were used by the Maintenance Districts to develop a ditching program. Rutting analyses have been used to determine locations for corrective treatments.

Long-term network needs have been projected in order to anticipate periods of peak needs and to develop strategies to address them. Requests for performance or history information for specific locations on the network are almost a daily occurrence.

Correlation with ISTEA

To comply with ISTEA requirements, about 250 centerline miles of urban roadways will be added to PMS. A cooperative information exchange with MPOs has been established and MDOT will collect and analyze the condition and roughness data. MPOs will provide history, preservation, and maintenance data. PMS currently includes all other mileages required by ISTEA.

ISTEA-type inventory, history, condition surveys, and traffic volumes were incorporated into PMS in the early-to-mid-1980s. Load data and data-base links to the Planning, Project Management, Construction, and Maintenance bureaus were added in the late 1980s.

ISTEA-type analyses have been in use since the mid-to-late 1980s, with the exception of remaining service life (RSL) and LCCA. RSL is calculated in the analysis models, but has been summarized and reported for special analyses only. LCCA has been used on a project basis for type selection. A benefit factor that is a surrogate for vehicle and maintenance cost is currently calculated in the analysis models. User cost values need to be determined, and treatment life data that are being updated from the Long-Term Monitoring sites will be used to refine the analysis models.

Experience has shown that MDOT's PMS is an effective and useful resource. It is responsive to the needs of the operating bureaus and uses an active feedback process to continually improve analysis and reporting capability to enhance product credibility.

Managing Pavements in Nevada

CHARLES A. BOSCH

The Nevada Department of Transportation's (NDOT's) pavement management system (PMS) was developed by an in-house advisory committee in 1979 and 1980. Impetus to develop the system came from the department's need to quantify statewide pavement needs and rank them in priority order.

Background

From the 1920s to the 1970s NDOT focused its attention mainly on new street and highway construction. By the late 1970s a schedule of state highway user fees that had worked well for 50 years began to run into trouble. Fuel shortages created by an oil embargo prompted the development of more fuel-efficient vehicles, which leveled off fuel consumption and gas tax revenue. Double-digit inflation robbed the purchasing power of the dollar for highway construction, with its high dependency on petroleum products, and a population explosion increased Nevada's population by 50 percent in 10 years. These elements all contributed to an accelerated rate of pavement deterioration of the state's aging network of streets and highways, leaving a large backlog of pavement rehabilitation and reconstruction work to be completed and inadequate funding to carry it out.

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Change in Priority

NDOT was forced to reevaluate its highway program and changed its first priority from new construction to preserving the existing highway system. NDOT's PMS was developed to quantify the backlog of pavement repairs on the state highway network, to identify project priorities, and to monitor the state's progress toward eliminating the backlog of pavement work. PMS is also used to identify NDOT's long-range funding needs to maintain the state highway network at a serviceable level.

Pavement Condition Survey

NDOT conducts a pavement condition survey annually under which a section of each mile in each direction of every state-maintained highway is evaluated. The severity and extent of the following pavement distresses are measured and recorded:

- Road roughness (rideability)
- Rut depth
- Alligator cracking
- Linear cracking
- Bleeding
- Raveling

NDOT also conducts pavement friction

testing annually on Nevada's Interstate highway system. On the remainder of Nevada roads on the National Highway System, friction testing is conducted every two years, and roadways under the Surface Transportation Program are tested every three years. The Department automatically schedules friction testing on any roadway that has received a pavement overlay or has experienced pavement-related traffic accidents.

These data are then entered into the PMS pavement condition file. Through computer analysis, each section surveyed is assigned pavement condition distress points commensurate with the severity and extent of each distress and the magnitude of the strategies required to repair the pavement. Each section is also placed into one of four repair strategy categories based on an accumulation of pavement distress points (see Table 1).

Centerline mileage for each highway system is categorized into one of these repair strategies, giving an indication of the overall health of the state highway network. A more detailed analysis is conducted on each lane mile categorized in need of an overlay or reconstruction to determine the estimated cost to complete all identified pavement rehabilitation work.

Project Priorities

A list of statewide candidate pavement preservation projects is developed, and each project is assigned a priority score ranging from 0 to 10, with 0 being the highest priority ranking and 10 the lowest. A priority score is calculated for each project by assigning the weights to the elements shown in Table 2.

TABLE 1 Pavement Condition Distress Points Used To Assign Repair Strategy Categories

Accumulated PMS Distress Points	Repair Strategy
0–49	Preventive maintenance
50–399	Corrective maintenance
400–699	Overlay
700 or greater	Reconstruct

TABLE 2 Priority Score for Ranking Statewide Candidate Pavement Preservation Projects

Element	Priority Weight (percent)
Road roughness (rideability)	= 15
Pavement condition	= 65
Maintenance cost-effectiveness	= 10
Safety (pavement-related accidents and low pavement friction	= 10

FHWA Review

In 1989 pavement engineers from the Federal Highway Administration (FHWA) reviewed NDOT's PMS to determine whether the system contained the elements required by federal regulations. On the basis of this review, three areas were identified as needing improvement or expansion to comply with FHWA's Pavement Policy Directive:

1. Expansion of the physical features inventory to include pavement structural materials, types, thicknesses, and dates of major work activities (project history data);
2. An automated common data-base system for storage and easy retrieval of information such as pavement condition data, physical features inventory, and pavement maintenance history; and
3. Expansion of data analysis capabilities to include development of pavement performance curves and optimization of pavement maintenance and rehabilitation strategies.

NDOT's lack of a modern relational data base management system delayed progress to bring its PMS up to the tech-

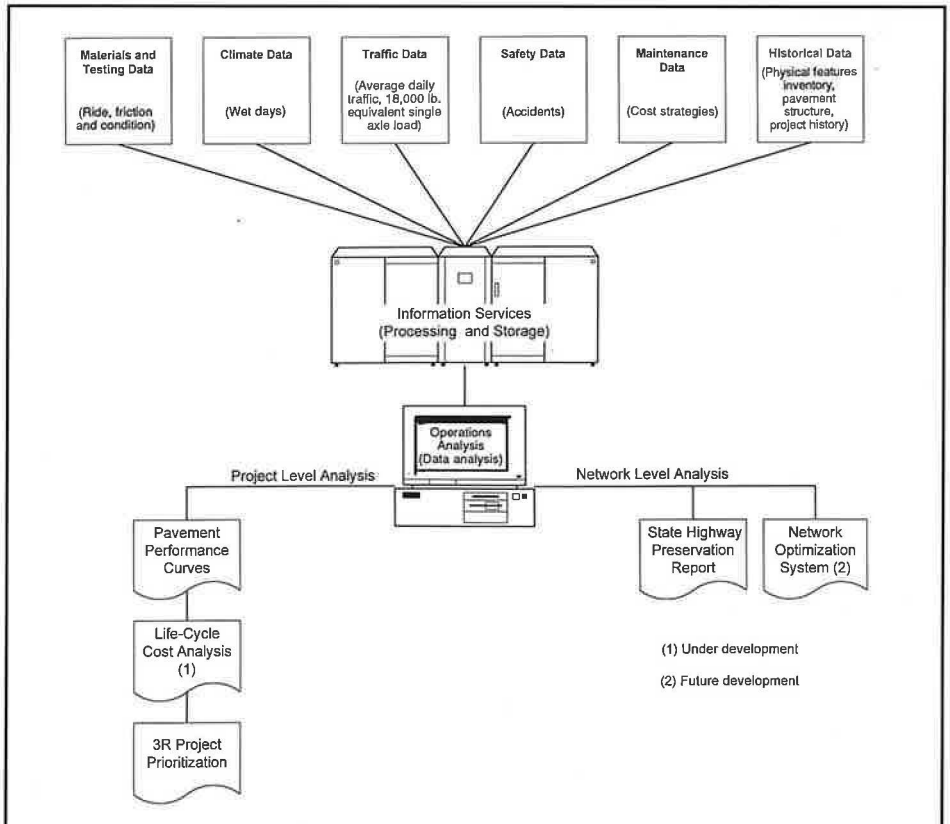


FIGURE 1 Nevada Department of Transportation's pavement management system.

nical level required by FHWA's pavement policy. However, the federal directive provided the impetus that enabled NDOT to acquire the computer hardware and software necessary to achieve compliance.

Development of Pavement Performance Models

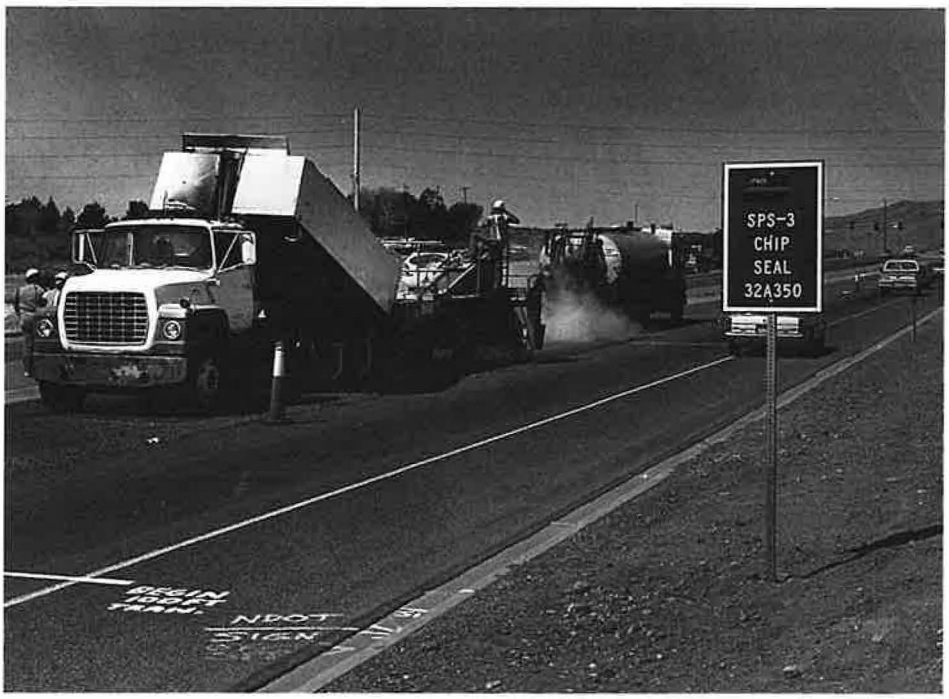
NDOT entered into a cooperative research project with the University of Nevada, Reno, College of Engineering, to develop pavement performance prediction models. Three of NDOT's most commonly deployed maintenance strategies and three pavement rehabilitation techniques were selected for the development of the prediction models. The maintenance strategies were flush seal, sand seal, and chip seal. The rehabilitation techniques included flexible pavement overlays, cold milling with an overlay, and roadbed modification, which consists of pulverizing and cement treating the existing base and surface and placing an asphalt concrete surface. The research also examined portland cement concrete pavement maintenance, repairs, and rehabilitation strategies, but it was determined that the state lacked a sufficient number of sample projects to develop statistically reliable models for this work.

Using linear regression analysis, a total of 16 flexible pavement performance models were developed, 9 for maintenance and 7 for rehabilitation strategies. A separate performance model for each technique was developed for each of NDOT's three engineering districts (with the exception of cold milling with an overlay, for which only one statewide model was developed). Each performance model relates a pavement's Present Serviceability Index to its age, material properties, traffic loading, and environmental conditions.

Continuing Research

Current research is focused on developing life-cycle cost analyses that will indicate when to apply these maintenance and rehabilitation strategies to achieve the desired pavement serviceability at a minimum cost. Continuing PMS research will concentrate on developing a program to systematically update pavement performance models and to create a network-optimization system. The department has recently tightened up pavement material and construction specifications, and it is imperative that PMS performance models reflect the latest construction practices and materials to achieve accurate results. The development of a network-optimization system will indicate how to invest NDOT's limited financial resources to provide the best highway performance at the network level. The network-optimization system will also have the capability to determine the minimum investment level required to bring the overall condition of NDOT's highway system up to any desired level of serviceability.

NDOT has long been committed to pavement management. Its PMS has proven to be an effective tool to inform the state legislature of the additional revenue needed to fund the state's Pavement Preservation Program, and to ensure that NDOT's limited financial resources are spent wisely.



Workers lay chip seal in Sparks, Nevada, as part of SHRP study to evaluate performance of various maintenance strategies for asphalt pavements.

NDOT will continue its search for new and innovative technologies to incorporate into its pavement program in the pursuit of improved pavement performance and to provide a safe, efficient, and economical highway system for the movement of people and goods in Nevada.