AN INTEGRATED PAVEMENT DATA MANAGEMENT AND FEEDBACK SYSTEM (PAMS)

FINAL REPORT

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ABSTRACT

This report discusses the implementation of a pavement condition rating (PCR) procedure to sample sections of the road network system. The resources needed are identified for such implementation. The uses of PCR data at the network and project level are also identified.

The report stresses the development of a data base for integration of the various engineering systems for pavement management information system. Recommendations include frequency of rating survey, a need for creation of master roadway identification file, assignment of central controlling authority for management of engineering data and, finally, a need for standardization, accuracy and integrity of data for pavement management purpose.

IMPLEMENTATION

The Department's existing system of managing pavements should be enhanced through implementation of the several recommendations listed in section 7 of this report. This enhancement should begin with the adoption of the condition rating procedure for network analysis, planning and programming. Automation and integration of pavement related files should begin with standardization and cleaning up of data within these files, and a creation of master roadway section location and identification file. Last, but not the least, the system should be monitored under a central control of engineering system information.

1. INTRODUCTION

This is the third and final report on Louisiana's effort to identify the need for development of a Pavement Management System (PAMS). The first report (1)* dealt with the identification of the present practices followed by the Department in managing some 16,000 miles of state highways. The report made several recommendations for enhancements or improvements to upgrade the present system. Some of the important recommendations were:

+ Use of control unit log mile as the key section identification scheme for all existing and future pavement related activities (files).

+ Identification of all construction and/or rehabilitation project boundaries by beginning and ending control unit log mile in addition to station numbers.

+ A more disciplined approach to identification of pavement condition using the ride and type severity and extent of pavement distress as the performance criteria.

+ Maintenance reporting to be by specific location in terms of control unit log mile.

+ A plan to automate the integration of various pavement management oriented engineering systems for data manipulation and retrieval.

Of the above recommendations, the first two have been adopted by the Department. The third item was the subject of the second report in this series (2). The Department is presently developing a

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* Underlined numbers in parentheses refer to list of references.

maintenance reporting system by control unit identification (recommendation 4).

The subject of this report is an extension of the second recommendation, namely, implementation of the pavement condition rating procedure to sample sections of the state's network of control units, and identification of the resources to accomplish the rating of these sections. The sections are those identified as the HPMS (Highway Performance Monitoring System) sections. The report also attempts to identify the integration of the Department's various engineering information systems for a working pavement management system.

2. OBJECTIVES

The primary objective of this last phase of the study was to continue application of the pavement condition survey procedure developed in the first phase of the study (1) and partially field evaluated in the second phase (2). More specifically, the objectives were:

1. To determine the resources necessary to accomplish the rating of sample sections of the network.

2. To create a data bank of pavement condition for future monitoring of these sample sections and identify the uses of the data in pavement management.

3. To identify the automation needs for integration of various engineering information systems for pavement management purposes.

3. PAVEMENT CONDITION RATING PROCEDURE

3.1. Development

The pavement condition rating (PCR) developed is a combination of the ride rating as measured by the Mays Ride Meter (MRM) and the Pavement Distress Rating (PDR) (1). The PDR involves identification of standardized distress types and subjective estimation of severity and extent level thereof. The end point of the method is a number ranging from 0 (total distress) to 25 (no distress) for rural roads and from 0 to 20 for urban roads. The overall pavement condition rating, PCR, is a combination of the Mays Ride Meter rating and PDR. The figures in Appendix A-1 through A-4 present the condition rating forms for the four pavement types. The worksheet type forms document the final ride rating and distress rating and their sum, the PCR. Once again, numerically, PCR would range from 0 to 50 for rural roads and 0 to 40 for urban roads with the high number signifying near perfect pavement condition.

3.2. Application of PCR Procedure to Sample Sections of The Highway Performance Monitoring System (HPMS).

As mentioned before, the rating procedure discussed above was field tested to determine the feasibility of its application in the highway needs inventory. The method was found to be valid, practical, quick and safe for use in an inventory mode (2). However, because of such limited evaluation (18 sections totaling 140 miles), the needed resources for statewide implementation could not be determined. To provide this information to the management, the effort was extended to include a much larger sample on a statewide basis. The Department's Highway Performance Monitoring System sections were selected as the representative sample of the state's network of roadways.

3.2.1. HPMS Sections

The Highway Performance Monitoring System, or HPMS, is a joint effort of the federal, state and local governments. The effort, organized and monitored by the Federal Highway Administration (FHWA), is geared towards providing information relative to the condition, usage, and operational characteristics of the road network system on the basis of sample sections. The impact of this effort is the determination of changes in performance over time using these data as reference points. The sample sections for monitoring were established using a statistically designed sampling plan based on the random selection of road sections within predetermined average annual daily traffic volume groups. These sample data will serve as a data base for evaluating changes in data element values over time, thereby providing a basis for the analysis of the performance of the nation's highways. There are approximately 3,200 miles of HPMS sections in the state. This represents about 30 percent of the total state maintained highway system. Practically all of the interstate system is included in the sample sections.

Table 3-1 shows the statewide mileage breakdown of HPMS sections by district and functional class (urban/rural). Table 3-2 is a breakdown of the HPMS sections by surface type evaluated for condition rating. Approximately 95 percent of the rural and 35 percent of the urban HPMS sample sections were rated in this study.

The HPMS sections are identified in terms of control-unit-subsection and the corresponding length of the subsection.

Thus, a control-unit-subsection will, in most cases, define the pavement section in terms of surface type. The shortest length of the subsection can be a tenth of a mile, and the largest can be as long as 50 miles. The mileage shown in Tables 3-1 and 3-2 represent cummulative mileage for the surface type in each district. A major deficiency in this surface identification system is the lack of differentiation of concrete pavements according to whether it is jointed or continuously reinforced concrete, or whether it is hot mix flexible or hot mix composite. For this study, an extra effort was made to identify the sections into four basic categories as shown in Table 3-2.

4. FIELD TESTING OF PCR PROCEDURE

The following items were studied to develop an implementable package for a condition rating survey procedure.

+ Survey Sections
+ Survey Team
+ Survey Vehicle and Speed
+ Distress Definition
+ Data Recording Forms and Procedures
+ Data Bank
+ Productivity & Cost of Data Collection

4.1. Survey Sections

All HPMS sections greater than one mile for urban areas and two miles for rural areas were included in the condition rating.

4.2. Survey Team

A team of two persons, a driver and a passenger, was used to survey the network HPMS sample. The passenger was responsible for distress recording on the prescribed forms. The driver's responsibility was to locate the beginning and ending of control unit subsections.

4.3. Survey Vehicle and Speed

Either a passenger car or a van can be used for the survey as was done in this study. A clear view of the pavement section from the side and front is an important factor in making a choice of vehicle. In this respect, a van provides a better view than the passenger car.

The speed was determined by the passenger based on the ability to identify and record the various distresses accurately. In some cases, the survey was made at highway speeds (50 mph). Based on the results of this study, it was observed that such high speed affects the accuracy of certain distress identification. The severity of rutting of asphaltic concrete hot mix sections and faulting of jointed concrete sections are examples of distresses that were found to be difficult to ascertain accurately. Generally, the accuracy of recording will diminish with increasing speed. It is felt that the survey speed should be selected to allow accurate recording of the most significant variables included in the distress index computations.

4.4. Data Recording Forms

The recording forms shown as Figures 1 through 4 were developed in the first phase of the study (1) and were modified continuously to accommodate the changes which were found necessary based on routine use and input from the survey team. The distress is recorded by circling the severity and extent level specifically developed for this evaluation. The form is self sufficient and follows through the computational procedure to arrive at the final condition rating. The basic control-unit subsection information is prerecorded prior to field survey.

The Mays ride meter tests were conducted either before or after the distress inspection.

4.5. Distress Definition

The definition of the distress manifestations identified for each pavement type is discussed in the Appendix. The integrity and accuracy of the data collected by the survey team hinges on the thorough familiarity of the various distresses and their identification in the field.

4.6. Data Bank

All recorded data are stored in form image in the computer. The data appearing at the top of each form are common to all pavements within each surface type category. Tables 3-1 and 3-2 were prepared from the stored data. Other peripheral information such as age of pavement, subsurface layers, traffic, etc., can be extracted through appropriate link and merge of the pavement related files. This aspect is discussed in detail in a separate section.

4.7. Productivity and Cost of Data Collection

The visual condition and the ride meter surveys of the sample sections were completed in 40-50 work days by one survey team.

Multiple teams could accomplish this in less time. The actual rating procedure, once the team is at the section site, takes less time than the time it takes to travel from section to section. It is felt that 50 team days would be required to do a thorough condition review of the HPMS sections.

The above productivity was achieved at a cost of $5.60 per HPMS mile. This cost includes cost to travel to section locations and is composed of salaries, equipment, and travel expenses. Based on this, the total cost of surveying the entire HPMS network would not exceed $25,000.

Whether such condition and ride surveys should be conducted each year will depend on the magnitude of the rating index of the section. In-service pavements lose their serviceability very slowly in initial stages (high PCR value) and, therefore, survey of such sections may be at less frequent intervals, say once every three years. Once the section approaches an intolerable value, the frequency of survey can be increased to once every two years or even every year. This will have to be determined as more data is collected and trends are developed as to the serviceability loss in terms of PCR and/or ride meter. However, it is anticipated that the cost figure indicated above will not be a yearly cost.

5. APPLICATION OF PCR SURVEY DATA

The usefulness of the condition survey data collected over a period of time can not be over-emphasized. It is a prerequisite to both the predictive and planning decision making process in a pavement management system. The application of the data depends on whether the decision is to be made at the network or program level or the project level. Some examples of the applications are illustrated through the following examples.

5.1. Monitoring of Pavement Condition Data for Decision Making at the Network Level

Traditionally, decision making at the network level includes programming, budgeting and planning activities. The decision involves overall budgeting process and general allocations over an entire network. Data is needed to determine the existing condition of the network as a whole. Information such as traffic and condition data can then be used to select policies relative to standards for different roads in the network. Several examples are illustrated through graphical presentation of the condition data collected in this study.

Figure 5-1 shows the statewide rural distribution of HPMS mileage of various pavement types falling into categorized PCR range. Thus, 5.95 percent of the total mileage of jointed concrete pavement (JCP) have a PCR range of 25 to 30. The corresponding mileage in this range for hot mix pavement is 9.84 percent. The plot indicates the general condition of the pavements in the state. If district wide distribution of such mileage is desired, figures (such as 5-2 through 5-5) can be prepared to show the divergence of pavement condition in each district for each pavement type. The network pavement condition relative to specific major distresses such as rutting on hot mix or faulting on jointed concrete pavements can be presented through figures 5-6 and 5-7, respectively. Thus, District 7 seems to have major problems with rutting on over 50 percent of their mileage. Likewise, the same district has faulting on most of their concrete pavements.

The above examples of pavement condition at the network level were presented for illustrative purposes only. Such periodic evaluation of sample sections can give an estimate of the current condition of the network and is a means of forecasting to some future period for development of a rehabilitation program. Once a trigger value of PCR is defined, programming decisions for planning and budgeting can be made. Figure 5-8 is an illustration of how this (planning and programming) can be accomplished through the use of PCR data. The figure is a plot of Mays Ride Meter index versus PCR of jointed concrete on the interstate system. The three blocks (groups) of data represent the degrees of rehabilitation required to bring the sections to some acceptable level. The symbols on the plot represent sections or projects. Such plots can be used to develop a short range plan (a 5-year plan, e.g.) or a strategy to rehabilitate the interstate system.

5.2. Monitoring Pavement Condition at the Project Level

Generally, individual projects would normally come 'on line' from the network analysis discussed above through some trigger value of PCR and/or Mays Ride Meter index.

Candidate projects for action (maintenance or rehabilitation) can be selected by the ranking method using PCR and/or ride meter index as the quantifiable attribute. This is the

simplest method of prioritizing candidate projects.
In the context of pavement management, maintenance activities do not necessarily enhance the serviceability but will preserve it. On the other hand rehabilitation activities may restore the pavement structure to its original condition.

The determination of appropriate rehabilitation alternatives can be made by processing each section or project through a rehabilitation decision matrix. The matrix, or tree, will then do the evaluation for practical combinations of existing surface distress conditions. If the rehabilitation strategies are defined, then on the basis of individual distress evaluation for each pavement type (Appendix A-1 through A-4), alternatives can be defined to correct the specific governing deficiency(s). Table 5-1 is an example listing of the decision matrix that can be used for asphalt surfaced pavements.

Another example of such a decision matrix is indicated in Table 5-2 for jointed PCC pavements. Cost matrices can also be developed to arrive at total cost of a given strategy. Such decision matrices can be as comprehensive as one would want to develop. Needless to say, the strategy to take any specific action (maintenance or rehabilitation) will necessarily depend on certain physical constraints such as performance standards to be met and availability of funds. If the latter is tight in the year of improvements, the consequences of delayed rehabilitation can be determined from such decision matrices.

6. INTEGRATION OF PAMS DATA SOURCES THROUGH AUTOMATION

A working pavement management system should be able to provide continual feedback of information to make decisions at the network or program level and at the project level. Figure 6-1 is a pictorial representation of this feedback system. Although less information is needed at the program level than the project level, both require historical data feedback at some level. In addition to the need for condition survey data (including roughness) discussed in the previous sections, data is also needed on traffic and axle loads, maintenance and rehabilitation actions and their associated costs, construction and materials inspection and characterization. However, data needs relative to section or project identification takes precedence over all other data.

6.1. Existing System

Figure 6-2 was prepared to identify the several engineering data systems currently used by individuals or sections to satisfy their needs. Each of the systems has some data that are pavement oriented or can be used for pavement management purposes. The systems or files can be classified into two groups: a network oriented group (upper blocks of Figure 6-2) and project oriented group (lower blocks of Figure 6-2). The network files are identified by control unit, and the boundaries within which this control unit falls in terms of beginning and ending log mile. The project oriented files are keyed to the same control unit with an added two digits signifying the number of improvements on that segment of the control unit. The project boundaries are also identified by begin and end log mile. [(This was one of the implementations recommended in the feasibility study (1)] In general, the data from these files fall into three bas categories: roadway location and description, roadway evaluation and roadway activities.

Roadway description data identifies the roadway section as to its location (district, parish, route, etc.), physical attributes (such as surface type, number of lanes, bridges, etc.) and design attributes (such as materials and associated thickness, etc.). Roadway evaluation data consists of condition rating, improvement needs, traffic trends, etc. Roadway activities describe the contract construction and maintenance projects including project description, contract cost, individual items and associated quantities and expenditures that make up the contract.

There is considerable overlap and repetition of data fields in all of the files in Figure 6-2. Thus, the MATT file and the RCUJ file both contain project oriented (roadway description above) information. Likewise, TAHI, HPMS, TAND and MNRS all have overlapping information relative to the description of the control units. Such overlap and/or repetition of data has created fragmentation on one hand and choking of data on the other hand and clearly points towards a lack of central control. This has also resulted in data redundancy, inaccuracy, incompleteness, and an inability to cross reference data files. The central controlling data base is the practical solution to this problem.

6.2. Data Management

Through the auspices of the Engineering Data Management Committee, composed of the author and other key personnel from the Chief Engineer's office, maintenance, planning, automation and a consultant, a plan was developed to address the data handling and file integration problem. The constraints were that the existing system must be used with minimum disruption and also that a plan requiring a massive long-term effort would not be considered. Finally, the system should be user oriented requiring a minimum of sophisticated programming, hardware, etc..

The major objective then was to determine if the data base concept could relieve the existing problem of data handling and cross referencing. A secondary objective was to determine if all needed data for PAMS was being obtained, the integrity and accuracy of such data and its timely update. The following section discusses some of the data handling procedures that would satisfy the defined objectives.

6.2.1 Packaged Software - SAS

The simplest approach to data handling from various files would be through the SAS package. SAS, an acronym for Statistical Analysis System, is a commercially available computer software system for total data management in one easy-to-use system (3). It provides all the tools needed for:

- Information Storage and Retrieval
- Data Modification and Planning
- Report Writing
- Statistical Analysis
- File Handling

The data-handling features of SAS are such that it can be used as a data base management system. SAS will run on IBM mainframes in batch and interactively under any environment (os, os/vs vm/cms,and TSO, etc.). The file handling feature of SAS allows the user to process multiple files, such as those identified in Figure 6-2, simultaneously for editing, subsetting, concatenating, merging, and updating data sets. Likewise simultaneous reports are possible in one sweep of the data.

Tables 3-1 & 3-2 and Figures 5-1 through 5-7 discussed in the previous portions of this report were all prepared through SAS. Files identified as PCR, HPMS & RCUJ in Figure 6-2 were merged to create the needed data for preparation of figures and tables. Merging was done through control-unit and log mile key which is common to all files.

An advantage of using SAS is that knowledge of programming language is not required. SAS has its own vocabulary and syntax and is easy to learn. However, the effectiveness of any software system is directly related to the accuracy and cleanliness of the data it is to handle and organize. Unfortunately, the data in the various files (Figure 6-2) lacks standardization and integrity. In that respect, these issues of data integrity, completeness, standardization, etc. should be addressed in a timely manner for effective implementation of a pavement management system.

6.2.2 Data Bases (4)

Data base literature describes three general data models: Relational (such as SQL/DS), Hierarchical (such as DL/1), and Networks.

The relational model provides a simple, uniform, logical way of looking at data. This approach is completely independent of actual storage structures and access techniques used to retrieve the data.

In a hierarchical or network model, access paths are predefined in the data structure definition. A user (or program) can use only the predefined paths to navigate through the data structure. This limits the use of the data. However, it is a strength if only those paths are needed, because the system can provide quick access through the predefined paths.

In a relational model, paths need not be predefined. Data requests are not expressed in terms of access paths. All access is accomplished by matching field values. Therefore, many different paths exist. Here is the source of the freedom needed for performing unplanned ("ad hoc") queries and frequent data evaluations or analyses. Thus the relational model has considerable potential for extensions and restructuring.

Based on the above alternatives, the committee, through the consultant's recommendations, decided to look into the SQL/DS software by IBM. SQL, an acronym for Structured Query Language, uses the relational model of data. A relation in the relational data model can be thought of as a simple two-dimensional table having a specific number of columns and some number of unordered rows. Each row represents an entry in the relation (in the table).

Data is defined and accessed in terms of tables and operations on tables. The tabular format for data is easy to use. Simple data needs can be implemented very easily. Complex data needs can be handled through a powerful set of operations on tables. Thus, the relational model supports a broad range of data requirements. All data inter-relationships (dependencies) are expressed in terms of the actual data values, not by pointers or storage adjacency. The ability to relate common fields of data found in more than one table is provided by the data access language (SQL in SQL/DS). SQL enables a user or program to specify the desired data in terms of properties the data possesses. The desired data is not specified in terms of a search.

Figure 6-3 is a flow chart showing the operation of the SQL data base. One of the constraints in using the SQL data base is that it can only be operated on VM files. This means converting all existing MVS files into VM before creating SQL data base. However, use of IBM's DB2 data base software will circumvent this VM requirement since the DB2 software is applicable in MVS environment.

Table 6-1 was prepared using SQL data base tables for files TAHI (highway inventory) and MATT (material testing). An interesting observation in this table is the mismatch of data values for the same variable. Thus ADT values in the MATT file and ADT STL in the TAHI file are at odds for the same control-unit-project number. An explanation could be that the ADT STL in the TAHI file must be the most up dated data, whereas, the ADT MATT represents the ADT as recorded when the construction project was let which may have been several years prior to the update in the TAHI file. The point that is being made here is the lack of integrity in data elements in some files. It also points to the need for a master file that would reflect the most updated information on roadway location and description.

6.3. Data Needs

A Review of data files identified in Figure 6-2 has indicated that there is no scarcity of data availability relative to its use in the pavement management information system. However, redundancy and lack of integrity and accuracy in data elements prevents the effective use of most of these files for pavement management information.

An effective information system requires central control of all engineering data relative to pavement management. This at present is nonexistent. The individual owners(s) of the files are responsible for their data management. Whereas there is nothing wrong with this policy, the general user may not be aware of how current the data is. Concurrent to this problem (lack of central control), is the fact that there does not exist a single file that could be considered a master or control file through which other files could feed. A central controlling file is a necessary prerequisite to such a management information system. Such a file should contain the basic information relative to the project. In the cluster of files in Figure 6-2, RCUJ and MATT system files come closest to that requirement. However, revisions to these files will have to be made to make it compatible with the required format for data base application.

The above two files can be combined to create the master file. This file should contain all necessary data on items relative to project identification (location, etc.), as built information (material type, section layer thickness, width, etc.) cost information, project start and completion date information, etc.. Table 6-2 is a listing of the data variables currently identified in the MATT file. The information is entered by district personnel as soon as the construction contract work order is issued and work begins on the project. Unfortunately, for whatever reason, all data does not get entered in a timely manner with the result that the majority of fields remain blank or contain dummy "9999". A logical solution to this 'data poverty' is to make the data entry at the source level, which in this case would be the project control. The project control is responsible for contract document preparation, and all current project oriented information is readily available to them. Delayed data, such as acceptance date, final cost, etc., can be updated at a later date.

Table 6-3 is a listing of the variables in the RCUJ file. This data is entered by the project control from a card file which incidently contains much more information than that entered in the computer. In the author's opinion, the RCUJ file serves little purpose in its present form. If it is to be used as an active master file, it need to be expanded to include other critical data elements such as those identified in Table 6-2 for the MATT system.

All in all, it is strongly recommended that the two files discussed above be combined into a single file with the ownership transferred to project control. Table 6-4 is a listing of the contents of such a master file as envisioned for PAMS.

7. SUMMARY AND RECOMMENDATIONS

In the preceding sections, an attempt was made to identify the needed resources to implementation of the pavement condition rating procedures. Also discussed was the use of the condition data as a decision tool for development of rehabilitation strategies at the program or network level and the project level. Finally, the automation and integration needs of various pavement management oriented data files were defined in terms of a project master file, data standardization, data accuracy and data ownership. The following recommendations are based on the above discussions and, if implemented, are anticipated to provide the Department with a working pavement management information system.

1. The Department should monitor the network using the pavement condition rating procedure discussed in this report.

2. The rating can be accomplished by a team of two at a cost of $5.60 per mile. The frequency of conducting the rating survey should be based on the current PCR and ridemeter values. The following is suggested as a possible survey frequency.

PCR	MRM	FREQUENCY
40	3.5 +	Once every three years
30 - 40	3.0 - 3.5	Once every two years
30	3.0	Once every year

3. A historical file of condition rating data should be created to develop performance prediction models from which decisions on planning and programming (budgetary) can be made at the network level and to determine

alternate strategies at the project level (using the decision matrix approach).

4. As a minimum, a pavement management information system should consist of data files relative to:

   + Roadway section location description & identification (master file)
   + Pavement condition history
   + Pavement materials & construction data
   + Traffic conditions
   + Maintenance items expenditures

5. All pavement management related files should have a common reference key in terms of control-unit-log mile.

6. A central authority, such as the Department's Automation Engineer, should be responsible for management of the above file to assure standardization, accuracy and integrity of data entered by the owners of the files.

7. Integration of files should be accomplished through relational data base softwares such as SQL/DS or DB2 or other softwares that would require minimum programming sophistication and revisions to existing files.

8. All of the above recommendations should be implemented

without further delay.

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REFERENCES

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