DEVELOPING A PAVEMENT FEEDBACK DATA SYSTEM

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One of the key phases of pavement design and management is performance evaluation. This activity is vital to the successful improvement and updating of any design and management working system, such as that developed for the Texas Highway Department. A feedback data system, which involves the systematic collection, storage, and retrieval of data, is in turn the major component of performance evaluation. This paper describes the initial planning and development of such a system that is part of the overall design and management system. The role of a pavement feedback data system within the area of pavement management is discussed. Its relation to other data files in the highway department is considered, and the functional requirements are discussed. A component format for the data system, involving a number of variables within a suggested classification of data files, is described. Some implementation requirements in terms of data flows and software development are considered.

•A COMPREHENSIVE pavement design and management working system has been developed for the Texas Highway Department (1, 2, 3) and has been implemented in selected areas. This working system is based on systems engineering principles and makes extensive use of the computer.

The underlying philosophy was that a working system should be developed and implemented now, based on the best existing technology and knowledge. Current information was organized and coordinated, and the system was designed such that new knowledge could be efficiently incorporated as it became available. It was felt that continued updating and improvement of a working system offered a better approach than did waiting for the ultimate, ideal method.

Because of this approach of continued updating and improving, it was necessary to plan for the systematic collection, storage, and retrieval of data on pavements designed by the working system. Consequently, the development and implementation of a pavement feedback data system were undertaken in 1970 (4).

This paper describes the initial development of the data system. In particular, attention is focused on the general principles involved, the requirements of the data system, the coordination with other highway department data files, and the structure of the pavement data system.

GENERAL PRINCIPLES OF DATA SYSTEM DEVELOPMENT

Function of a Data System

The basic function of a data system is to provide information efficiently, quickly, and cheaply for planning, design, and operational needs. In scope, the following aspects are involved: (a) proposed use of the data, (b) collecting data, (c) organizing and processing data, (d) storing data, (e) retrieving data, and (f) analyzing data.

Some sort of automated means is usually required for these functions. However, it is very easy to underestimate the effort required to institute and maintain a data system.

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Overall Highway Data System

Highway departments usually maintain data files (some of which are automated) on practically all aspects of their operations, but the establishment of an overall, automated, and integrated data system for the entire department is a complex and comprehensive task. Nevertheless, the Wisconsin Department of Transportation is establishing a comprehensive highway network data and information system (5). As well, the Texas Highway Department has reported its efforts toward analyzing and automating where possible a major portion of its planning information (6).

A pavement data system should be developed within the context of such a broad highway data system. The major considerations involved include the following: (a) relation of data system to planning, (b) basic design and use criteria, and (c) indexing, control, and coordination.

Most highway departments are concerned with resource allocation over some time span. The effectiveness of the decision to allocate resources is directly related to the level of support information available on economic, physical, and social factors. A properly designed data system can provide this support base.

The basic design and use criteria involve the storage of data in a single-element manner, although a number of individuals or sections of the department may need the data at various times. Obviously, it is desirable to institute common controls so that data can be requested from individual systems.

Proper indexing, control, and coordination are the keys to satisfying these criteria. A common locational index is probably the best method for accomplishing this [i.e., route location and number, geographical coordinates (7), or project number].

The development of a data management system on a widespread basis requires the inclusion of a very large number of comprehensive data files. Wisconsin (5) has emphasized that this requires many years and that staged implementation is a necessity.

Type of Data System Required

The type of data system required depends on a number of factors. One of the most important is the previously mentioned need for common indexing and access to all data files. This is best satisfied by an integrated computer system (4), especially in view of the computer hardware available to most highway departments.

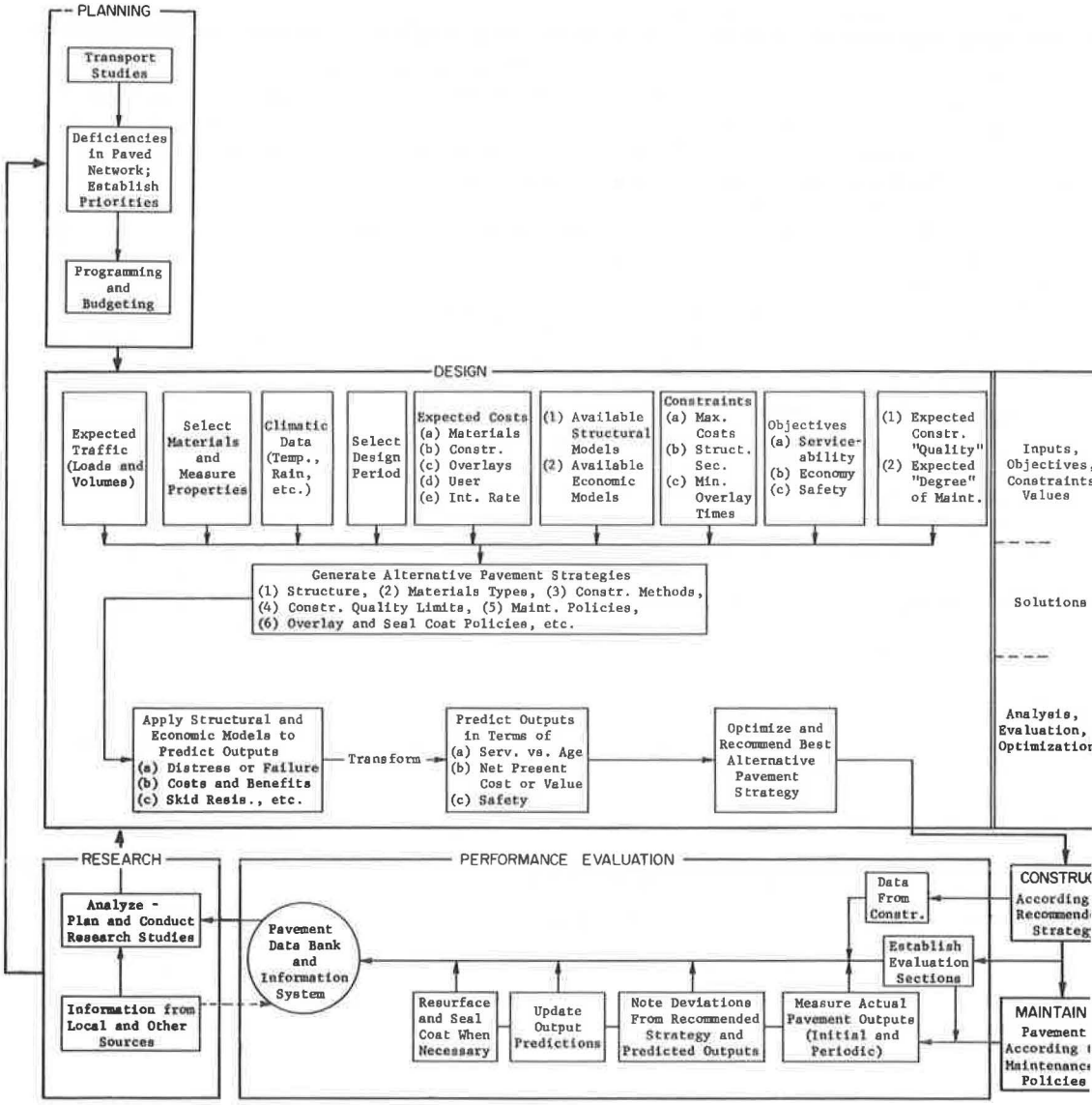
Role of the Data System in Pavement Management

Pavement management consists of a large number of interrelated activities in the planning, design, construction, maintenance, performance evaluation, and research of pavements. Figure 1 shows these major management phases. The role of the data system as a major component of the performance evaluation phase is indicated.

The design and implementation of an overall performance evaluation scheme have been discussed by Haas and Hudson (4, 8). They have pointed out that the following are involved:

1. Preliminary planning, including inventories of current practices and data collection resources, a review of other systems in use, a statement of objectives and constraints, a preliminary schedule, and a preliminary estimate of costs;
2. Identification and classification of all factors (climatic, materials, load, construction, maintenance, costs, etc.), including an initial selection of key factors;
3. Selection and/or development of techniques and/or units for quantitatively measuring the performance factors;
4. Development of a coding, indexing, and data aquisition format for the various factors;
5. Development of a sampling plan, including operational manuals, on the various evaluation segments of the paved network;
6. Testing and implementation of the sampling plan;
7. Design and implementation of the data bank itself, including software development for data storage and retrieval; and

Figure 1. Role of the data system in the pavement management system.



8. Development of analysis techniques on stored data for checking and updating models, establishing sensitivity of performance factors, evaluating maintenance strategies, and updating terminal serviceability predictions for programming and budgeting purposes.

EXISTING DATA FILES IN THE HIGHWAY DEPARTMENT

The Texas Highway Department has 16 headquarters' divisions, 25 districts, and the Houston Urban Project, which all acquire and use data of various forms. There are a very large number of data files in existence, and it would be a massive task to document and integrate all of these. However, the Planning and Survey Division (D-10) provides much of the documentation relevant to the pavement design and management system and is the principal repository for a large amount of information. A complete listing and description of this documentation is given elsewhere (6). A list of data files directly relevant to the pavement data system can be found in another publication (4).

An example data file from D-10 is shown in Figure 2. It shows the inputs, operations, and outputs associated with the state roadway file. Also shown in the diagram are some of the output reports that are currently being produced from this file.

FUNCTIONAL REQUIREMENTS FOR THE PAVEMENT DATA SYSTEM

General Requirements

The pavement data system was to be an explicit part of the overall pavement design and management system. However, the following basic questions had to be faced in the planning phase: Should the entire paved network be included in the data system, or should only certain, selected evaluation segments be included?

Although programming and budgeting require data on the whole network, it was decided (on the basis of available resources) that the second approach was more feasible for the initial data system.

Nevertheless, a general requirement was to provide in the data system flexibility for expansion to include any number of additional portions of the network. In this way, for example, a particular district could collect widespread information on one or more specific data items (e.g., skid resistance, present serviceability index, etc.) with no change in format.

Another obvious requirement was to include the data system factors that related to the physical and economic models in the flexible and rigid pavement design system.

Finally, a major requirement was the provision for accessing other data files, such as that previously described. It has been pointed out that this can be accomplished by proper indexing, control, and coordination.

Figure 3 shows the overall requirements for the pavement data system. It points out that there is both a supplier and a user of data, which in many cases may be the same person, section, division, or district.

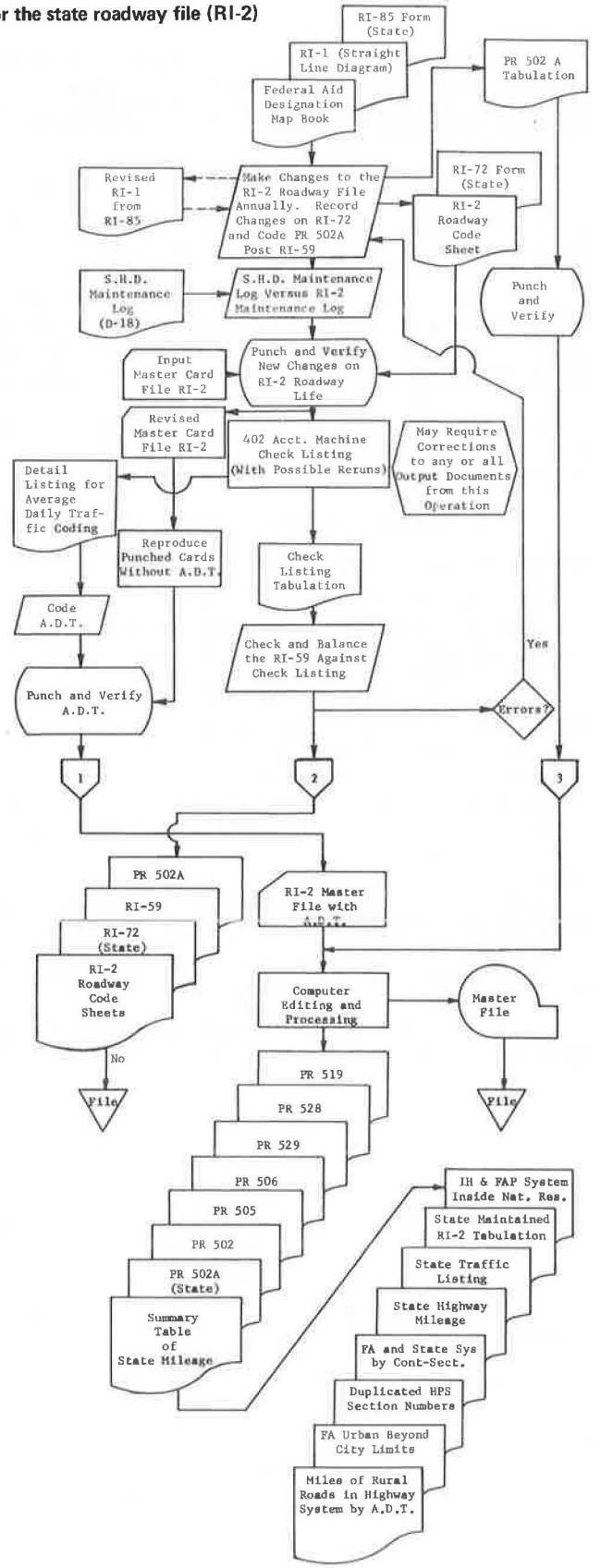
Specific Requirements

The successful implementation of a pavement data system depends on prior and specific consideration of the general, major requirements. This may be done by first listing the classes in which they fit and then by considering these classes in more detail:

1. Existing channels of communication in the highway department's administrative structure should be used to acquire and transmit data;
2. The data system should be implemented on a progressive or staged basis, including trial and testing work; and
3. A means for determining the usefulness or value of the data system should be established.

Communication of data requires the following: (a) computer programs for processing input data, updating files, processing output data requests, and accessing other data files; (b) availability of equipment (field, laboratory, and computer hardware); (c) delineation of the highway department's organizational structure, particularly relating

Figure 2. Inputs, operations, and outputs for the state roadway file (RI-2) (taken from Kher et al., 3).



to pavement management information flows; (d) operational guides and sampling plans for field staff engaged in acquiring and forwarding raw data; (e) description, for distribution, of the standard retrieval output reports available; and (f) no constraints within the data system itself on the amount of information that can be handled.

Progressive implementation is a logical and more feasible approach that can incorporate improvements on a stepwise basis. The following are required for such a staged implementation:

1. Selection of one or more short, representative evaluation segments on each section designed by the working system—this provides an orderly annual addition to the total inventory covered by the data system;
2. Output reports having an initial, finite, and standard form—this recognizes the major task of software development; and
3. Provision for adding future, new data fields—this recognizes initial resource limitations on acquiring data and allows for the possibility of currently "unimportant" factors changing in status.

Determining the usefulness of the system is necessary in order to avoid continued collection of useless data while perhaps neglecting the addition of new, important data fields. The following standards of comparison have been adopted for the overall project (discussed more extensively elsewhere, 1, 4) and are applicable to the pavement data system: operationality, rationality, acceptability, and reviseability.

DEVELOPING THE COMPONENT FORMAT OF THE DATA SYSTEM

Planned Operating State

The data system was planned on an integrated basis, within the overall development and application scheme shown in Figure 1. The planned operating state of such an integrated, computer-based, pavement data system is shown in Figure 4.

Identification of Factors and Classification for Data Files

The identification and classification of factors are iterative processes requiring considerable judgment, some of which is perhaps arbitrary. Because of the extremely large variety of factors possibly relevant to pavements, we selected as a starting point the variables used in the models in the flexible and rigid pavement working design systems.

A number of classification schemes were considered, along with the many variables. Table 1 gives the final classification scheme that was selected. It is in the form of various data files, similar in concept to the data files used by the Planning and Survey Division (D-10). The "123" number relates to the original project number and provides sufficient "open" numbers for any D-10 increase of road inventory files. A listing of the actual factors in each of the data files given in Table 1 and a detailed description of each file are contained elsewhere (4). The following discussion is a brief summary of some of these descriptions.

The master file (RI-123) essentially contains data on the initial as-built pavement, which primarily relate to the dimensions of the pavement structure, the materials used, and the cost of the materials. It is therefore a file of initial information, as contrasted with the subfiles that contain provision for future changes or additions and for periodic data acquisition. The locational identifiers for RI-123 and for all the subfiles correspond to those used by D-10. As well, the pavement data system files provide for a beginning and ending mile point for each evaluation segment (in addition to provision for point, lane, and wheelpath location if desired) within a state highway department section number. This in effect makes possible the development of variable length records within each section. A number of factors in RI-123 and in the subfiles are in coded form for efficiency and convenience. The development of the appropriate codes is facilitated by the design of coding sheets. An example is given in the next section.

The performance data subfile (RI-123-01) has been designed for periodic measurements of the pavement surface in order to assess the level of service provided by the

Figure 3. General functional format for a pavement data system.

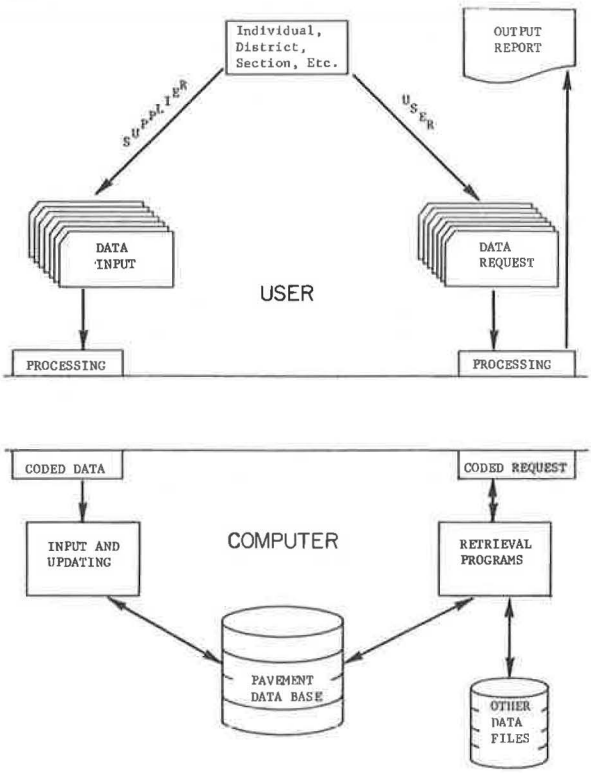


Figure 4. General operating state of an integrated, computer-based pavement data system for Project 123.

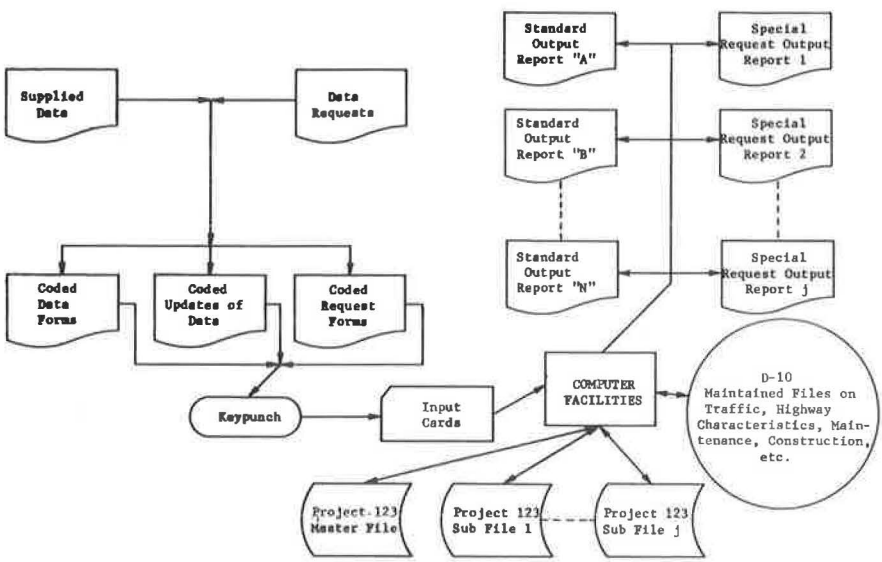


Table 1. Classification of Project 123 pavement data files.

File Number	File Name	Remark
RI-123	Master file	Contains as-built data on dimensions of pavement structure, construction and materials costs, etc.
RI-123-01	Performance data subfile	Contains periodic performance data on roughness, pavement deterioration, skid resistance, etc.
RI-123-02	Structure capacity subfile	Contains periodic structural capacity measurements for deflection.
RI-123-03	Maintenance, resurfacing, and seal coats subfile	Contains periodic data on maintenance, resurfacing, and seal coats types and costs.
RI-123-04	Environment subfile	Contains periodic data on rainfall, temperature, moisture variations, freezing, etc.
RI-123-05	Materials data subfile	Contains as-built and periodic data on physical and chemical properties of pavement component materials.
RI-123-06	Traffic data subfile	Contains initial and periodic data on traffic volumes, truck percentages, weights, etc. (access to D-10 traffic data file).

Figure 5. Coding sheets for the performance data subfile (RI-123-01).

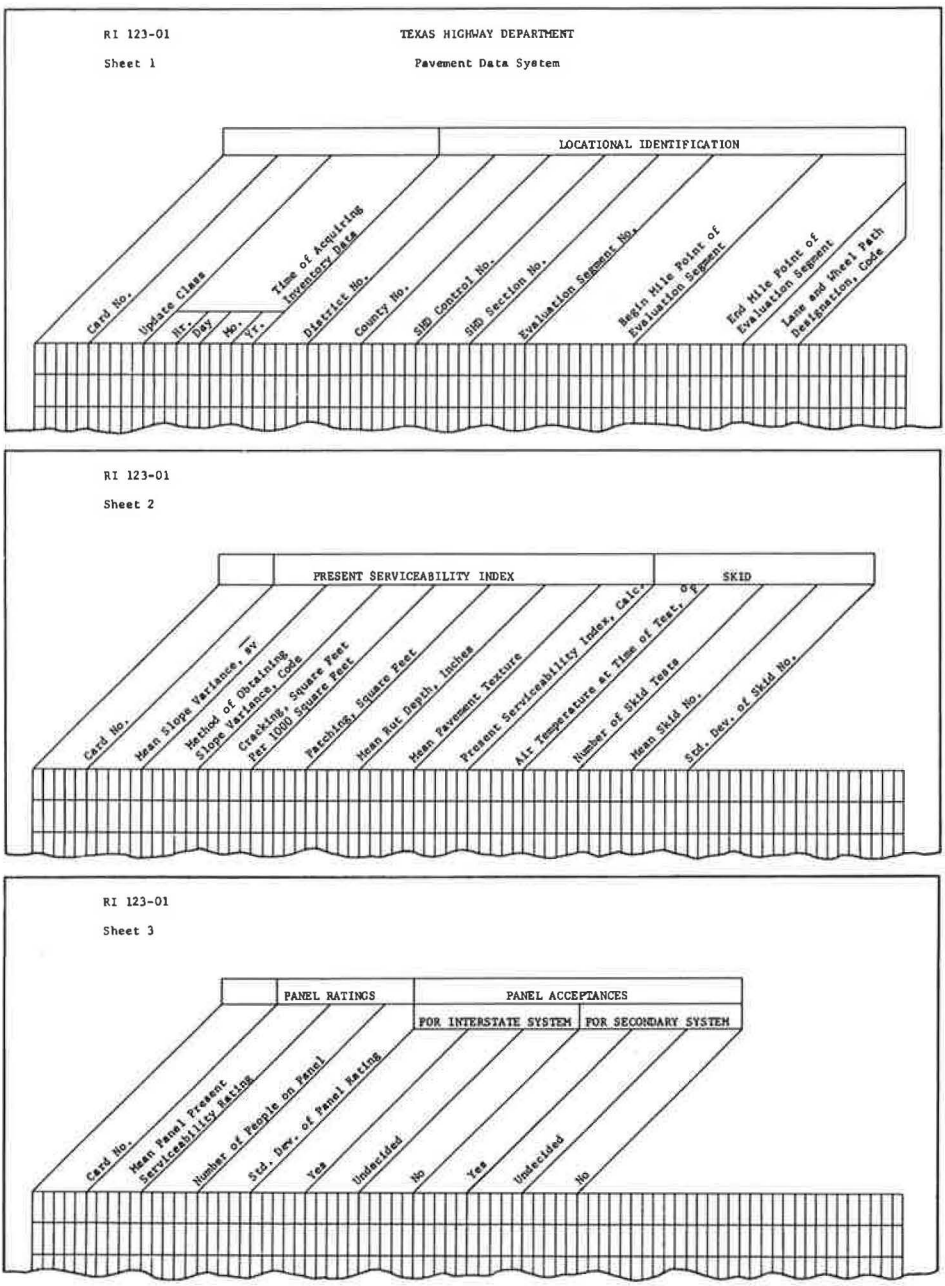


Figure 6. General communication and data flow channels for the Project 123 pavement data system.

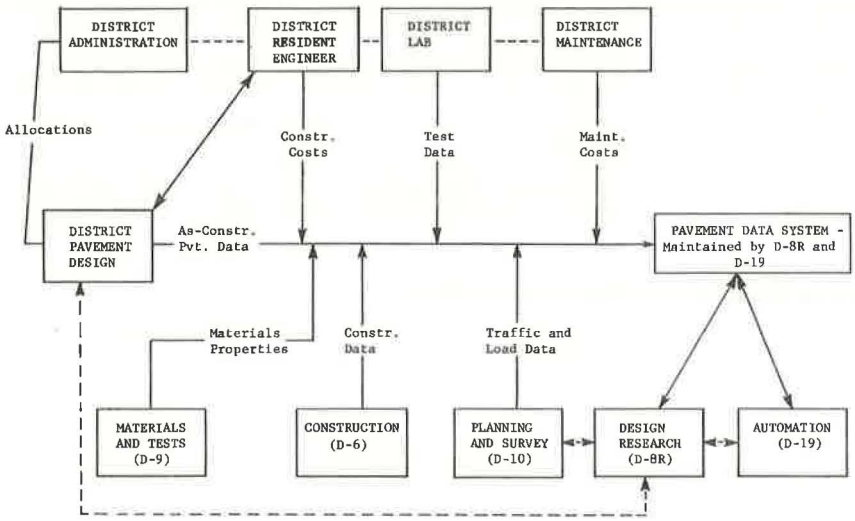


Figure 7. Example retrieval from the Project 123 pavement data system.

TEXAS HIGHWAY DEPARTMENT

PAVEMENT DATA SYSTEM - DATA RETRIEVAL

INVENTORY OF PAVEMENT EVALUATION SEGMENTS DESIGNED BY FPS AND RPS

FILES ACCESSED- RI-123
RI-123-01
RI-123-06

HWY	CONTL	SEC NO	EVAL SEG NO	BEG MI PT	END MI PT	DATE PVT COMPL	PVT SURF TYPE	BASE TYPE	SUBB TYPE	SUBGR SOIL TYPE	TOT PVT DEPTH	INITIAL PSI	INITIAL ADT
IH35	15	7	3	24.610	25.083	30AUG68	2	0	1	A-7-5	9	4.5	25000
IH35	15	8	3	34.700	35.173	11SEP68	2	0	1	A-7-5	9	4.5	25000
IH35	15	9	3	43.240	43.713	01OCT68	2	0	1	A-7-5	9	4.5	25000
IH35	15	10	4	52.115	52.588	17OCT68	2	0	1	A-7-6	9	4.5	25000
US77	371	3	1	18.210	18.683	10FEB69	1	2	1	A-2-7	12	4.3	15000
US77	371	4	2	22.450	22.923	12FEB69	1	2	1	A-2-7	12	4.4	15000
SH103	336	5	1	15.335	15.808	25APR69	1	2	4	A-4	13	4.2	12000
SH103	336	6	2	25.650	26.123	30APR69	1	2	4	A-5	13	4.2	12000
SH103	336	7	3	33.825	34.298	02MAY69	1	2	4	A-3	13	4.0	12000
SH103	336	8	4	41.220	41.693	05MAY69	1	2	4	A-4	13	4.4	12000
US377	80	2	1	40.400	40.873	01JUN70	1	2	1	A-7-5	12	4.4	16000
US377	80	3	2	45.265	45.738	06JUN70	1	2	1	A-7-6	12	4.5	16000

pavement. The most important of these performance indicators, in terms of current technology, are the present serviceability index (PSI) and the skid resistance factor. The RI-123-01 file also contains data items for panel ratings. This is an example of data that may be collected only at infrequent intervals, such as part of a special study. An example of the coding sheets used for this subfile is shown in Figure 5. Coding sheets for the other files have been designed in a similar manner.

The structure capacity subfile (RI-123-02) has also been designed for periodic measurements, primarily using Dynaflect measurement data because they are used by the working design system for flexible pavements. The RI-123-02 file also contains data items for structural parameters of the layers used in elastic "n-layer" analyses.

The maintenance, resurfacing, and seal coats subfile (RI-123-03) provides data not only useful for modifying the design models per se but also useful for periodically updating the original design predictions. The data collected primarily relate to periodic costs incurred.

The environment subfile (RI-123-04) is primarily used for recording climatic data. It is also designed to include some general topographic and drainage information as well as temperature and moisture data through the pavement depth.

The materials data subfile (RI-123-05) has been held to slightly more than a hundred items. This may seem extreme, but several hundred variables could quite easily be included. As well, the final sampling plan will contain only certain key items from this list for routine measurement. The others are included, as for other data files, to provide flexibility for expansion and for special studies.

The traffic data subfile (RI-124-06) is designated as a distinct part of the pavement data system but will initially operate only on the basis of accessing the Planning and Survey Division's data files.

IMPLEMENTATION

Sampling Plan and Data Flows

A sampling plan and operational guides are currently being developed. Because the major amount of data will come from district staffs, the resources available in the district are carefully considered in selecting the number of evaluation segments and the intensity or frequency of sampling.

The data flows involved are shown in Figure 6. Although pavement design is separated from district resident engineer, these coincide in a number of cases.

Because the primary initial purpose of the data system is for checking and updating design models, the Research Section of the Design Division (D-8R) will have responsibility for its maintenance. The Automation Division (D-19) will handle data processing and storage.

Software Development

One of the major developmental tasks that is needed before full implementation can be realized involves writing a variety of data retrieval programs. There are, of course, a large number of possible types of retrieval that may be desired. Figure 7 is an example output showing some data as they would be "stored" in the system. Other forms of output might include varying degrees of analysis and/or correlation.

There are two basic types of retrieval programs: (a) periodic, "standard" outputs, primarily for trend analyses; and (b) special outputs, for research purposes.

CONCLUSIONS

Pavement design and management incorporate a variety of interrelated activities, most of which function better with an adequate data base. This paper has demonstrated that a feedback data system is vital to the efficient, continued updating and improvement of pavement management activities.

The initial planning and development of a pavement data system for the Texas Highway Department have been outlined in the paper. Other data files in the highway department have been considered in designing the component format. A classification scheme

for the pavement data files has been described. Finally some suggestions have been set forth for data flow and software development requirements.

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