is shown in Figure 5.6.

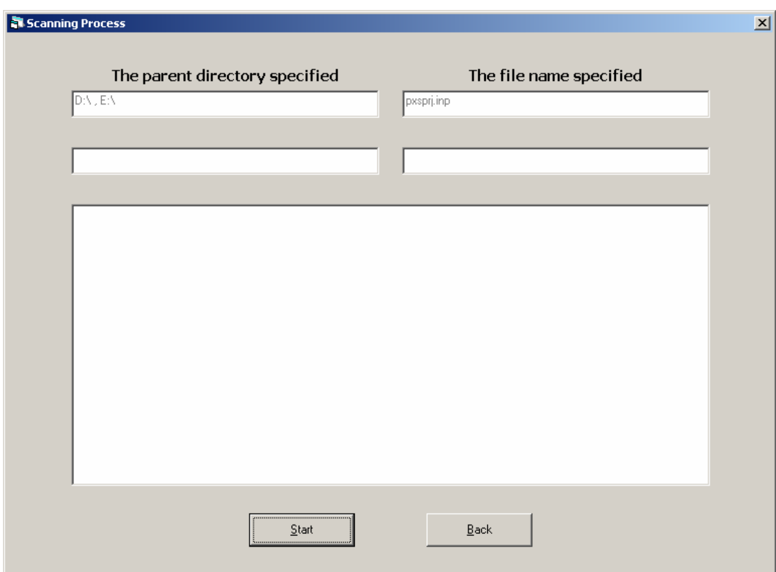


Figure 5.6 Scanning Process Dialog Box

After the data extraction process is done, the number and total size of new input files found on the specified hard drive(s) and the file properties of each input file are displayed in the Scanning Process dialog box, as illustrated in Figure 5.7.

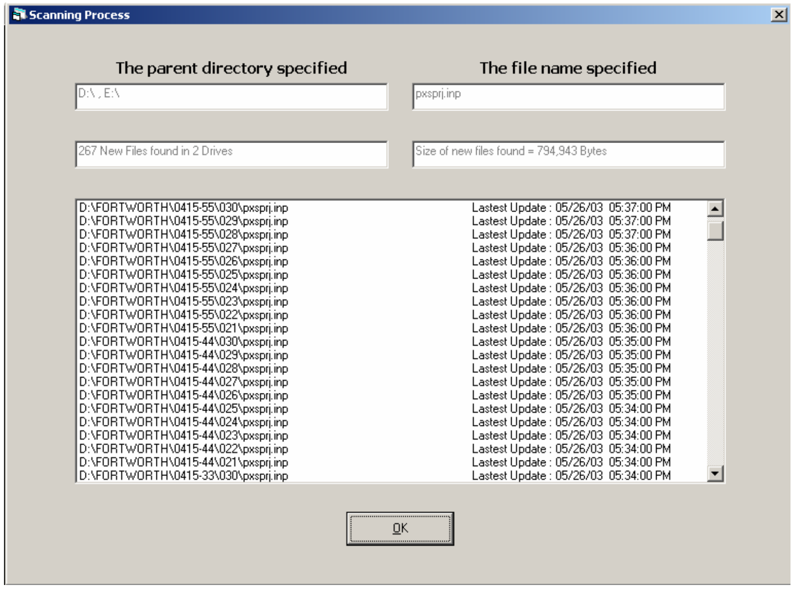


Figure 5.7 Scanning Process Dialog Box with Properties of Input Files

To view, modify, or export the pavement layer information stored in the output file to the pavement layer database, the user has to click the "OK" button shown in Figure 5.7 to proceed to the next step. After clicking "OK", the Scanning Process dialog box will be closed, while the View, Modify, and Update Menus become accessible.

5.2.4 View Menu

The View menu allows the user to view all the pavement layer information of each pavement section stored in the output file. It has only one submenu item, which is the "View Output File" menu. The "View Output File" menu item executes the View dialog box, which is linked to the output file specified in the Output dialog box. With this function, the user is able to verify whether all the layer information in the output file is in the format recognized by the automated software so that all required information can be exported to the pavement layer database systematically. The View dialog box is illustrated in Figure 5.8.

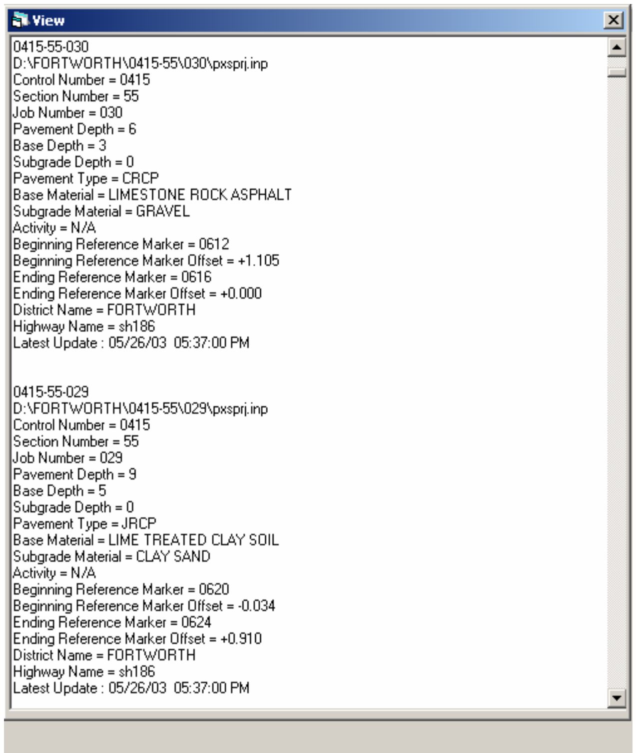


Figure 5.8 View Dialog Box

It should be noted that the pavement layer data in the View dialog box is for viewing purpose only. The user cannot modify the information in this dialog box. To modify the data, the user has to use the "Modify" function.

5.2.5 Modify Menu

The Modify menu is used to manage the pavement layer information of each pavement section stored in the output file. It has only one submenu item, "Modify Layer Information." The user can click the "Modify Layer Information" menu item to open the Information Modification dialog box, as illustrated in Figure 5.9.

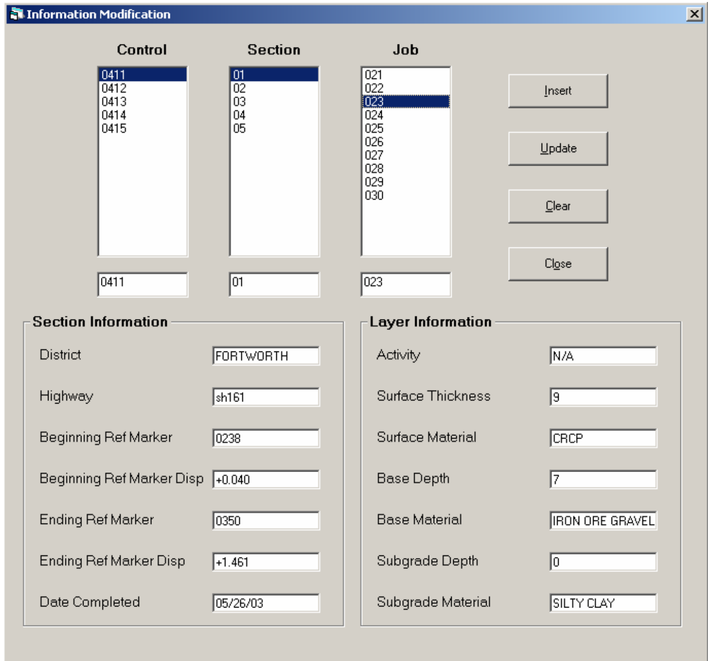


Figure 5.9 Information Modification Dialog Box

To modify the pavement layer information of each specific pavement section stored in the output file, the user must specify the Control-Section-Job (CSJ) number of a section by either entering the CSJ number in the provided text boxes or selecting the CSJ number in the Control, Section, and Job list boxes. Once the CSJ number is specified, the pavement layer information as well as the section description data of the selected section will be displayed in the dialog box.

In the Information Modification dialog box, the pavement layer data of each CSJ section is grouped into two parts: the general section information and the layer information. The Automated Updating System provides the function keys Insert, Update, Clear, and Close, which can be used to manage both general pavement section information and pavement layer information.

5.2.5.1 Insert

To insert a new pavement section, the user clicks the "Insert" button on the Information Modification dialog box. This action opens a window message box, as shown in Figure 5.10, to allow the user to confirm the operation. To proceed, the user has to click the

"Yes" button. If the user clicks "No," the message box closes and the user is returned to the Information Modification dialog box. If the "Cancel" button is clicked, the Information Modification dialog box will be unloaded and the software will return to the Main Menu window.

Figure 5.10 Insert New CSJ Record Message Box

After clicking "Yes," the software will prompt the user to enter the CSJ number of the new pavement section into the "Enter New CSJ Record" dialog box, as illustrated in Figure 5.11.

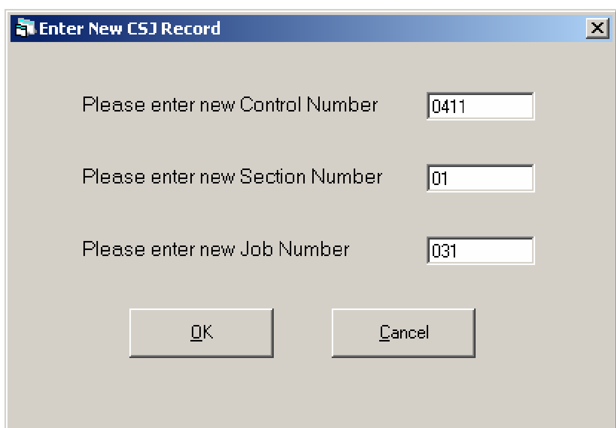


Figure 5.11 Enter New CSJ Record Dialog Box

The user can then type in the new Control, Section, and Job numbers and click on the "OK" button. The "Enter New CSJ Information" message box will pop up, as shown in Figure 5.12, to allow the user to proceed. Alternatively, the user can click the "Cancel" button in the "Enter New CSJ Record" dialog box to return to the Information Modification dialog box without adding a new pavement section.

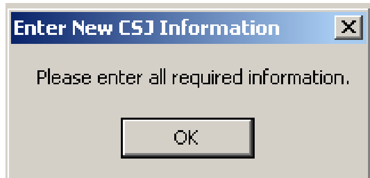


Figure 5.12 Enter New CSJ Information Message Box

After confirming that a new pavement section is to be inserted, the user has to input both the section description data and the layer information of the new pavement section. The user provides this information in the blank fields of the Information Modification dialog box, as illustrated in Figure 5.13.

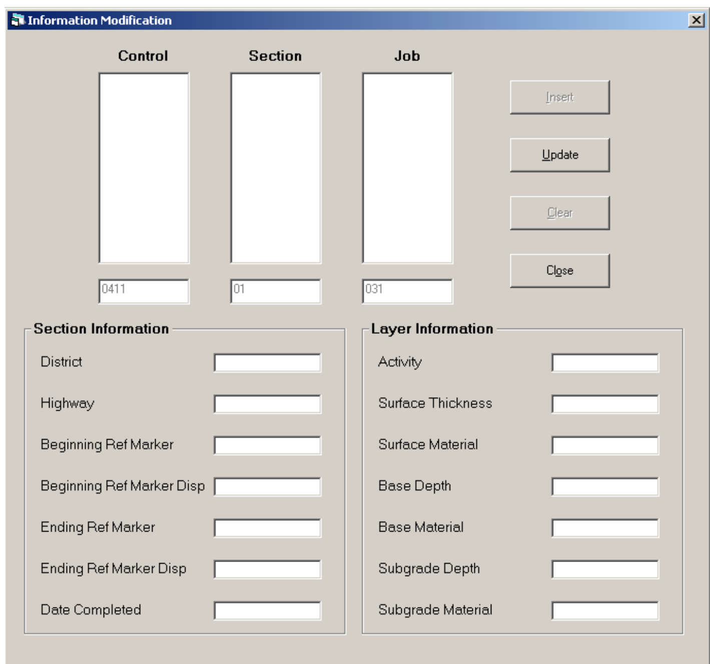


Figure 5.13 Information Modification Dialog Box for a New CSJ Record

Once the required pavement information is entered in all of the blank fields in the dialog box, the user has to click the "Update" button to save the new pavement section in the output file.

5.2.5.2 Update

The Update function key is used to modify the pavement layer information stored in the output file or to append the new pavement section to the output file, as stated in the previous section. After the information of any pavement section has been modified, the user has to click the “Update” button in the Information Modification dialog box to complete the modification operation.

It is important to note that the “Update” button is accessible only if the CSJ number of a pavement section is identified by the user.

5.2.5.3 Clear

The Clear function is used to delete all the information of the selected pavement section displayed in the Information Modification dialog box. Since this function is used to delete all the data of the selected section stored in the output file, its result might be catastrophic. Therefore, to complete the clear operation for each selected pavement section, the user has to click the “Update” button to confirm the operation. It should be noted that the “Clear” button is available only if the user has already specified the CSJ number of the desired pavement section.

5.2.5.4 Close

The Close function is used to close the Information Modification dialog box and return to the Main Menu window of the Automated Updating System.

5.2.6 Database Menu

The Database menu is used to update the pavement layer database with the pavement layer information of the preferred pavement section(s) stored in the output file. The Database menu has only one submenu item, which is the “Update Database” menu. The “Update Database” menu executes the Database Updating Process dialog box, illustrated in Figure 5.14.

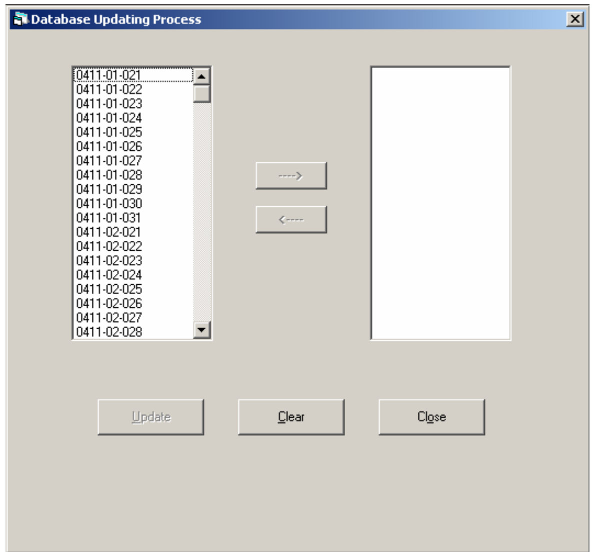


Figure 5.14 Database Updating Process Dialog Box

The database updating function is intended to update the pavement layer database with the pavement layer information of a set of complete construction projects. It allows the user to export the layer information of those pavement sections that are completely constructed to the pavement layer database.

The Automated Updating System provides the function keys Update, Clear, and Close , which can be used for the database updating process.

5.2.6.1 Update

The Update function key is used to export the pavement layer information of a set of selected pavement sections to the pavement layer database. In the Database Updating Process dialog box, all pavement sections stored in the output file will be displayed in the left-side list box. To export the layer information of only one pavement section to the database, the user selects a specific pavement section in the left-side list box and then clicks the button. This action transfers the selected pavement section to the right-side list box. To export the layer information of a group of pavement sections (i.e., to make multiple selections), the user presses and holds down the Shift key while selecting the pavement sections. All the pavement sections displayed in the right-side list box will be transferred to the pavement layer database at the end of the updating process.

To remove any unintentionally selected pavement sections from the right-side list box, the user selects these pavement sections and clicks the  button to move the selected pavement sections from the right-side list box to the left-side list box.

Once all desired pavement sections are selected, the user clicks the "Update" button in the Database Updating Process dialog box to complete the operation.

It is important to note that the pavement sections, which are uploaded to the pavement layer database, will be permanently removed from the output file to prevent system inconsistency.

5.2.6.2 Clear

The Clear function is used to remove the selected pavement sections from the right-side list box and add them back to the left-side list box. The "Clear" button is enabled only if there is at least one pavement section in the right-side list box.

5.2.6.3 Close

The Close function is used to close the Information Modification dialog box and return to the Main Menu window of the Automated Updating System.

5.2.7 Layer Menu

The Layer menu is used not only to display the layer information of all pavement sections stored in the pavement layer database but also to determine the current layer information of the pavement sections along a highway. As stated in the earlier chapter, management of the pavement layer database is based on the CSJ system. Since the CSJ number is a unique, identifying nine-digit number of a project done on a pavement section, it does not represent the exact boundaries of each construction project performed on the highway. Therefore, the Texas Reference Marker system is used to determine the exact boundaries of each construction job performed on a specific highway section so that the current layer information of the pavement sections along the highway can be determined.

The Layer menu has only one submenu item, "Current Layer Information," which is used to open the Current Layer Information dialog box, as illustrated in Figure 5.15.

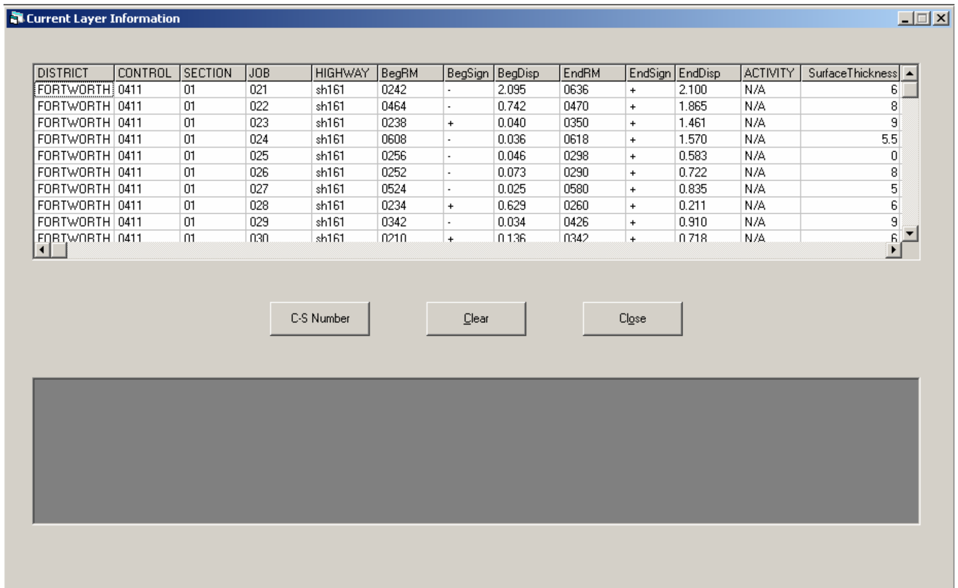


Figure 5.15 Current Layer Information Dialog Box

In the Current Layer Information dialog box, the pavement layer information stored in the pavement layer database is displayed in the top window and listed by district and CSJ number, while the bottom window is intended for displaying the current pavement layer information along a selected C-S section based on the Texas Reference Marker System.

This operation compares the Date of Completion data item of all construction jobs performed on the selected C-S section to determine the current pavement layer information along the roadway section.

To determine the current pavement layer information and display them in the bottom window object, the user can either select one of the CSJ sections displayed in the top window or click the "C-S Number" button to specify the desired C-S section. If one of the CSJ sections displayed in the top window is selected, the Automated Updating System will read the Control and Section numbers of the selected section and search through the whole pavement layer database for all the construction work performed within the selected C-S section.

The other way to display the current layer information of a desired C-S section is through the use of the "C-S Number" button, as stated earlier. This button opens the "Please Enter Control and Section Numbers" dialog box, which prompts the user to choose the desired Control and Section numbers from the dropdown menus, as illustrated in Figure 5.16. The Control and Section numbers available in the dropdown menus are retrieved from the pavement sections stored in the pavement layer database. The pavement sections that are stored in the output file but not yet exported to the pavement layer database are not available in the dropdown menus.

Once the desired Control and Section numbers in the dropdown menus are selected, the user can click the "OK" button to proceed. On the other hand, if the user does not want to proceed, the user can click the "Cancel" button to close this dialog box and return to the Current Layer Information dialog box.

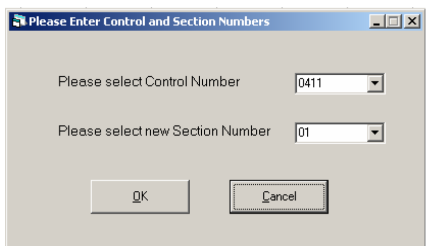


Figure 5.16 Please Enter Control and Section Numbers Dialog Box

Once the desired Control and Section numbers are specified by the user, the automated software will determine the current layer information of the specific C-S section and store this information in the "Layer History" table in the pavement layer database. The Layer History table is then displayed in the bottom window of the Current Layer Information dialog box, as shown in Figure 5.17.

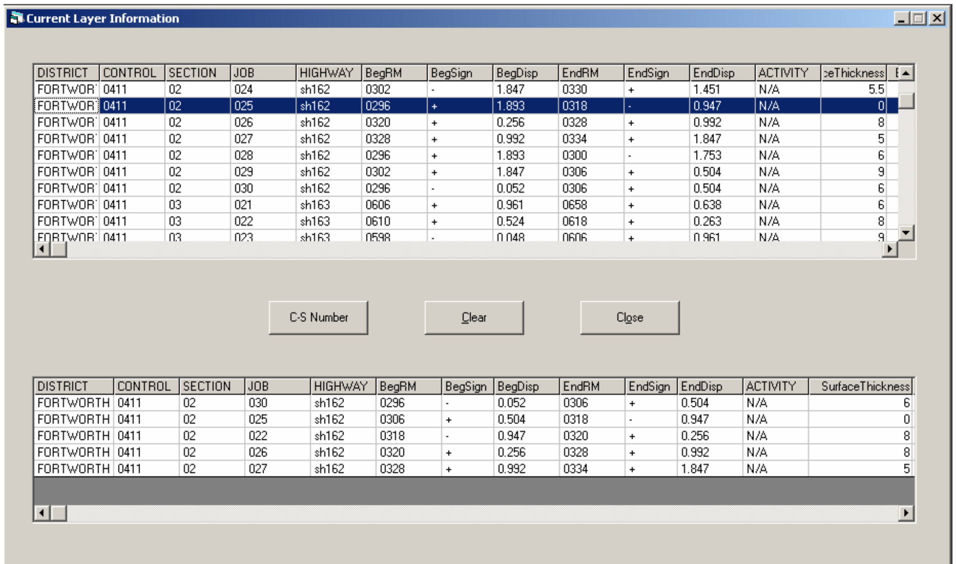


Figure 5.17 Selected C-S Section Information Displayed in the Current Layer Information Dialog Box

Figure 5.17 displays how the current layer information is managed based on the Texas Reference Marker System. The automated software uses the Beginning and Ending Reference Markers, the Beginning and Ending Reference Marker Signs, the Beginning and Ending Reference Marker Displacements, and the date of completion of all construction work performed on the desired C-S section to determine the current layer information.

It can be seen that there are five records displayed in the bottom window. All of these records represent the most recent pavement layer information along the desired C-S section. For example, the end of the first record is connected to the beginning of the second record, and the end of the second record is connected to the beginning of the third record, and so on.

To clear the current layer information displayed in the bottom window of the Current Layer Information dialog box, the user clicks the “Clear” button. Clicking the Close function closes the dialog box and returns the user to the Main Menu window of the Automated Updating System.

5.2.8 Operation of the Automated System after the First-Time Execution

After the first-time execution, when the Automated Updating System is run by the Scheduled Tasks utility, the user does not have to go through the Input, Output, and Data Extraction operations again since the automated software will automatically execute the data extraction process using the input and output information stored in a log file generated every time after the input and output information is given by the user.

Once the automated software is executed, the Setting Information dialog box, as illustrated in Figure 5.18, will open and allow the user to cancel the new data extraction operation within fifteen seconds in case the user wants to change either the input or output information given in the earlier execution, such as adding more hard drives to be searched, removing a hard drive from the data extraction process, and so on.

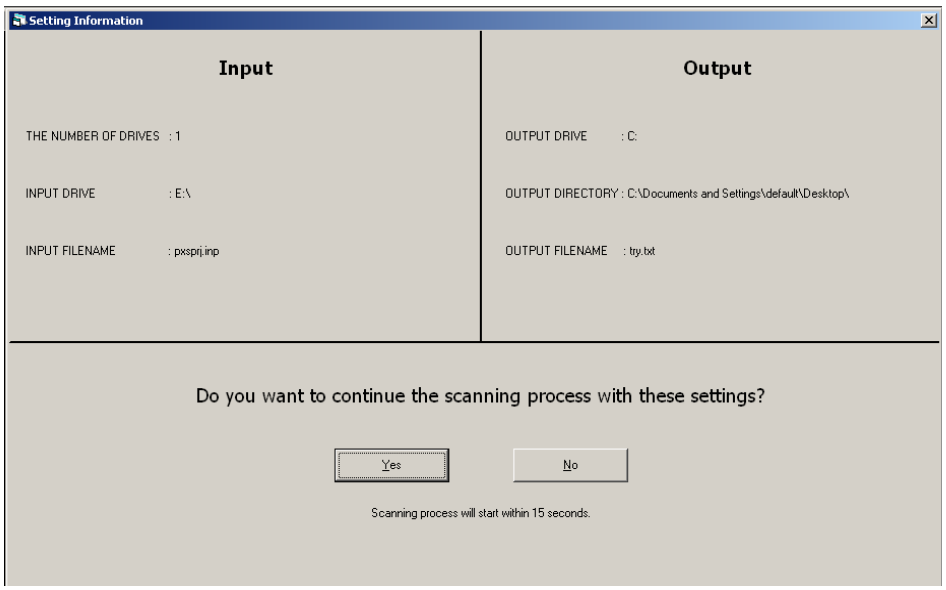


Figure 5.18 Setting Information Dialog Box

In the "Setting Information" dialog box, the input and output information is displayed so that the user can verify if the information is appropriate. The user can either click the "Yes" button to start the data extraction process or wait for the Automated Updating System to automatically launch the extraction process in fifteen seconds. To cancel the data extraction process, the user can click the "No" button to terminate the countdown operation and return to the Main Menu window of the automated software.

In summary, guidelines for using the Automated Updating System software provided in this chapter can serve as the user manual for this software. A summary of the study and conclusions of this report are given in Chapter 6.

CHAPTER 6 SUMMARY AND CONCLUSIONS

The purpose of Research Project 0-4381, entitled "Develop an Automated System for Updating Pavement Layer Data," is to develop a system with the appropriate mechanism and the corresponding algorithms that can be used to build an automated relationship between the pavement layer database and other potential source(s) of pavement layer information at TxDOT. As a result, this report presents the automated updating system designed to achieve a live and accurate pavement layer database. Because of the Automated Updating System software, the pavement layer information of any construction activity made to a pavement layer structure can be automatically captured and the pavement layer database can be systematically updated with the captured pavement layer information.

The following two sections summarize this study and present the conclusions of the report.

6.1 Summary

The purpose of this study is to develop an automated system for updating pavement layer data that can be potentially implemented by TxDOT. The Automated Updating System software developed in this study can serve as the central component of the automated updating procedure.

The major research efforts under this study are summarized as follows:

1. A thorough literature review of the potential data sources for the automated updating system has been performed. Each data source was carefully analyzed with regard to its potential as the candidate data source for the automated system. From the literature, it was clear that high priority should be given to the input files created in the GEOPAK processes as the source of the layer data for the automated system.

2. Careful consideration has been given to what data should be included in the pavement layer database. Since each data item to be included in the pavement layer database has a direct impact on the automation procedure, it is critical that

the data items be kept at a minimal level while not losing the information intended for the pavement layer database.

3. The GEOPAK design process was carefully studied to identify the essential data items that are not currently available within the design process. The recommendations for making each of the missing data items available have been developed.
4. The system design of the automated updating system has been conceptualized. System design of the automated updating system concentrates on two important tasks: (1) to electronically capture the pavement layer information from the input files created by GEOPAK at the end of the Proposed Cross Sections design process and (2) to automatically update the pavement layer database with the captured information. With the automated updating system, resources required from the District and Division offices of TxDOT to maintain the layer database can be minimized.
5. The Automated Updating System software has been developed so that it can be used as a tool to achieve a live and accurate pavement layer database.
6. Guidelines for using the Automated Updating System software have been developed.
7. Recommendations for statewide implementation of the Automated Updating System have been given to assist TxDOT in putting the developed system into practice.
8. Recommendations for future development of the Automated Updating System software have been developed.

6.2 Conclusions

Based on the research findings from this study, the following conclusions can be drawn:

1. In general, electronic data sources represent a better opportunity for developing a mechanism for pavement layer data to be updated automatically.

2. It was found that the GEOPAK input files, prxprj.inp, produced at the end of the Proposed Cross Sections design process, are the most suitable data source of pavement layer data for the Automated Updating System.

3. With the current GEOPAK design procedures at TxDOT, it is not feasible to obtain all pavement layer data items essential for inclusion in the pavement layer database, especially section description data, which cannot be captured from the input files generated by GEOPAK.

4. With some recommended procedural changes to the current GEOPAK design processes at TxDOT, it has been verified with some pilot data that all missing pavement layer data important to the pavement layer database can be effectively and efficiently captured and processed by the Automated Updating System.

5. From a pilot test of 260 GEOPAK design projects, it can be concluded that the Automated Updating System is a viable solution to achieve a live and accurate pavement layer database because the developed system is consistent with the current design practice at TxDOT, and the efforts and resources required from TxDOT Division and District Offices to maintain the pavement layer database are minimal.

6. The benefits of the Automated Updating System are summarized as follows:
   - Minimizes the manual effort
   - Minimizes the disruption to the current practice
   - Minimizes the extra work of the Districts
   - Maximizes the quality of pavement layer information
   - Significantly reduces the resources needed to maintain the database
   - Decreases the risk of poor decisions due to incomplete pavement layer data
   - Provides easy access to information
   - Provides more up-to-date information
   - Reduces manual errors
   - Prevents duplication of pavement layer data from the same section
   - Provides a systematic procedure for updating pavement layer database

7. The following initiatives are required to successfully implement the Automated Updating System:
    - Changes in the GEOPAK design processes at TxDOT
    - Training of the TxDOT personnel to effectively use the automated updating application
    - Additional training in the use of the dummy criteria file in the Proposed Cross Sections design process of GEOPAK

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