National Perspective on Pavement Management

FRANK BOTELHO

The nation's highway network represents a multibillion dollar investment that allows for the essential movement of people and goods.

Sound decisions on preventive maintenance, rehabilitation, and reconstruction of highway pavements are crucial to protecting that investment. For this reason, Pavement Management Systems (PMS) have become increasingly important and are now federally mandated on all Federal-aid highways. PMS provide valuable assistance to decision makers in determining cost-effective strategies for providing and maintaining pavements in serviceable condition.

History of PMS

Unlike other management systems that have begun in recent years, PMS were started two decades ago. Although they have made steady progress since that time, they are still new compared with other institutional functions such as planning, design, construction, maintenance, and research.

By the mid-1980s PMS were proving themselves and the benefits were being documented. By the end of the 1980s more than half the states were developing or implementing PMS. In 1989 the Federal Highway Administration (FHWA) issued a policy requiring all states to have a PMS that would cover principal arterials under the states' jurisdiction. It was therefore apparent to FHWA that a PMS was needed by all to ensure the cost-effective expenditure of Federal-aid funds.

The scope of federal and state involvement in PMS expanded when Congress passed the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and required all states to have a PMS that covers all Federal-aid highways. The most significant aspect of this law was the expanded network coverage. FHWA's 1989 policy covered 313,700 centerline miles and ISTEA approximately tripled that coverage, increasing it to 916,200 centerline miles. This expanded coverage translates into a need for significant coordination among state and local governments. For example, of the total of 916,200 miles covered, 365,200 are under local jurisdiction.

In December 1993, FHWA issued a regulation covering all management systems. Section 500, Subpart B, of the regulation describes the ISTEA requirements for PMS. The following items are noteworthy:

1. The regulation is nonprescriptive;
2. Federal-aid funds are eligible for the development, implementation, and annual operation of a PMS;
3. States must develop their work plan by October 1994, designed to meet the implementation requirements;
4. Standards are included for the National Highway System (NHS);
5. The PMS for the NHS must be fully operational by October 1995;
6. The states have full flexibility to develop the standards for the PMS that cover the non-NHS routes;
7. The PMS for non-NHS routes must be fully operational by October 1997; and
8. PMS information must be used as input into the development of the metropolitan and statewide transportation plans and improvement programs.

Section 500.207, PMS Components, contains the components of a PMS for highways on NHS. There are three primary components: data collection, analyses, and update. The components under data collection include

1. *Inventory:* physical pavement features including the number of lanes, length, width, surface type, functional classification, and shoulder information;
2. *History:* project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance;
3. *Condition survey:* roughness or ride, pavement distress, rutting, and surface friction;
4. *Traffic:* volume, vehicle type, and load data; and
5. *Data base:* compilation of all data files used in the PMS.

The components under analyses include

Frank Botelho is Chief, Pavement Management Branch, Federal Highway Administration.

1. *Condition analysis:* ride, distress, rutting, and surface friction;

2. *Performance analysis:* pavement performance analysis and an estimate of remaining service life;

3. *Investment analysis:* an estimate of network and project level investment strategies. These include single- and multi-year period analyses and should consider life-cycle cost evaluation;

4. *Engineering analysis:* evaluation of design, construction, rehabilitation, materials, mix designs, and maintenance; and

5. *Feedback analysis:* evaluation and updating of procedures and calibration of relationships using PMS performance data and current engineering criteria.

Advantages of PMS

A PMS involves a systematic approach that supplies quantifiable engineering information to help highway engineers and administrators manage highway pavements. The total decision-making process is based on information from PMS coupled with engineering experience, budget constraints, scheduling parameters, management prerogatives, public input, political considerations, and planning and programming factors.

The purpose of a PMS is to enhance the way an agency manages and engineers the preservation of its pavement network. A PMS brings to the table "condition data," the past, present, and predicted future condition of the pavement network. Coupled with inventory, project history, and cost data, a PMS can perform a myriad of engineering, management, and investment analyses.

A PMS helps provide the engineering justification for a multiyear network-level pavement preservation program. It can be used to measure the cost-effectiveness of the preservation program and in doing so it can determine the value added to the assets. When all the information in a PMS is analyzed (including key items such as the remaining service life), an agency can determine if it is meeting its own goals. Some basic questions a PMS should answer are

- Is the network in acceptable condition according to the agency's policy?
- Is the trend in condition staying the same, improving, or declining?
- Is there a backlog, and if so, how large is it?

A PMS should explore and seize opportunities to extend the service life of pavements—a major investment in the future of the nation's infrastructure. This goal can be accomplished by using the information in a PMS data base (i.e., performance data) to evaluate how well pavements are designed, constructed, and maintained. The quality of engineering and the materials used are of the utmost importance because these factors determine the rate at which pavements deteriorate. In general terms, a PMS should help accomplish work more efficiently and provide a way to measure how well it is carried out.


TOBIAS

ISTEA requires that states have pavement management systems covering all Federal-aid highways, many of which are under local jurisdiction.

PMS Perspective

The following is an item-by-item perspective on current practices, future trends, and common hurdles in PMS.

Inventory

Most, if not all, states have an inventory of the physical features that are on the surface of the pavement (i.e., number of lanes, length, width, surface type, functional classification, and shoulder information). A number of states are lacking information on features that lie below the surface because of the time and expense involved in coring the pavement. The newest proven technology being used by the states to measure pavement layer thicknesses is ground-penetrating radar. When calibrated and using computer analysis, ground-penetrating radar can measure pavement layer thickness within plus or minus 5 percent for materials that have different dielectric constants. State-of-the-art equipment operates at highway speeds that makes it fast, safe, and cost-effective.

Project History

Most states do not have a complete project history (i.e., preventive maintenance, rehabilitation, and reconstruction data) for the NHS. Maintenance information is the weakest link. Most states have recently developed, or are in the process of developing, a PMS file for preventive maintenance activities. In cases for which it is impractical to resurrect the pavement history because of time, labor, and cost, agencies are now beginning to track the project history.

Roughness

The technology for measuring pavement roughness at the network level generally began with response-type devices, followed by ultrasonic and visible optical devices. The future trend is toward infrared optical and laser profile devices.

Rutting

When PMS was first introduced 15 to 20 years ago, rutting was measured using straight edges and string lines. During the past 10 years, most state highway agencies (SHA) have acquired automated devices that measure rutting at highway speeds. These are typically ultrasonic devices with either three or five sensors. There are two other devices: one has 19 ultrasonic sensors and another has 11 lasers.

Cracking

In general, cracking is the distress that "drives" most PMS. For many years, cracks were measured using trained survey crews who walked or drove on the pavement. There are two types of driven surveys: slow and highway speeds (typically 40 to 50 mph). Currently, various SHAs use 35-mm film and super VHS video to photograph the surface of the pavement. The film and videos are then viewed on a monitor at an office workstation by a trained observer who performs the distress survey.

Viewing a film or video at an office workstation is safer and more convenient than conducting a walking field survey. However, pavement management engineers using walking surveys are able to detect more low-severity distresses than they can by watching a film or video survey because of its limited resolution.

A number of PMS engineers believe the optimum system is a fully automated approach that uses the science of pattern recognition. This type of system videotapes the pavement surface, enhances the images using gray scales and pattern recognition, and counts the cracks using computer software and algorithms. The obvious advantages of this type of system are high-speed data processing, safety, labor savings, and consistent data. Fully automated systems have now been developed, including one by the Texas Department of Transportation.

CMI CORPORATION

Pavement management systems provide valuable help in determining cost-effective strategies for providing and maintaining pavements in serviceable condition.

Structural Carrying Capacity

Only a handful of states are currently measuring the structural carrying capacity of their pavements at the network level using deflection measurements. Network-level measurements are not intended to have the same degree of accuracy as project design measurements. States that collect network-level data have shown them to be good general indicators of the overall carrying capacity of the network. These types of data and analysis can flag attention to special situations; for example when certain roads appear to have less carrying capacity than needed. Stationary deflection-measuring devices do not lend themselves to network-level PMS because the process is slow and costly. In the future, PMS will need a deflection-measuring device that operates at or near highway speeds. The deflection measurements obtained from a "rolling deflectometer," as it is known, and the pavement layer thicknesses obtained from the ground-penetrating radar, are used to compute the structural carrying capacity of the pavement.

Performance

Most states have the raw data needed to monitor and predict pavement performance, which is typically measured as condition or serviceability over a period of time. Currently half the states have performance curves, one-quarter are in the process of developing performance, and the remainder are not yet active. Excellent off-the-shelf software packages that PMS engineers can use for regression analysis are available. In the future, these software packages, coupled with today's high-speed and ever-more-powerful PCs, will enable PMS engineers to track and predict performance on a "route-specific" basis. This capability has already been proven and put into operation in at least some SHAs.

Traffic and Load Data

PMS need average daily traffic flow maps and equivalent single-axle load (ESAL) flow maps on a route-specific basis. Currently all SHAs have traffic flow maps. However, few SHAs have or can produce ESAL flow maps. Most traffic-collection procedures are geared toward collecting traffic volumes, which are primarily used by highway engineers and planners for capacity analysis. Until PMS came along, there was no need to collect traffic data for load analysis on a route-specific basis. Unfortunately for PMS engineers, collecting load data on a route-specific basis is more expensive than the existing traffic-collection process and it is not known if the additional expense (which has not been calculated for each state) is justifiable. More study is needed on this topic. Many PMS engineers and planners believe that better traffic- and load-prediction models are needed.

Ranking Projects

The backbone and heart of a PMS is its ability to rank in priority order pavement preservation projects that are justifiable and cost-effective. The most important phrase in the new (December 1993) FHWA regulation on management systems is the requirement that PMS for NHS produce "a prioritized list of recommended candidate projects with recommended preservation treatments that span single-year and multi-year periods using life-cycle cost analysis." Currently most state PMS do not produce a multiyear ranked list of projects with recommended treatments using life-cycle cost analysis, but are expected to have this capability in the future.

Remaining Service Life

Determining "remaining service life" is a requirement in the new regulation for NHS. Currently only 10 SHAs perform this analysis, but in the future it is anticipated that most will find this an unencumbered task. It is important to monitor the long-range health of a network and this analysis enables managers and programmers to maintain a "steady state" in their multiyear workload and budget.

Relational Data Base

A PMS cannot automatically, systematically, consistently, and efficiently function without a "relational data base" because the amount and complexity of data cannot be computed manually for a typical state PMS. Currently half the SHAs have relational data bases, one-quarter are developing them, and the remainder are not active at the present time. Given the state-of-the-art capabilities in relational data-base management systems, it is anticipated that most SHAs will have relational data bases in the near future.

Uniformity

Currently there is little-to-no uniformity among the states in the way they measure, collect, and report PMS condition data. The reason is that all states developed their PMS independently. This independence, of course, has many advantages for designing a PMS to meet the needs and objectives of any agency. But states are at a disadvantage when communicating with each other about basic condition information such as roughness, rutting, and cracking. They will find a lack of uniformity, which means that they cannot communicate or help each other to enhance this area of PMS. Efforts are under way and accomplishments have been made by ASTM and the Road Profiler Users Group (RPUG) that deserve commendation. The other management systems such as bridge and safety already have national standards for data collection and reporting.

PMS will benefit if the 50 states, Puerto Rico, and the District of Columbia agree to adopt more uniform methods to collect and report condition data. Future efforts by ASTM; RPUG; Strategic Highway Research Program, Long-Term Pavement Performance; FHWA; and the American Association of State Highway and Transportation Officials' Task Force on Pavements are aimed in that direction.

In-House and Outside Resources

Pavement management is a procedure that includes a wide variety of technical components. Some of these require a high degree of technical skill to develop and implement, whereas others require a high concentration of effort to establish. Each agency should carefully and objectively weigh its in-house capabilities, and if it does not have the resources, it should seriously consider seeking assistance from a consultant or a university. In the long run, it will save a lot of time and money and result in a better final product.

Staffing

The biggest problem the states face in developing, implementing, updating, and operating a PMS is staffing. There is a significant shortage of people who understand PMS. Once employees are trained and gain some experience, they are often promoted or transferred to other jobs. For the past five years, the annual turnover rate of state PMS engineers has been approximately 25 percent. The state incentives for early retirements have fueled that rate in the past two years. Generally, most SHAs have only one person who oversees the management and daily operation of the complete PMS program, and when that person leaves, most often the PMS shuts down. This situation occurs quite frequently and because of the current budget constraints and staffing ceilings in most highway agencies, it is not likely to improve. Unfortunately there is no quick fix to this problem.

Future Implementation of PMS

In gauging the future success of implementing PMS as called for in ISTEA, organizations must first decide whether they are serious about PMS. If so, and the commitment is made to do the work, supply the resources, and use the system, then PMS use is likely to be successful.

Students in the nation's colleges and universities will provide the life blood for PMS in the future. Currently 24 such institutions offer courses on PMS, but more are needed. FHWA and SHAs should support academia in providing more education about PMS and other management systems.

The largest institutional obstacle facing PMS today is acceptance by all managers and engineers in all agencies (including federal, state, and local). The reasons for this are many. The future holds more hard work for those who are serious about pavement management.