Implementation of a Pavement Management System on Forest Service Low-Volume Roads

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The Pacific Northwest region of the USDA Forest Service manages some 3,600 mi of low-volume paved roads. The region has been faced with a need to identify procedures by which the selection and timing of maintenance activities can be ordered by priority for funding purposes. After review of available pavement management systems (PMSs), the Metropolitan Transportation Commission's PMS (MTC–PMS) was found to be appropriate for low-volume road agencies. Developed for the San Francisco Bay area, the MTC–PMS is a computer-assisted method of analyzing information about pavement condition for developing cost-effective, long-term maintenance strategies. The implementation of the MTC–PMS on low-volume paved roads within the Forest Service is described. A pilot implementation of the MTC–PMS was conducted to determine if the system could meet the pavement management needs of the Forest Service. In the summer of 1988, pavement condition data were collected on approximately 600 mi of road. A 280-mi paved road network on the Siuslaw National Forest was analyzed in detail by all of the MTC–PMS procedures. The results from the pilot implementation period indicate that the MTC–PMS can be used as an effective pavement management tool for the Forest Service.

The Pacific Northwest region of the USDA Forest Service manages an estimated network of 91,500 mi of surfaced and unsurfaced roads. Four percent of the mileage is paved, 37 percent is surfaced with aggregate, and 59 percent is unsurfaced. In 1989, an estimated $39,000,000 of appropriated and commercial use fee monies were used to maintain this investment.

Selecting road improvement programs in the Forest Service that will have the greatest benefit for the least total cost is of paramount importance, not only to meet budget constraints but also to provide the best investment for the public dollar. Many road management agencies, including the Forest Service, are considering a pavement management system (PMS) approach to help focus this complex decision process.

The principal objectives of a PMS are to identify road sections in need of treatment, predict future improvement needs, and select cost-effective alternatives. They can be used to provide a logical timing sequence for treatment needs, and to predict long-term performance consequences of management and budget decisions (*1*).

There are two levels of pavement management, the network level and the project level. Pavement management at the network level deals with the planning, programming, and budgeting decisions made for the entire highway network (*2,3*). Project level pavement management, on the other hand, deals with the specific technical requirements of individual projects.

A Construction Technology Improvement Program study, sponsored by FHWA, was initiated to determine an appropriate PMS for use on low-volume federal lands roads. Benefiting agencies represented were the Bureau of Land Management, Bureau of Indian Affairs, FHWA, National Park Service, and Forest Service.

After a review of available pavement management systems, it was recommended that the Metropolitan Transportation Commission's Pavement Management System (MTC–PMS) be adopted. This system was selected because it is simple, flexible, and is supported by a large group of agencies (*4*). The implementation of a pavement management system on low-volume paved roads in the Forest Service's Pacific Northwest region is described.

MTC–PMS OVERVIEW

The Metropolitan Transportation Commission (MTC), Oakland, California, is the transportation planning agency responsible for more than 100 cities and counties in the San Francisco Bay area. The MTC–PMS was developed in 1986 to help manage local area road networks (*5,6*). The MTC–PMS provides a computerized method for analyzing information about pavement condition and for developing cost-effective maintenance strategies (*7,8*). Adopted by over 40 California public agencies, the MTC–PMS is supported by a clear users manual, video presentations, personal telephone help, and software updates.

The methodology used by the MTC–PMS is summarized in the following sections. A more detailed description of the analysis techniques used by the MTC–PMS is found in the literature (*7–9*).

MTC–PMS Framework

The MTC–PMS is a network-level system designed for the budget planning and project identification phase of the pavement management process. The MTC–PMS is used to select and to order by priority candidate maintenance and rehabilitation projects for subsequent detailed project level evaluation. The basic process involved includes the following (*7*):

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1. Identification of the pavements to be managed,
2. Determination of current pavement condition,
3. Identification of present and future budget needs,
4. Selection of pavement sections for maintenance and rehabilitation consideration,
5. Determination of the influence of different budget levels on the network condition, and
6. Selection of the most effective maintenance and rehabilitation projects when all cannot be funded.

Inventory Data

The MTC-PMS network inventory procedure is designed to provide the road manager with information about the road network. The first phase in the inventory process is to divide the road network into uniform pavement segments. The uniform pavement segments, referred to as management sections, are those sections of paved roads that would typically perform in a similar fashion. Information collected about a particular management section includes surface type, construction date, maintenance and rehabilitation history, and functional classification. The MTC-PMS uses functional classification as a surrogate for traffic loads and structural strength (*7,8*). The functional groupings are arterial, collector, and residential. As the majority of commercial traffic on forest roads is because of timber haul, the Forest Service defined functional classification as follows:

1. Arterial—more than 50 million board feet (mmbf) hauled per year,
2. Collector—between 20 and 50 mmbf (4,000 to 10,000 trucks) per year, and
3. Residential—less than 20 mmbf per year.

The second phase in the inventory procedure is to collect information about the pavement condition of each management section. The pavement condition survey is performed by measuring the extent and severity of the following distress types (*9*):

1. Alligator cracking,
2. Block cracking,
3. Distortions,
4. Longitudinal and transverse cracking,
5. Patching and utility patching,
6. Rutting and depressions, and
7. Weathering and raveling.

Because of the excessive time and cost required to inspect each entire management section, a detailed condition survey is performed on approximately 10 percent of the area within each management section. Typically, three 200-ft long segments per mile of management section are surveyed. These short segments are known as inspection units. The condition information is used to calculate a condition score for a management section. This condition score, known as the pavement condition index (PCI), is similar to that developed by the U.S. Army Construction Engineering Research Laboratory (*10*). The PCI rating ranges from 0 to 100 as shown in Figure 1. A PCI rating of 100 defines a pavement in a new

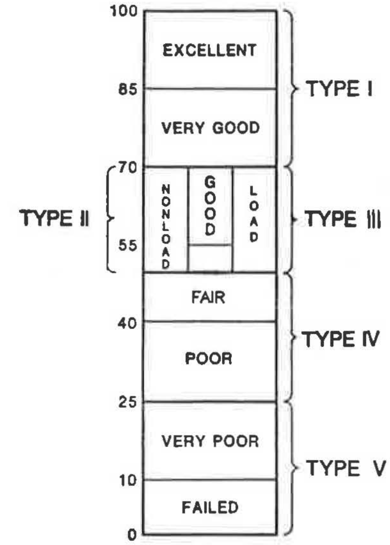

FIGURE 1 Pavement condition scale with descriptive ratings and condition categories (*9*).

condition before the development of the first crack. The lower range of the scale, 0 to 10 (failed), represents a pavement that has failed to a disintegrated condition (*7*).

Performance Prediction

To identify future budget needs, the MTC-PMS projects the PCI of each management section 5 years into the future. This feature is also used to develop alternative budget scenarios and identify long-term maintenance and rehabilitation needs.

To project the pavement condition, MTC has developed a series of family performance curves. These curves are derived from the performance of existing Bay Area pavements in terms of functional classification, surface type, PCI rating, and pavement age in years. As shown in Figure 2, the PCI rating decreases as the age of the pavement increases. There are separate curves for each combination of functional class and surface type. When the PCI rating calculated from the condition survey data does not fall directly on the family curve, the curve is adjusted to conform to the observed performance point (*8*).

Maintenance and Rehabilitation Assignment Procedure

A five-category condition definition related to the PCI scale is shown in Figure 1. Condition Category I is defined as a pavement with a PCI rating greater than 70. Category II, with the PCI ranging from 50 to 70, has primarily non-load-related distress types. Category III also has the PCI rating ranging from 50 to 70, but the distress types are primarily load related (*7*). Table 1 presents distress types that are considered to be load related and non-load-related.

The five condition categories are used for assigning user-defined maintenance and rehabilitation treatments by means of a decision tree. A typical decision tree is shown in Figure

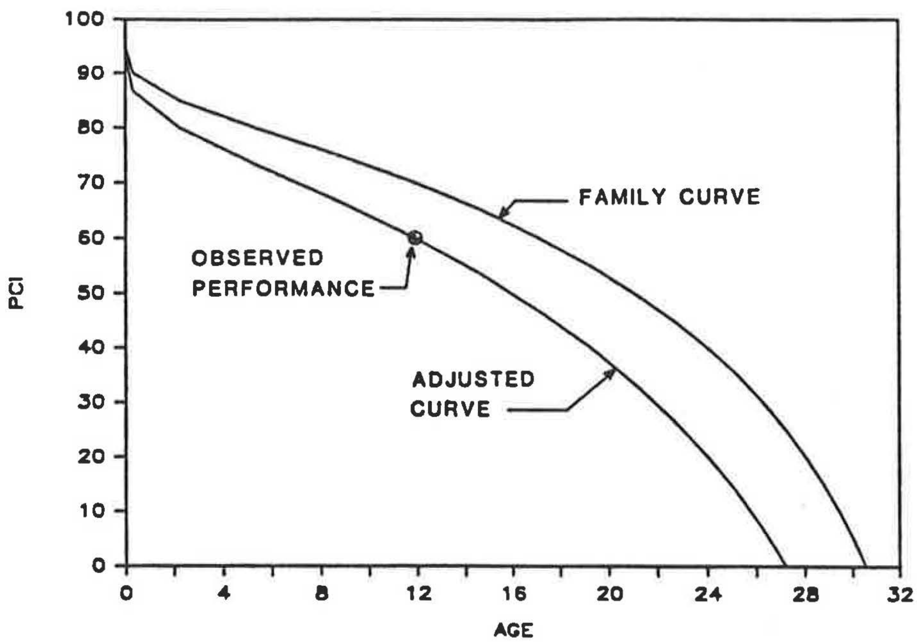

FIGURE 2 Family curve and curve adjusted for observed performance (*9*).

TABLE 1 ALLOCATION OF DISTRESS TYPE AND SEVERITY COMBINATIONS TO CAUSE OF DISTRESS (*9*)

Distress Type	Severity	Primary Cause
Alligator Cracking	All	Load
Block Cracking	Low, Medium High	Environmental Load
Distortions	All	Other
Longitudinal Cracking	Low, Medium	Environmental
Patching	All	1/2 Load & 1/2 Other
Weathering & Raveling	All	Environmental

3. Given a specific combination of functional classification, surface type, and condition category, treatments are assigned to each management section.

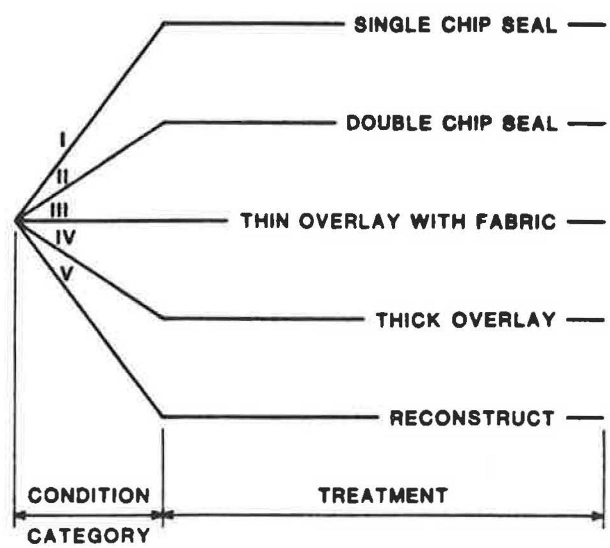

FIGURE 3 Example decision tree for a functional classification surface type combination (*9*).

Budget Analysis Techniques

Using the unit costs associated with the treatments contained in the decision tree, funding levels are determined for each year of a 5-year analysis period. The available funds are then compared with the funding requirements. MTC–PMS next orders by priority identified projects so that the most cost-effective projects are funded first (*7*).

TRIAL IMPLEMENTATION ON FOREST ROADS

Paved low-volume log haul roads have maintenance needs and conditions unique to the forest environment. It was perceived that the urban-developed MTC–PMS would require some modification to better match the maintenance and management needs of Forest Service low-volume paved roads. In the summer of 1988, the MTC–PMS was implemented on four forests in the Pacific Northwest Region to determine if the system could be adapted to suit forest conditions. The following sections describe the implementation process on one of the forests, the Siuslaw National Forest.

Siuslaw National Forest Road System

The Siuslaw National Forest is located in the coastal mountain range in the center of the state of Oregon. The Siuslaw National Forest manages approximately 2,500 mi of native, aggregate, and asphalt-surfaced roads. Approximately 280 mi of this road system is paved with asphalt concrete. Most of the pavement was placed between the early 1970s and the mid-1980s.

Pavement Inventory

Based on the timber haul flow patterns and on information determined by interviewing the road managers on each ranger district, the Siuslaw road network was divided into 80 management sections. The average annual timber haul for the asphalt road system was estimated to be 4.6 mmbf per year, or about 1,200 trucks per year, when other road users are included. A significant portion of the timber haul occurred during the winter months when subgrade strength is the lowest. The majority of the management sections were assigned a functional classification of residential because they carried less than 20 mmbf (4,000 trucks) of haul per year. The surface types present were either asphalt concrete or an asphalt concrete overlay.

A distress survey was performed on approximately 10 percent of the surface area of each of the management sections. The distress surveys were performed in 1988 during the months of August and September and in July of 1989. A single surveyor had a production rate of 8 mi/day. With the help of an assistant, production increased to 18 mi/day.

The main cause of pavement deterioration on the Siuslaw National Forest was found to be the effects of timber haul traffic. Outside shoulder settlement, influence of environmental factors (i.e., oxidation, slope instability), chip seal raveling, surface abrasion from heavy equipment, and occasionally moss growing on pavement surfaces, were other distress types present.

The mean PCI rating of the paved roads on the Siuslaw as of September 1989 was 69 (good). Figure 4 shows the relative condition of the Siuslaw road system as a percentage of the total network surface area. Sixty percent of the road system was in very good to excellent condition with a PCI rating of 70 to 100. Thirty-five percent of the road system had a PCI rating of 50 to 69 (fair to good). Approximately 5 percent of the road system had a PCI rating of 25 to 49 (poor).

Selection of Performance Curves

There was some concern whether pavement performance curves developed from urban streets would adequately predict the performance of low-volume forest roads. Most of the Siuslaw roads were a residential functional class. Figure 5 shows an MTC–PMS performance curve along with some observed data points. Approximately 1,500 data points collected both from the Siuslaw and the Gifford Pinchot National Forests were used to determine if there was a significant difference between the observed PCI ratings and those calculated from the performance equations. A *t*-test was used to evaluate the differences between the observed data and the values predicted by the MTC–PMS. For each combination of functional classification and surface type, no significant difference was found between the means of the observed and predicted PCI ratings for a particular pavement age (V. Grilley, unpublished data).

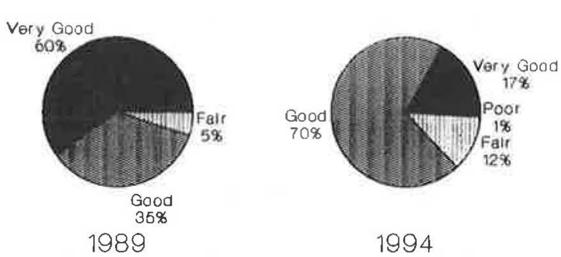

FIGURE 4 Network condition summary in 1989 and in 1994 without treatment.

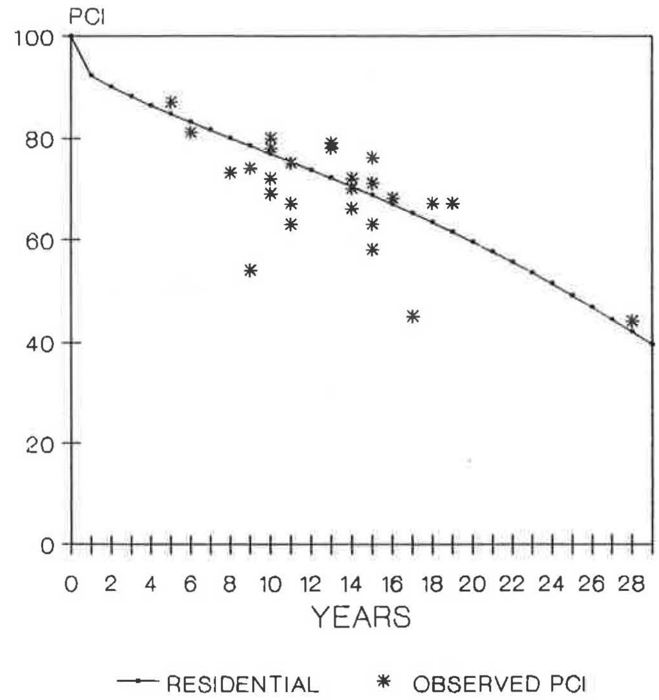

FIGURE 5 MTC family curve for residentials with asphalt surface type. The age versus PCI data points observed on the Siuslaw National Forest are plotted for visual comparison to MTC curve.

The performance curves developed for urban traffic adequately predicted the performance on the low-volume, log haul roads of the two forests. The performance curves are also anticipated to be adequate for other forest paved-road systems with similar soils, climates, and traffic loadings.

Maintenance and Rehabilitation Assignment

The maintenance and rehabilitation treatments used on the Siuslaw differ somewhat from the treatments supplied by the MTC–PMS. Consequently, the pavement repair strategies built into the MTC–PMS default decision tree were modified to better reflect the treatments and costs currently used on the Siuslaw. The types of maintenance and rehabilitation activities commonly practiced on the forest are as follows:

1. Deep patching to correct structural deficiencies,
2. Repeated patching of shoulder settlement areas,

3. Patching with geotextile fabric,
4. Skin patching,
5. Minor pothole patching,
6. Crack sealing,
7. Chip sealing,
8. Overlay at 2 to 3 inch depth, and
9. Surface reconstruction with repair of structural base.

The timing of maintenance and rehabilitation treatments on the forest are dependent on the occurrence of timber harvest activities, spending limitations on collections in the form of road user fees, availability of capital investment funds, complaints, safety, pavement condition, and policy. Selection of maintenance and rehabilitation fixes are based on experience—i.e., what has worked in the past—and pavement evaluation techniques. Maintenance and rehabilitation activities are usually planned on a project-by-project basis.

The decision tree treatments, assignment criteria, and costs were based on an interpretation of the maintenance and rehabilitation histories of each pavement section and discussions with the engineering units on the Siuslaw National Forest. The modified decision tree developed for the Siuslaw is shown in Figure 6. The unit costs developed for the Siuslaw decision tree were based on estimates from current pavement contract

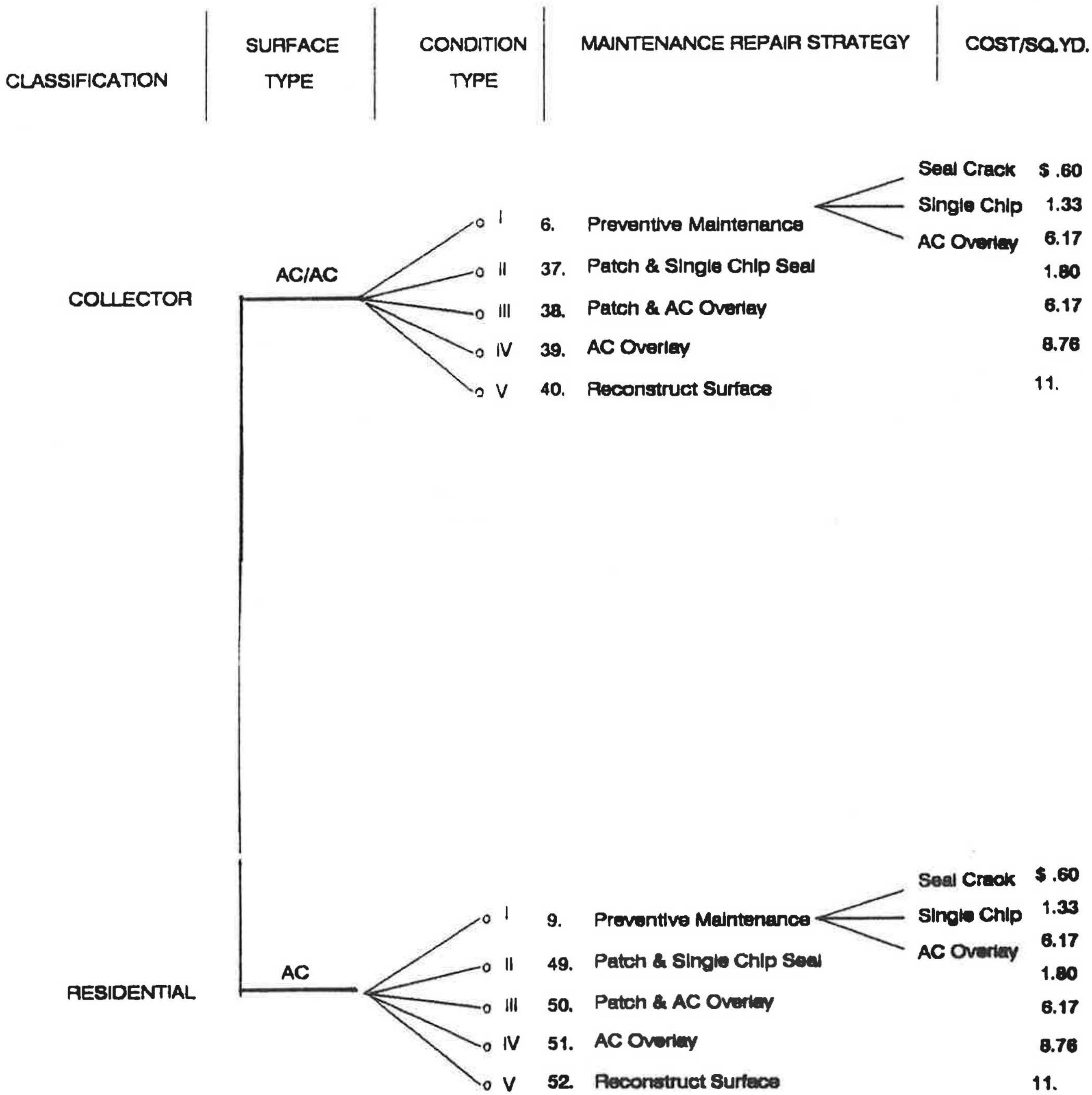

FIGURE 6 MTC–PMS decision tree modified for the Siuslaw National Forest road system.

costs occurring on the forest in 1988 and 1989. MTC–PMS default treatments and costs were used in cases when local information was not readily available.

Budgeting Alternatives

As shown in Figure 4, 60 percent of the Siuslaw network was in the very good condition category in 1989. With no maintenance or rehabilitation, it was predicted that the percentage in the very good category would fall to 17 percent by 1994. Only 5 percent of the pavements fell into the fair category in 1989; this increased to 12 percent in 1994. Without maintenance or rehabilitation, the Siuslaw network average PCI rating was predicted to fall from 69 to 58 within the 5-year analysis period.

If all the treatments assigned by the decision tree were applied, the average PCI for the Siuslaw network would increase to 80 by 1994. The cost of applying these treatments would be $7.7 million.

Long-Term Strategies

An analysis was performed to determine what the most cost-efficient strategy would be over a 25-year life. A 110-mi representative sample of the 280-mi road system was selected for a detailed alternative analysis. Table 2 is a summary of the alternatives and their costs.

The do-nothing strategy (Alternative 1) results in zero maintenance costs. However, Figure 7 shows that the Siuslaw road system deteriorates to a failed condition over a 25-year period. As more pavements approach a failed condition, unsafe driving conditions and user costs are likely to increase significantly, a situation considered unacceptable for the Siuslaw.

Alternative 2 involves managing the Siuslaw road system for a network mean PCI rating of 70. This procedure resulted in the lowest acceptable equivalent uniform annual cost (EUAC) for a 20-year period. Managing the network for this condition level typically avoids allowing pavement sections to deteriorate such that reconstruction is needed. This alternative also avoids overmaintaining the road system. The advantage of this strategy is that higher-priority roads can receive the necessary treatment and promote cost-effective expenditure of road maintenance funds. This alternative was the preferred one.

Alternative 3 involved maintaining the network at an average PCI rating of 80. Maintaining the network to this extent would cost more than 20 percent more on a yearly basis than to manage to a PCI rating of 70. The benefits of increasing the PCI rating from 70 to 80 do not appear to be justified in terms of cost.

Alternative 4 resulted in the highest EUAC for the 25-year analysis period. In this alternative, each pavement is reconstructed only after failure (PCI = 25). The PCI trend for this strategy is presented in Figure 8. The mean network PCI rating appears to reach a low of 50 (fair) but rising to 70 (very good) at the end of the 25-year period. However, because of this management strategy, there are always a number of roads approaching a failed condition. This strategy may result in some roads being in a condition unacceptable for timber haul or recreation use.

TABLE 2 ALTERNATIVE MANAGEMENT STRATEGIES

Alternative	Management Strategy	EUAC
1	Do Nothing	0
2	Maintain Mean Network PCI of 70	$250,000
3	Maintain Mean Network PCI of 80	$300,000
4	Reconstruct Pavements The Year After They Reach a PCI of 25	$400,000

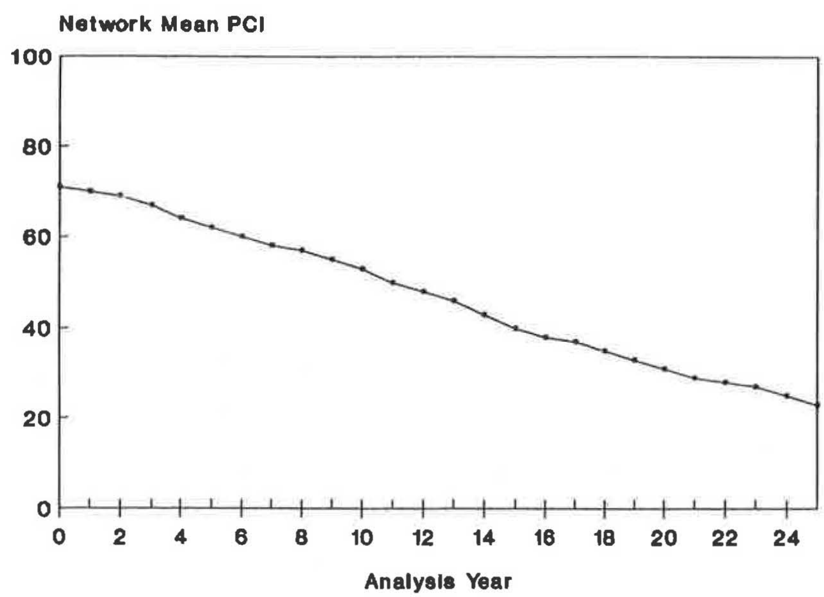

FIGURE 7 Mean PCI rating for the do-nothing strategy.

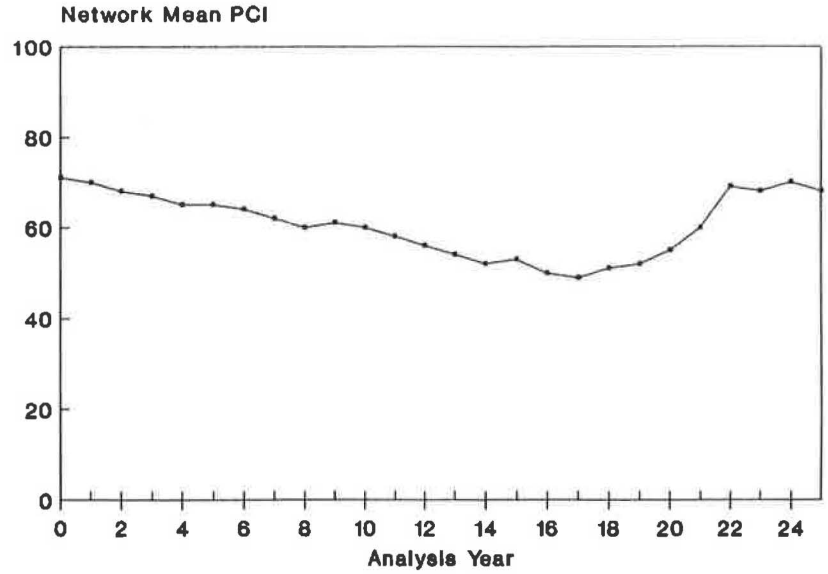

FIGURE 8 PCI rating trend when the pavements are reconstructed after failure.

CONCLUSIONS

On the basis of the experience with the Siuslaw and other forests, it can be concluded that the MTC–PMS possesses the features necessary to be a useful pavement management tool for the Forest Service. The usefulness of the MTC–PMS as a tool will depend on how well experience and good engineering judgment are blended with the computing capabilities provided by the software. Effective pavement management in the Forest Service will require the coordinated input from many sources, including

1. The engineering judgment and expertise of the field personnel who drive and care for the roads on a daily basis,
2. Budgeting personnel who use the MTC–PMS as a long-range planning and budgeting tool, and
3. Pavement engineers who can conduct project level analyses once the network level input is supplied by MTC–PMS.

Benefits Provided by MTC–PMS

Some of the features provided by the MTC–PMS that can be used to advantage by the Forest Service include the following:

1. The system provides the Forest Service with better inventory data on the paved road system.
2. The MTC–PMS provides a consistent and objective procedure for rating the condition of each pavement section. Use of the PCI rating scale can lead to better communication among Forest Service road management personnel. The PCI rating scale can also enhance communication between engineering and other Forest Service disciplines in regards to explaining the condition and needs of the asphalt paved road system. The PCI rating scale can also be used to help explain the asphalt road management policy to the public, which is increasingly using the Forest Service road system.
3. The system provides an analytical method for identifying, ordering by priority, and justifying pavement rehabilitation and maintenance proposals.
4. The MTC–PMS provides a tool that can evaluate the future impact of budgeting decisions made in the present. Impact can be measured in terms of the change in PCI value, deferred costs, and distress.
5. The system provides a means for monitoring or tracking the condition and cost of the paved road system over an extended period of time. Although it was found that the performance equations contained within the MTC–PMS adequately predicted the performance of low-volume roads with seasonal traffic, this information would be useful for project level analysis.

Limitations When Applied to a National Forest Road System

A few features of the MTC–PMS were found to be incompatible with some of the conditions found in the National Forest road system. Some of these conditions include

1. Outside shoulder settlement distress areas are not fully accounted for in the distress survey procedure. Some interpretation is required.
2. The program is somewhat sensitive to data input errors. The developers of the program are in the process of fixing this problem.

CONTINUING EFFORTS

Eleven out of the 19 national forests in the Pacific Northwest region have begun implementing the MTC–PMS. The remaining eight forests have less than 100 mi of paved road each. By March 1990, most forests have completed the inventory process and are beginning to determine what maintenance and rehabilitation treatments are needed on their road networks. The following recommendations apply to the continuing implementation effort currently underway in the Pacific Northwest region.

1. Provide a format for cooperation and sharing of information, techniques, and expertise among PMS users.
2. Develop auxiliary data bases for each forest to track traffic, timber haul, season of haul, pavement condition (PCI rating), treatments, and costs over an extended period of time for each pavement section. Use these data to perform project level analyses and to set road user fees.

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