Case Studies of the Administration of Three Statewide Pavement Management Systems

T. H. Maze, Neal R. Hawkins, and James K. Cable

This paper discusses three case studies of the pavement management systems used by the state departments of transportation in Iowa, Arizona, and Pennsylvania. These case studies demonstrate how existing successful systems operate from an administrative point of view. The original intent of the research was to answer a number of practical questions raised by the managers of a state department of transportation that was considering the use of a pavement management system. Some of the questions asked included: How much will the system cost? How will a pavement management system impact current decision making? Should pavement management be controlled within the central office? Should field divisions play a major role in the system? This paper seeks to provide solutions to these questions through the examples provided by other states.

The purpose of the research described by this paper is to demonstrate how respected statewide pavement management systems operate from an administrative point of view. Much information is available on the pavement management techniques used by various agencies (such as the distress measures collected, the use of optimization programs for allocating resources, and decision rules for selecting pavement treatments). However, little is available regarding the role of the pavement management system within these agencies, the cost of planning, designing, developing, operating, and maintaining a pavement management system, and how the pavement management system helps determine the allocation of resources.

Originally, the research was conducted for a state department of transportation that was considering the development of a statewide system (*1*). At the feasibility stage, top management acknowledged a number of organizational and administrative issues, including the following practical concerns:

- How much will the system cost?
- How will a pavement management system impact current decision making?
- Should restoration, rehabilitation, and reconstruction programming, which use the pavement management system as a resource, be controlled by the central office with regional offices only reviewing the program, or should the process be initiated at the regional level?

Researchers were sent to state departments of transportation that were respected for their pavement management systems. The states visited were Iowa, Arizona, and Pennsylvania. The systems in each of these states were developed with different approaches, take different approaches to the pavement management process, and evolved at different paces.

Iowa State University, Ames, Iowa 50011.

IOWA PAVEMENT MANAGEMENT INFORMATION SYSTEM

The Iowa Pavement Management Information System (IPMIS) was, for the most part, developed in-house. The Iowa Department of Transportation (IDOT) has collected pavement conditions (such as roughness and structural capacity) since the late 1950s and maintained the information in various uncoordinated forms. In the late 1970s, IDOT decided to integrate its pavement condition measurement surveys and automate its condition data processing. The joining of these independent efforts into a systematic data collection effort became the existing IPMIS.

The current computer software for the IPMIS resides on IDOT's mainframe computer, and the individual pavement condition and pavement construction history files reside in individual flat files (not a relational/hierarchical data base file). A new data management system is being installed to merge the pavement condition and construction history data files into one relational data base system, integrate data storage and retrieval, and permit ad hoc data queries.

Pavement Condition Data Collection

The IPMIS contains data that cover five pavement condition attributes (*2*):

1. Skid resistance measured using locked wheel skid trailers,
2. Structural adequacy measured using a Road Rater,
3. Roughness measured using an electromechanical ride meter (the Iowa, Johannsen, and Kirk Ride Indicator),
4. Surface distress visually measured using a crack-and-patch survey, and
5. Remaining pavement life measured in 18-kip equivalent single-axle loads (ESALs) until terminal pavement serviceability is reached.

Pavement Section Evaluation

IDOT uses the field-generated condition data, except the skid resistance data, to evaluate pavement sections through a pave-

	Factor Value						
	1	2	3	4	5	6	7
Percent Remaining 18 Kips	<-19	-19	0	10	25	45	>70
P.C.C. D-Crack Occurrence Factor	> 4	4	3	2	1		0
Relative Structural Ratio	0.40	0.50	0.60	0.70	0.80	0.90	1.00
Maintenance Costs							
Rut Depth	> .50	.40	.30	.20	.10	.05	< .05
PSI Deduction	> .80	.60	.40	.25	.15	.05	< .05
Longitudinal Profile Value (I.J.K. Ride)	< 3.00	3.20	3.40	3.55	3.65	3.75	> 3.75
P.S.I. Decrease/Year 6 year basis	> .20	.20	.17	.14	.11	.08	< .05

Add factors and compute to a 7 point scale.

If PSI<2.0, the Δ_6 in PSI will reflect a factor value of 0

FIGURE 1 Iowa pavement management matrix.

ment management matrix. The matrix contains values for eight measures of pavement condition:

1. Percentage of remaining 18-kip ESAL life,
2. D-cracking occurrence,
3. Structural rating,
4. Maintenance costs,
5. Average rut depth,
6. Present Serviceability Index (PSI) (*3*),
7. Roughness, and
8. PSI decrease per year.

As shown in Figure 1, each of these eight condition measurements is divided into seven individual categories (factor scores), where 1 is poor condition pavement and 7 is good condition pavement. The matrix value for a pavement section is determined by entering the matrix for each factor and measured value and obtaining the corresponding factor value at the top of the appropriate column. For example, if the pavement has received loadings equal to its design life (0 percent remaining), then the pavement receives a factor score of 3 for the remaining pavement life. To obtain an overall measure of the pavement condition, the factor scores of all pavement condition measures are added and the sum is recomputed into a score on a scale from 1 to 7. Summary listings in decreasing matrix value, by highway district, or by matrix factor can be generated to assist administrators in developing construction and maintenance programs for the next 1 to 5 yr.

IDOT is developing a pavement condition rating (PCR) system for the condition measurement included in the pavement management matrix. The PCR would be a composite score from 0 to 100, where 0 is the poorest condition pavement and 100 is the best condition pavement. The rating system will be dependent on the pavement type, such as asphalt concrete (AC) pavement, portland cement concrete (PCC) pavement, continuously reinforced PCC pavement, and PCC pavement overlaid with AC (composite pavement). By independently factoring the condition scores to a 100-point scale for each pavement type, the composite ratings are customized for each pavement type and become comparable. Therefore, the 100-point system will permit prediction and prioritization of pavements for rehabilitation. Further, a 100-point scale PCR will be compatible with IDOT's 100-point scale sufficiency rating, which will permit the two systems to be used together to develop programs that meet pavement rehabilitation and traffic capacity needs concurrently.

Role of Pavement Management at IDOT

The IPMIS is currently managed by IDOT's Office of Materials, which is part of the Highway Division. The Office of Materials has historically been responsible for collecting pavement condition data and performing some data evaluation. When the IPMIS becomes completely operational, the Planning and Research Division will assume management responsibility for the IPMIS. The Highway Division will continue to collect and evaluate the condition data, while the Planning and Research Division conducts programming activities. This will provide a system of checks and balances to improve data quality and encourage cooperation among IDOT units.

The primary role top management foresees for the IPMIS

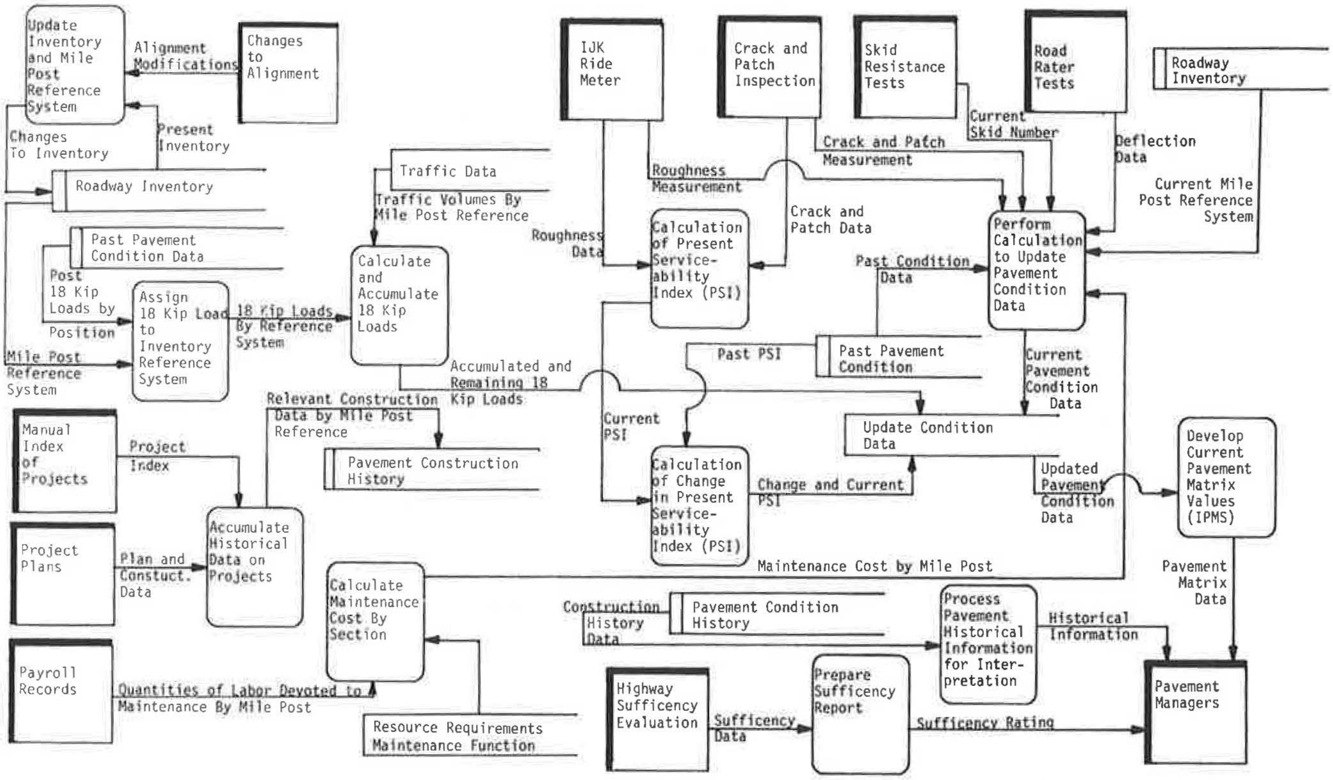

FIGURE 2 Data flow diagram of the Iowa pavement management system.

is in the programming of major pavement rehabilitation. Once the 100-point scale PCR system is operational, then the PCR will complement IDOT's sufficiency rating in the development of the highway improvement program.

The pavement management system administration has evolved from a Pavement Management Task Force consisting mostly of top management staff to the current Pavement Management Committee. Because of the top managers' demanding schedules, the task force met infrequently and the pavement management staff did not receive adequate direction. As a result, the development of the IPMIS lacked momentum. More recently, a Pavement Management Committee Task Force was formed of mid-level managers. These members meet more frequently and administer developmental activities, while the Pavement Management Committee sets policies and reviews task force activities. The development pace of Iowa's system has quickened since this task force was established.

System Inputs, Outputs, and Processes

Figure 2 is a simplified diagram outline of the data flow in the IPMIS. The flat rectangles represent data stores (data files), the double-edged boxes are external entities that begin or end data flows (pavement condition collectors and output users), the rounded rectangles are processes (compiling of data and computing), and the arrows are data flows. Some of the data stores have been drawn more than once to reduce the clutter. These data stores have a double line across their left-hand side.

The current IPMIS is a relatively simple data base system with a series of flat files. However, the development of this system took roughly 5 man-years, and an estimated 2 man-years will be required to place the IPMIS on a relational data base management system.

One of the largest difficulties in managing the data base has been the coordination of a nonstandard pavement location coordinate system. Iowa's pavement management system operates both on a physical milepost location system that originates at the west and south state lines and on an imaginary milepoint system that originates at the west or south line of each county for a particular route. Other data are referenced in other nonstandard systems. For example, limits of construction projects are based on milepoints.

TABLE 1 IOWA COST OF PAVEMENT CONDITION TESTS

Evaluation Test	Cost/2-Lane Mile ($)
IJK Ride Meter	9.41
Skid resistance test	15.06
Pavement deflection	34.92
Pavement texture test	86.16
Crack and patch survey	101.71

Costs

IDOT's costs of performing pavement condition tests per mile are listed in Table 1. These figures include labor cost, depreciation on test equipment, and the cost of equipment maintenance and operation. It should be noted that, although the entire state highway system condition is measured, measure-

TABLE 2 ANNUAL OPERATING AND ADMINISTRATION COSTS OF IPMIS

Data Collection	Two-Lane Miles		Cost/Mile		Total
IJK Roadmeter	5,050	X	$ 9.41	=	$ 47,521
Friction (not in Matrix)	5,000	X	15.06	=	75,300
Road Rater	3,000	X	34.92	=	104,760
Crack & Patch Survey	800	X	101.71	=	81,368
Administration (2 P.E.s, 1 E.I.T., 1 Tech-4, 1 Tech Supervisor-2, and 2 Temp. Eng. Students)					50,000
Traffic, truck weight and class, 18 kip ESALs			Est.	=	50,000
Equipment Maintenance Costs			Est.	=	30,000
Computer Program Development			Est.	=	35,000
Pavement Management Task Force (5 people x 2 hours/week x 52 weeks/year x $20/hour)					10,400
Pavement Management Committee (8 people x 2 hours/month x 12 month/year x $30/hour)					5,760
					$490,109
			(roughly $500,000 per year)		

ments are made only on random samples. For example, the crack-and-patch survey is conducted on ½-mi subsections within each 5-mi section. Therefore, the cost per mile of a crack-and-patch survey is actually the cost of evaluating two 5-mi sections.

The costs of operating and administering the IDOT pavement management system are listed in Table 2. These costs have increased dramatically in the past few years because of increased pavement management activity. In 1987 it cost IDOT roughly $500,000 to operate and administer the IPMIS, while in 1985 only $225,000 was spent on the operation and administration of the system.

ARIZONA PAVEMENT MANAGEMENT SYSTEM

The Arizona Department of Transportation (ADOT) began investigating the development of a pavement management system in the mid and late 1970s. At that time, there were two primary management issues that ADOT hoped to address through the use of a pavement management system (*4*):

1. Estimates of preservation needs and maintenance decisions were mostly based on the judgment of district engineers. The concern was that judgmental decision making might lead to nonuniform pavement conditions across the state. Also, the state government was aware of the subjective nature of these decisions and was reluctant to appropriate additional funds when resource allocation decisions were made in this manner.
2. A method for predicting the long- and short-term effects of funding shortages on road conditions and a systematic procedure to cope with budget cuts were needed.

In 1978, ADOT hired a consultant to develop a pavement management decision-making tool for Arizona. The focus of this system is at the network level. The optimization uses a Markov chain model, which forecasts the proportion of the highway network that will change from one condition state to another during a given year. A linear program is then used to select treatments and allocate resources each year. Unfortunately, the network optimization forecasts only proportions of the entire highway network that will be in a specific condition state. In other words, the identity of each section is lost.

The network optimization system forms the focal point of Arizona's current pavement management system. However, ADOT has developed programs to augment the original system and collects data in its pavement evaluation that are not used by the original model. For example, one of ADOT's key pavement management tools is a heuristic algorithm used to predict the condition of a specific pavement section and automatically select rehabilitation treatments. When results of the heuristic algorithm are compared to those of the optimization, the cost forecasts are generally very close.

Pavement Condition Data Collection

ADOT collects and maintains data files for several types of pavement condition data:

- Surface distress measured through a visual survey of the first 1,000 ft^2 of the pavement at each milepost,
- Skid resistance measured using a Mu-Meter,
- Roughness measured using a Mays Ride Meter mounted on the rear axle of a specially equipped passenger car, and
- Structural adequacy measured using either a Dynaflect unit or a Falling Weight Deflectometer.

Role of Pavement Management at ADOT

ADOT's pavement management system is currently managed within the Materials Section, which is part of the Highway Division. The Highway Division is divided into two groups: the Highway Development Group and the Highway Operations Group. The Materials Section is part of the Highway Operations Group. The Materials Section contains three areas: Geotechnical Services, Testing Services, and Pavement Services. Pavement Services includes the Pavement Management Branch and the Pavement Design Branch.

The Pavement Management Branch has 11 employees and is managed by a pavement management engineer. This branch is responsible for collecting pavement condition data and managing the pavement management data base and the pavement management programs.

The primary management responsibility of the Pavement Management Branch is the identification of pavement preservation projects. In 1987, ADOT's pavement preservation budget was roughly $62,000,000. At the start of each fiscal year (July 1), the pavement management engineer meets with the district engineers to begin developing a preservation program. In these meetings, pavement projects and priorities are discussed. Over the next few months, a draft preservation program is developed and the pavement management data base is updated with condition data collected during the summer. After the data base is updated, the network-level models are run and the pavement management engineer refines the preservation projects based on current data. Another meeting is then held with the district engineers to settle on a final preservation program. This program is then presented to the priority planning subcommittee at the beginning of the year, to be included in the 5-yr construction program, which is forwarded to ADOT's board for final approval.

The past pavement management engineer estimated that between 70 and 80 percent of the projects selected through the pavement management system agree with those selected by the district engineers. These groups tend to agree more on the dollars programmed for preservation and less on the specific miles identified for restoration. This is because more expensive projects (such as Interstate restoration) are more easily identified.

The pavement management system was placed in the Materials Section because this section has always performed pavement testing. Pavement management was simply considered an extension of this role. Interestingly, pavement management has largely been used as a network-level pavement restoration planning tool. Even though this planning function is based outside of the Planning Division, ADOT does not intend to change this structure.

System Inputs, Outputs, and Processes

Figure 3 is a data flow diagram of ADOT's pavement management system. The network optimization is a sophisticated program that involves the use of Markov chains and a linear programming model.

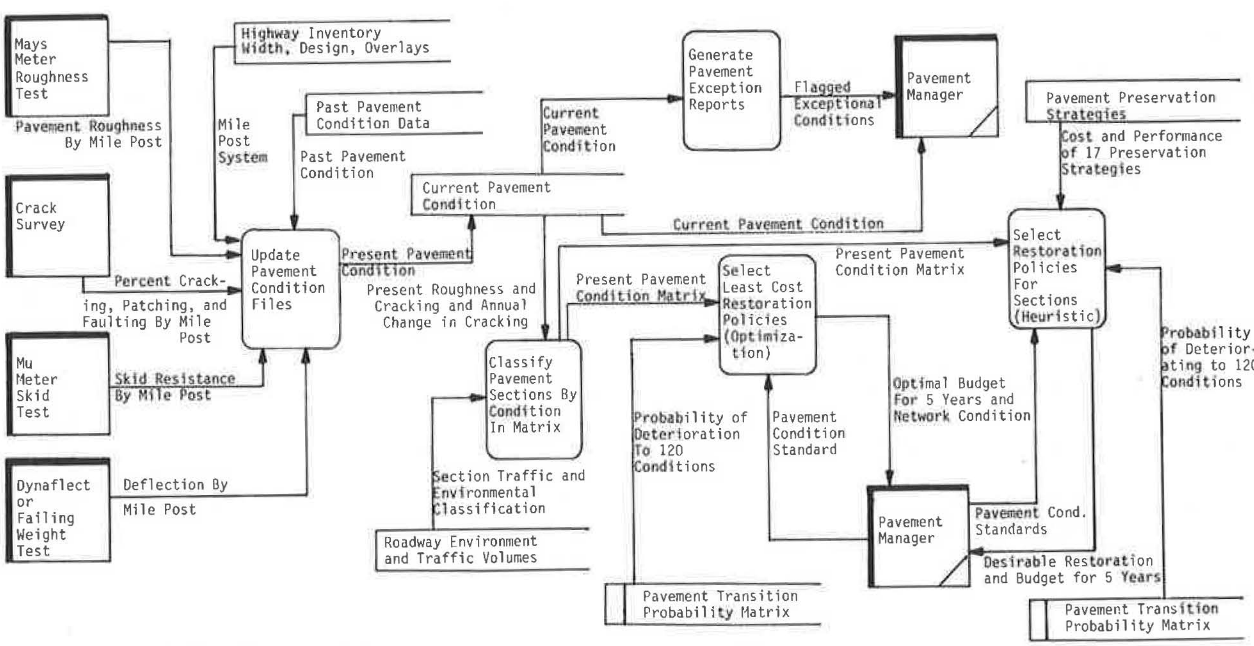

FIGURE 3 Data flow diagram of the Arizona pavement management system.

TABLE 3 ARIZONA COST OF PAVEMENT CONDITION TESTS

Evaluation Test	Cost/2-Lane Mile ($)
Mays Meter Roughness Test	3.48
Cracking and distress visual inspection	4.85
Mu-Meter skid resistance test	5.77
Dynaflect deflection test	21.78
Falling weight deflectometer test	53.22

Costs

To develop the network optimization, ADOT spent roughly $300,000 on consulting services in 1979. Temporary staff were hired for a total of about 13 man-years to work on the pavement management system during its development.

The costs of performing pavement condition tests per mile are listed in Table 3. These figures include labor cost, vehicle rental rates, and employee per diem. They do not reflect the cost of survey equipment depreciation. The cost of visual crack-and-distress tests are low because ADOT inspects only the first 83 ft of each mile of roadway surface (12-ft lane width $\times$ 83 ft = 1,000 ft^2). The annual labor cost of operating the ADOT pavement system is roughly $275,000 (11 staff members).

PENNSYLVANIA'S SYSTEMATIC TECHNIQUE TO ANALYZE AND MANAGE PAVEMENTS

Before 1983, the Pennsylvania Department of Transportation (PennDOT) made several overtures toward the development of a pavement management system. Various committees were appointed to investigate pavement management, but little progress was made. Finally, in 1983, the Pennsylvania secretary of transportation named an eight-person task force to investigate the possibility of developing a pavement management system for PennDOT. If the task force determined that a system was feasible, it would assume responsibility for the development.

The task force members were all mid- to upper-level managers (a district engineer, assistant district engineers, and division managers). Until their first meeting, none of the members knew the identity of the others.

Once the task force had decided that it was feasible to develop a pavement management system, the members were relieved of their normal duties and sequestered for the duration of the project, which took 9 mo to complete. The prototype system took roughly 6 man-years of the cumulative task force members' time.

The original pavement management system designed by the task force was given the name "Systematic Techniques to Analyze and Manage Pennsylvania's Pavements" (STAMPP). The computer program used to automate STAMPP was written in BASIC and run on a microcomputer (*5*). During the development phase, a demonstration of STAMPP was conducted by applying the system to a single county. Once STAMPP was refined and tested, it was considered ready for application to the remaining highway system.

The PennDOT philosophy on pavement works from the bottom up. The pavement management system is used by the county manager to set pavement maintenance and betterment priorities within the county. An assistant district engineer considers the county manager's recommendations when making project selections for the district. All project-level pavement management analysis is conducted at the district level, whereas network-level pavement management analysis is conducted at PennDOT headquarters. The involvement of headquarters in the process ensures consistency between districts. If a district recommendation deviates from the action recommended by STAMPP, ample justification must be given for not following the program's recommendations. Because STAMPP has only been in operation a short time, PennDOT has not yet developed performance curves to forecast future performance of the system.

Pavement Condition Data Collection

PennDOT has divided the state highway system into approximately 90,000 inventory segments that are roughly ½ mi long. The segment divisions are located at physical changes in the pavement or changes in the characteristics of the traffic loadings (such as an intersection). The beginning and ending of segments are marked by inventory posts, and the segments are used to identify the highway system for all other inventories (such as accident locations and traffic control device locations).

PennDOT collects several types of condition data:

- An extensive visual inspection of the pavement condition is conducted by two individuals (a driver and an evaluator) in a moving vehicle. Five percent of the sections are resampled for quality control. Each year, the entire pavement section is rated and all sections are inspected. Visual evaluations cost slightly less than $13 per mile.
- Roughness is measured using Mays Ride Meters.
- Skid resistance is measured using locked wheel skid trailers.
- Structural adequacy is measured using a Falling Weight Deflectometer on PCC pavements and a Road Rater on AC pavements. These tests average around $88 per mile.

The Role of Pavement Management at PennDOT

In 1983, PennDOT was reorganized to structure the Department by function. The management function of the highway system was placed in a new bureau called the Bureau of Bridge and Roadway Technology. This bureau has three divisions:

1. The Engineering Technology Division, which is responsible for electronic data processing, value engineering coordination, new product evaluations, experimentation and evaluation projects, and technology transfer;
2. The Bridge Management Systems Division, which is responsible for bridge system evaluation and bridge experimentation projects; and
3. The Roadway Management Division, which is responsible for pavement management, pavement design practice, and pavement experimentation projects.

Although these three management divisions control the development of roadway and bridge design and maintenance prac-

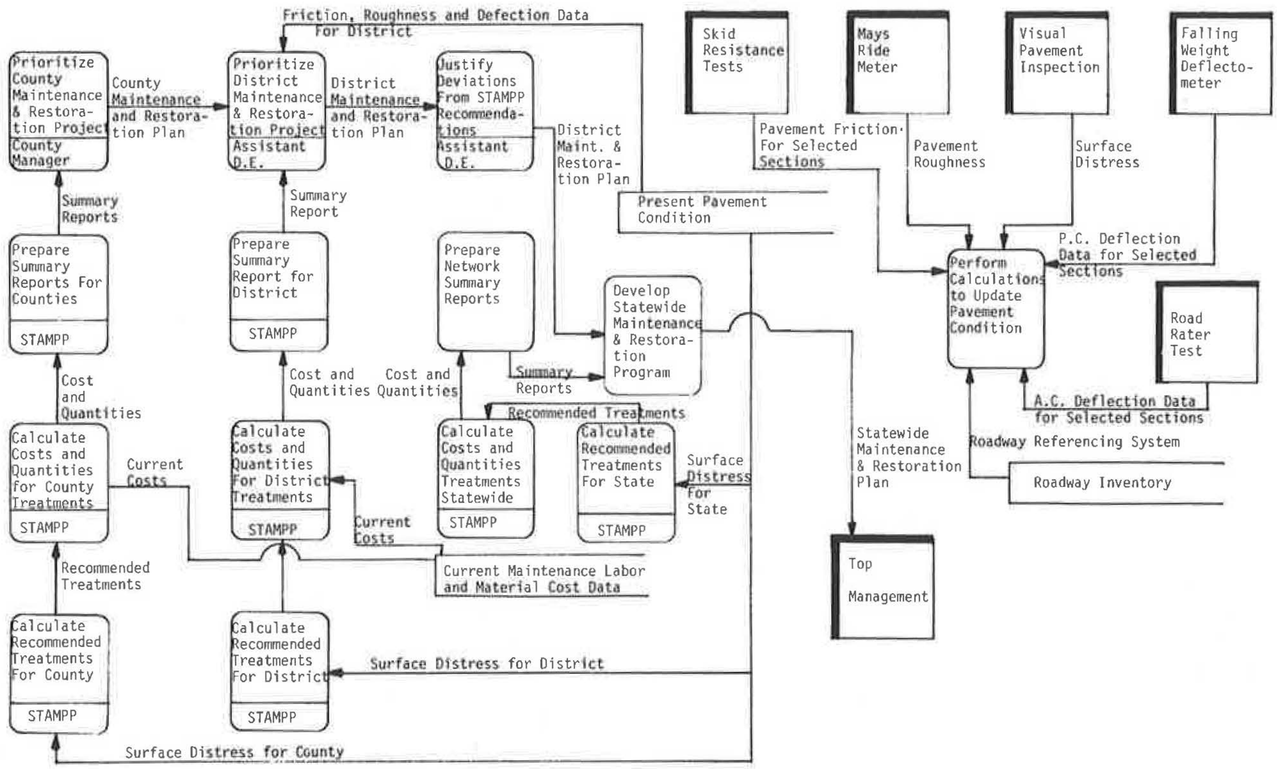

FIGURE 4 Data flow diagram of the Pennsylvania pavement management system.

tice, actual design and maintenance are conducted by the Bureau of Design and the Bureau of Maintenance and Operations.

By reorganizing, PennDOT has avoided orienting the pavement management system toward the objectives of a functional area (such as maintenance, materials, design, or planning). Instead, the system is a management tool available to all functional areas.

System Inputs, Outputs, and Processes

Figure 4 is a data flow diagram of STAMPP. Although STAMPP was originally designed as a standalone system, it is currently a module of the PennDOT roadway management system (RMS). RMS is a computerized information system that integrates pavement management, roadway information (data covering descriptions of the roadway and construction history), special processes (traffic data, accident data, and others), computer-generated straight-line diagrams, and other management functions. Development and testing of the RMS is expected to cost approximately $20 million.

FINDINGS

Each of the three case studies provides a distinctly different approach to the development and administration of a pavement management system. The Iowa system was developed in-house. It has been slow to evolve over its 9-yr history, but progress now seems to be more rapid. Arizona's system was developed by a consultant and later modified in-house. In this highly centralized system, the pavement preservation program is initiated at headquarters, then reviewed and critiqued by the field districts. The Arizona system's primary emphasis is at the network level, and it is principally used in project planning and programming. Pennsylvania's system was developed in-house by a committee of mid- to upper-level managers. It is very decentralized and begins at the county level. This system focuses on the selection of individual projects and is not currently capable of projecting pavement conditions for planning purposes.

RECOMMENDATIONS

From the case studies, general and specific recommendations were made for the state that originally sponsored the research. Many of these recommendations were unique to that state. For example, one critical issue was the pavement management process flow. Should the field divisions begin the annual and 5-yr programming and planning process, following the Pennsylvania model, or should the central office start the process, as in the Arizona model? In the sponsor state, the field divisions had enjoyed a good deal of autonomy in selecting maintenance and restoration projects for the non-Interstate state highway system. Many field division personnel felt that centralizing the processes would erode their ability to direct resources effectively using judgmental factors that could only be known through local experience. Therefore, it was recommended that the project planning and programming process should start within the field divisions and that uniformity between these divisions should be governed by that process.

Other recommendations that involved the unique characteristics of the sponsor state regarded whether the system should be developed in-house or by a consultant and whether the system should initially focus on the development of network-level capabilities or on identifying and prioritizing projects.

The following recommendations can be applied to all agencies:

- Top managers must be committed to the systematic management of pavements. They should be willing to commit a significant level of human and capital resources to the planning, design, and implementation of the system, and system maintenance, operation, and improvement must receive a substantial and continuous flow of resources.
- General education on the pavement management process should be conducted during the initial planning stages to reduce misconceptions by staff members and facilitate receptiveness to the process.
- A committee of mid-level managers and engineers should be appointed to guide the planning, design, and implementation of the pavement management process. These individuals must be relieved of enough routine duties that they can devote a substantial level of effort to their committee assignments. They should attend in-depth pavement management training programs through as many different organizations as possible to expose them to a variety of pavement management philosophies. The training should also include site visits to other states.

In addition, the study identified six major issues that should be addressed in the management plan for a system's development, implementation, and operations. The plan must

1. Establish clearly defined objectives with quantifiable measures of accomplishment. The functions of the pavement management system should be apparent through the objectives. For example, one objective might be that the system should be able to allocate funds, budget, and program projects for up to 5 yr with the goal of minimizing the life-cycle costs of the pavement network. Implied in this objective is that the system will be able to conduct adequate pavement performance forecasts, estimate revenue, establish priorities, and optimize the allocation of funds.
2. Identify output requirements for the various divisions of the department. For example, if one objective is to have the pavement system automatically estimate budgets, the system must be able to output the desired maintenance treatment for pavements calculated by areal measurement.
3. Identify data requirements for the desired outputs. For example, if the system is to select maintenance actions based on the thresholds of deteriorating pavement conditions, then the appropriate conditions must be included in the data collected.
4. Recommend appropriate changes or improvements to current data collection practices. For example, the sponsoring agency is likely to require better collection of truck axle load data. Therefore, improved data collection procedures are necessary.
5. Identify the management positions and staffing levels needed to operate the pavement system. The permanent positions of an engineer-manager, other professionals, and technicians as well as temporary pavement condition survey labor, represent a significant, recurring cost.
6. Determine an oversight role for a pavement management committee. This committee should be responsible for the review and guidance of the permanent staff.

It was recommended that the sponsoring agency should undertake a list of eight activities once the management plan is completed and the above issues are addressed. These activities were all given deadlines and range from top management initiating the pavement management system development process to long-term system development activities.

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