CONCLUSIONS

A method of rating unsurfaced roads has been developed and field-validated at seven test areas across the United States from New England to Alaska. This method can be used alone to rate unsurfaced roads, or it can be incorporated into automatic, computer-aided pavement maintenance management systems for paved roads, such as PAVER.

Manual or computer-aided PMS use of this rating method should provide the data necessary for optimum allocation of resources and maintenance of unsurfaced roads in the best possible condition for the least cost.

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Pavement Management for Low-Volume Roads

CAROL W. BLAIR, EDWARD G. BATES, JR., AND DAVID M. DREVINSKY

***Pavement Management for Communities* is a manual for small road networks. Every road agency with maintenance responsibilities is experiencing the problem of escalating costs and deteriorating road conditions; pavement management is a solution. However, many smaller communities do not have the resources to implement the pavement management methods offered in an abundance of literature on the subject. Some methods require extensive data. Others require the use of a computer. Most involve a significant amount of time to understand the methodology and collect data, or a considerable investment in outside services. The goals of the manual discussed in this paper are to introduce local officials and highway superintendents to the concept and benefits of pavement management, and to distill the extensive work of others into a simplified approach to pavement management. The alternatives begin with a basic, stripped-down method, suitable for situations that demand a quick turn-around with a minimum of resources. The basic method is presented in detail and appropriate charts and forms are included. Possible refinements are then discussed and modifications are offered to include additional factors or to gain precision. Available information on pavement management software and consultants is included. Communities are encouraged to adapt these methods to best suit their particular needs and resources.**

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This paper is based on the premise that pavement management is important for low-volume roads. Although some jurisdictions may have adequate maintenance budgets, others regularly defer part of their maintenance program because of inadequate funding. The costs of deferring maintenance are significant and should be addressed in the process of budgeting for maintenance activities. Furthermore, ranking road maintenance projects systematically, with the goal of minimizing long-term maintenance expenditures, is essential in cases in which a budget shortfall exists. A description is provided of work performed by the Metropolitan Area Planning Council (MAPC) (Boston) in response to a need among member communities to formalize the pavement management process.

After it was recognized that limited resources were available for such an activity, a simplified manual was developed to demonstrate how to document maintenance needs and program needed improvements. The manual is based on the synthesis of existing pavement management manuals and the seasoned advice of a panel whose members were drawn from universities, consulting firms, and government. There are no new or global solutions to the problems of inadequate budgets and deferred maintenance, but the simple methods described offer the tools needed to justify increased funding and to effectively spend the funds that are available.

THE NEED FOR PAVEMENT MANAGEMENT

Pavement management is the process of overseeing the maintenance and repair of a network of roadways. Unfortunately, pavement management programs and their required funds are generally not adequately documented. This makes road maintenance funding proposals especially vulnerable to budget cuts, and even meager funding requests are often deferred.

The costs of deferring maintenance are great. Poorer road conditions result in higher vehicle maintenance costs, reduced safety, and loss of rideability. Furthermore, a deferred project is likely to cost more later because of inflation. By the time it is implemented, the proposed project may be inadequate to rehabilitate the further deteriorated road.

The latter point is critical to pavement management, and is illustrated by Figures 1 and 2 (*1*). Note that the cost of renovating a road at 75 percent of its service life may be as little as 20 percent of the cost of the renovation deferred to the point at which the road has reached 87 percent of its service life. Timely maintenance is obviously fundamental to effective pavement management.

The literature on pavement management and the software developed to date have been excellent. Both have provided well-reasoned methods to survey, analyze, and program any system of roads or pavement. However, the resources required to implement some of these methods are beyond what many jurisdictions are prepared to invest, at least until the value of pavement management is proven to local officials.

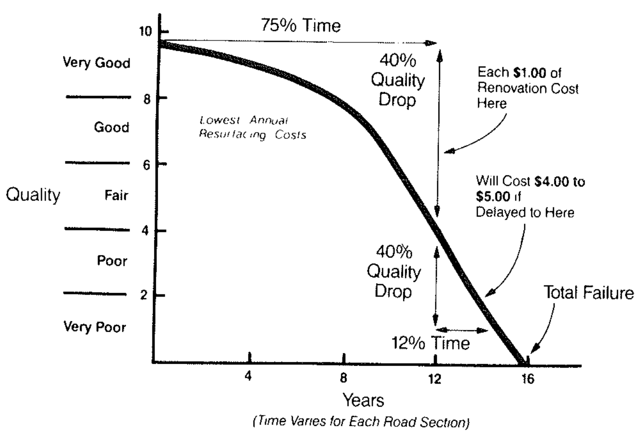


FIGURE 1 The cost of timely maintenance.

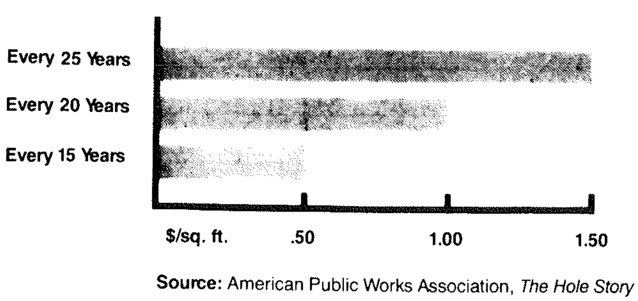


FIGURE 2 Annualized cost to overlay every 15, 20, and 25 years.

PAVEMENT MANAGEMENT FOR LOW-VOLUME ROADS

Pavement management has many applications, and each deserves a different response. An agency that has a significant backlog of maintenance work, many roadways in poor condition, and little or no experience in pavement management needs a simple method to summarize maintenance needs and document priorities. A jurisdiction that has an effective program of pavement maintenance can use pavement management to make more cost-effective decisions at the project level. This situation requires more detailed data and more sophisticated methods. It is likely that, for many jurisdictions, the pavement management process will evolve from the first effort to harness a runaway problem of escalating costs and deteriorating roads to a more sophisticated position of optimizing maintenance costs and road conditions.

The 101 member communities of the MAPC include both urban and rural communities with large and small road systems; most of these communities are facing the problem of reduced budgets and deteriorated roads. The MAPC offered *Pavement Management: A Manual for Communities* to these communities to present diverse pavement management options. The goal of the manual is to provide a basic method that any road maintenance organization would be able to use, and a complete selection of options for refinements.

The manual was developed with extensive participation by experts and potential users. A technical advisory committee of 10 active members involved in research, consulting, and highway administration provided valuable information and insights. Three communities participated in testing the procedures of the manual, and about 50 communities participated in the training workshops that followed.

The manual is organized in five chapters. After the introduction, the second chapter asks the reader "What Can a Pavement Management Program Do for You?" and includes AWPA's *The Hole Story* with concise and dramatic arguments for maintenance programming. Chapter 3, "Pavement Management Made Simple," provides a basic method for dealing with road maintenance needs. Chapter 4, "Refinements," offers alternative techniques for greater precision in each of the steps involved in programming. The pavement management experiences of five communities are reported in the last chapter. The remainder of this discussion centers on the methods offered in this manual.

PAVEMENT MANAGEMENT MADE SIMPLE

A basic method of developing a pavement maintenance program is presented in Chapter 3 of the manual. This method can be used by superintendents who cannot devote a lot of time to planning, but who recognize that maintenance needs must now be documented in order to procure adequate funds.

The five steps presented in this chapter are flexible and can be tailored to individual needs. This method could easily be computerized using commonly available spreadsheet software.

The five steps suggested in this chapter are shown in Figure 3. Step 1 is the production of a street inventory that defines the street network by segments. Step 2 is the survey of pavement conditions and the documentation of required maintenance for each street segment. Step 3 is the ranking of projects to ensure that the most severe problems and the most cost-effective projects are considered first. Step 4 involves the scheduling and funding of the work to be performed. Step 5 is the implementation of the program; it represents the feedback between maintenance needs and fiscal resources. This step also relates the program to the realized outcome (work completed). Good record-keeping practices are an essential component of this process.

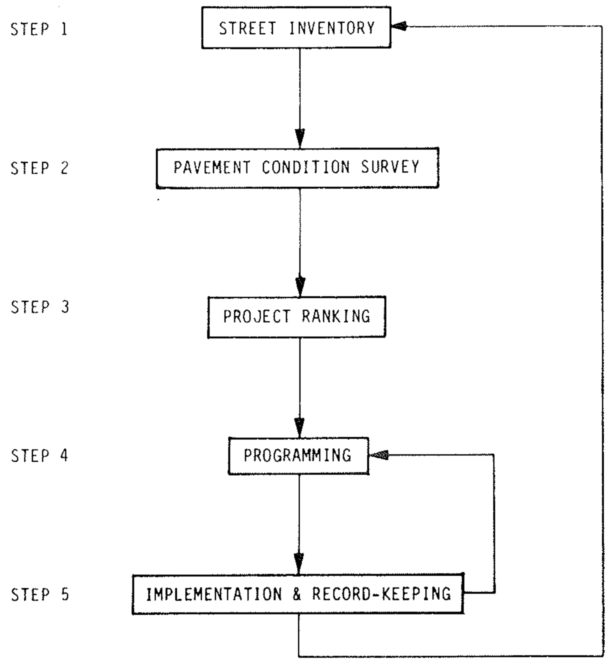


FIGURE 3 Pavement management in five steps.

Step 1: Street Network Inventory

The inventory is a list of street names and their corresponding length and width. A sample data form is shown in Figure 4. Surface type (i.e., paved or unpaved) should be included in the initial survey. In addition, a system for dividing the road network into manageable segments must be devised. A simple approach is to designate sections that correspond to intersections or to changes in pavement condition. Sections can be identified by house number, street name, or any other device, provided the landmark is permanent.

Step 2: Pavement Condition Survey

The pavement condition survey should collect the information needed to identify the following:

- Streets that need no immediate maintenance and therefore no immediate expenditures;
- Streets that require minor or routine maintenance and immediate expenditures;
- Streets that require preventive maintenance activities such as asphalt overlays or seals; and
- Streets that need major rehabilitation or reconstruction. These roads have deteriorated to the point that maintenance is no longer cost-effective and more major work is required to raise the condition to an acceptable level (*2*).

The sample condition survey form shown in Figure 5 is a simple tool for gathering the survey data. This form assumes the same section numbers that were noted on the previous street inventory form (Figure 4). Pavement condition is identified from one of the six levels described on the form, so that the inspector can refer to the definitions if, for example, there is doubt as to whether the pavement is in fair or poor condition. Drainage is rated from 1 to 3 in the same fashion, using qualitatively defined conditions.

The inspector should take advantage of the space provided for comments to record any observations that might affect the work to be recommended. For instance, if the pavement is rated at condition C and appears to have deteriorated faster than was expected because of a drainage problem, this should be noted. In this case a plan for treating the drainage problem would be a necessary part of maintaining the roadway.

The recommended action is an essential part of the condition survey and can be inferred from the graph shown on the survey form. If the inspector has considerable experience in pavement maintenance, the recommendation may reflect relevant factors not specified in this form, such as obvious safety hazards or a poor road base. These other factors should also be noted.

Inspector's Name ______________________ Date ______________

Street ____
(name and section number)

From: ______________________

To: ______________________

Length: ________ Average Width: __________

Traffic (circle one)

Low Medium High

Trucks (circle one)

Low Medium High

Surface Type (circle one)

Aggregate Bituminous Pavement Concrete Pavement

FIGURE 4 Sample pavement inventory form.

Street Name & Section Number:____________________

Inspector's Name:____________________ Date:______

Pavement Condition: (circle one)

A. Excellent — Little distress. New or nearly new pavement.

B. Good — Significant distress. Treatable with sealing and patching.

C. Fair — Moderate distress. Deteriorating rapidly.

D. Poor — Extensive distress. Thin overlay may be ineffective.

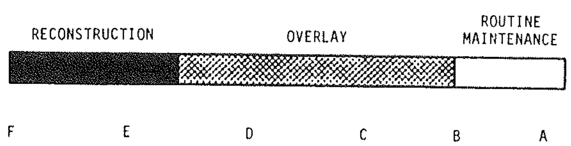
E. Very Poor — Near failure.

F. Failure — Dangerous. Requires constant repair.

Drainage Conditions:

1. Good: Ditches, culverts, inlets clean. Road shoulders slope down away from roadway in most places.
2. Fair: Ditches, culverts, inlets fairly clean. Road shoulders slope down away from roadway in most places.
3. Poor: Ditches not clean, culverts and inlets clogged. Road shoulders are often higher than the roadway.

Recommended Action (circle one)



Year when this work should take place:

COMMENTS:

FIGURE 5 Sample pavement condition survey form.

The year specified for the proposed maintenance or improvements is also important. The inspector should estimate the best time to perform the work and, if possible, include a comment about the alternatives. For instance, the recommendation might be to resurface (overlay) in year 2, with the comment that if the overlay is not in place within 3 years, reconstruction of the pavement and base will be required.

Step 3: Project Ranking

When the pavement survey is complete and maintenance needs have been determined, the next step is to rank the recommended maintenance actions for specific street segments. The philosophy of project ranking reflects both the worst-first and best-first concepts. The pavements in the poorest condition clearly have high priority. These sections cause unnecessary wear and tear to vehicles, are expensive to maintain, and may be hazardous. However, the best roads, those that are well-built and in good condition, represent an investment that should be protected against normal deterioration.

To satisfy the need to set dual priorities, the worst-first criterion is applied within each type of maintenance: rehabilitation and reconstruction. No priorities are set for routine maintenance, which is presumably accomplished within adequate force accounts. The best-first criterion is then used in the programming stage (Step 4) to ensure that routine and preventive maintenance is not short-changed in favor of the more conspicuous reconstruction projects. A separate list of ranked projects should be developed for rehabilitation and reconstruction. The trade-offs between these two categories are a matter of policy, set in programming (Step 4). Again, routine maintenance should not be a priority and should be funded as a group before any other projects.

If one regards pavement condition as the sole criterion for ranking projects, it is not necessary to use the following scoring formula and one should refer to Step 5. If projects are ranked according to traffic loads, a priority score can be estimated from survey information on pavement condition, traffic volume, and truck traffic. The formula for the priority score, P, is as follows:

$$P = PC \times (TV + TT) \tag{1}$$

where

PC = pavement condition,
TV = traffic volume, and
TT = truck traffic.

Note that this formula requires that descriptive information from the survey be translated into numeric values, as shown in Table 1. An example of the priority list for rehabilitation projects is shown in Table 2.

The three lists of projects that result for routine maintenance, rehabilitation, and reconstruction form the basis for the rational programming of funds in Step 4.

TABLE 1 NUMERIC CODES FOR SURVEY INFORMATION

Descriptive Information	Survey Description	Numeric Value
Pavement Condition	A Excellent	1
	B Good	2
	C Fair	3
	D Poor	4
	E Very poor	5
	F Failure	6
Traffic Volume	Low	1
	Medium	2
	High	3
Truck Traffic	Low	1
	Medium	2
	High	3

Step 4: Programming

After all maintenance needs and their relative priorities are listed within each type of maintenance project, a decision must be made on where to spend the limited funds available and whether additional funds should be appropriated.

The cost of each project must first be estimated. In this planning stage, approximate unit costs are sufficient. A list of unit costs that were developed for one pavement management program is shown in Table 3. Other examples are provided in the appendix of the manual.

Each jurisdiction should make a short list of unit costs for treatments that were used recently. This will avoid confusion concerning the procedure being estimated, changing costs over time, and local price differences. It may be convenient to specify average unit costs per mile for specific procedures, such as crack

TABLE 2 A RANKED LIST OF REHABILITATION PROJECTS

Year	Street	Pavement Condition	Traffic Volume	Truck Traffic	Priority Score (*P*)
1	Main	4	3	2	20
1	Maple	4	2	2	16
1	Washington	3	2	3	15
2	School	4	2	1	12
2	Cross	3	1	2	9
2	Hill	3	1	1	6
3	Woodridge	2	2	1	6
3	Holly	2	1	1	4

TABLE 3 SAMPLE UNIT COSTS FOR PROPOSED MAINTENANCE (*3*)

Treatment Type	Description	Cost per Square Yard ($)
Reconstruct	Full depth, local street	9.08
Reconstruct	Full depth, collector street	12.49
Reconstruct	Full depth, arterial street	16.98
Reconstruct	Pavement reclamation	8.28
Rehabilitation	Leveling course and overlay	4.98
Rehabilitation	1-1/2 in overlay	2.57
Rehabilitation	5 percent patch and crack seal, then chip seal	3.23
Rehabilitation	20 percent patch and overlay	5.21
Rehabilitation	Cold planing and overlay	5.57
Rehabilitation	Crack seal and overlay	2.98
Maintenance	5 percent patch and crack seal, then chip seal	1.93
Maintenance	Chip seal with crack seal	1.27
Maintenance	Crack seal low	0.41
Maintenance	Crack seal high	1.26
Maintenance	5 percent patch	0.66
Maintenance	20 percent patch	0.64
Maintenance	Patch and seal	0.54

sealing, 1-1/2 in overlay, and reconstruction to 12 in. These costs can then be easily applied to the road segments measured in Step 1 to yield rough estimates of the project costs.

Project costs can be summed within each maintenance category to estimate total dollar needs. Comparison of these dollar needs with currently available funds will raise the necessary programming questions of whether additional funds can be allocated to the program and over how many years this program can be spread. Even if the first question is never finally answered, a clear maintenance program can provide the information needed for budget decisions and for lobbying to increase funding for road maintenance.

The second question is more technical and must be answered by the road superintendent. The finance committee can benefit from a prospective look at the long-term future, which could be about 10 years. However, projections for maintenance after about 5 years may be of value only at the network level. Answering these questions is an iterative process.

The first round continues with the assignment of funds to each category. For instance, the initial policy may be to fund 100 percent of routine maintenance, 80 percent of rehabilitation work, and 40 percent of reconstruction projects in the first year. The result is that 20 percent of the rehabilitation work and 60 percent of reconstruction work must be postponed to the second year.

As projects are assigned to the work program for the first year, the second year, and so on, the penalties for postponing work are felt. For each of the deferred projects, routine maintenance must be funded for the current year. Furthermore, the original recommendation may require revision. If, for instance, a street recommended for an overlay in year 1 is deferred to year 4, it will most likely require reconstruction by the time the work is to be performed.

If the resulting program promises to maintain the street network at the current level of service, then the program is complete. Once funded, it is ready for implementation (Step 5).

If the resulting program indicates that the condition of roads and the level of service provided will decline, on average, over the course of the program, then the programming process has been invaluable. Without it, the current levels of maintenance funding and projects would have led to a system of failing roadways. That could be disastrous in economic terms because it could take four or five times greater expenditures to rebuild after a failure than it would have taken to rehabilitate only a few years earlier. This program obviously should be presented to the mayor together with a second program proposing an increase in street maintenance funds to maintain the system properly in the coming years.

Step 5: Implementation and Record-Keeping

The feedback process is important in pavement management. The first list of maintenance needs developed by the superintendent must respond to fiscal limitations. Repeated adjustments are then required to achieve the program that will buy the most in terms of long-term pavement service with the resources the local government has allocated.

The approved program can then be implemented. Further adjustments may be necessary as a result of delays in contract work, unforeseen maintenance problems, and so forth. In any case, the program should be updated every year or two to reflect both work completed and further deterioration of pavements.

An essential part of the updating process is good record-keeping. A street-by-street file for tracking pavement condition and maintenance actions over the years should include a record for each street segment (see Figure 6). Maintenance should be recorded as it is performed. Data on pavement conditions can be updated as staff time is available. Once the programming process is established, updating the data and recommendations can be a routine function.

REFINEMENTS

The basic method presented in Chapter 3 can be refined in many ways, including incrementally, if necessary. The refinements offered in Chapter 4 include expanded inventory, details of pavement condition, drainage problems, economic analysis, maintenance alternatives, and computerization.

Expanded Inventory

A simple form is offered in Chapter 3 to record the following:

- Street name and segment,
- End points,
- Length and width,
- Total traffic and truck traffic, and
- Surface type.

Any of several other attributes of the road could be relevant in setting maintenance priorities, including drainage, traffic capacity, and safety factors. A sample form is presented in Figure 7 that can be used in a comprehensive inventory.

This added information can be used to rank projects, as demonstrated in Chapter 3. Each measure is translated into a score that indicates adequacy and is then used as a multiplier in the priority score. For example, the following formula for priority, P, is given in Chapter 3:

$$P = PC \times (TV + TT) \quad (1)$$

where

PC = pavement condition,
TV = traffic volume, and
TT = truck traffic.

Maintenance Summary Form

SECTION NUMBER ______________ YEAR CONSTRUCTED ______________

MAINTENANCE ACTIVITY	PAVEMENT TYPE	RATE OR THICKNESS	DATE	UNIT COST

MAINTENANCE ACTIVITY - OVERLAY CHIP SEAL
REHABILITATION
RECONSTRUCTION
OTHER (DESCRIBE)

FIGURE 6 Sample maintenance summary form (*2*).

Urban Inventory Form

SECTION IDENTIFICATION	SECTION NO. ____ DATE ____ COMPLETED BY ____ FED. AID ROUTE NO. ____ NAME ____ FUNCTIONAL CLASS ____ FROM ____ LENGTH ____ TO ____ JURISDICTION ____ R.O.W. WIDTH ____			
PAVEMENT	TYPE ____ WIDTH ____ NO. OF TRAVEL LANES ____ NO. OF PARKING LANES ____			
SHOULDERS	LEFT PAVED ____ UNPAVED ____ TYPE ____ WIDTH ____	RIGHT PAVED ____ UNPAVED ____ TYPE ____ WIDTH ____		
DRAINAGE	LEFT ☐ CURB & GUTTER CURB HT. ____ NO. OF INLETS ____ LENGTH ____ TYPE ____ ☐ PAVED DITCH ☐ UNPAVED DITCH	RIGHT ☐ CURB & GUTTER CURB HT. ____ NO. OF INLETS ____ LENGTH ____ TYPE ____ ☐ PAVED DITCH ☐ UNPAVED DITCH		
TRAFFIC	CURRENT ADT ____ % TRUCKS ____ YEAR ____ ☐ COUNT ☐ ESTIMATE	PROJECTED ADT ____ % TRUCKS ____ YEAR ____		
UTILITIES	NO. MANHOLES ____ NO. UTILITY BOX COVERS ____ ☐ ELECTRICAL ☐ BURIED ☐ OVERHEAD OWNER ____ ☐ TELEPHONE ☐ BURIED ☐ OVERHEAD OWNER ____ ☐ WATER OWNER ____ ☐ GAS OWNER ____ ☐ STREET LIGHTING OWNER ____ ☐ SANITARY SEWER OWNER ____			
STRUCTURE	STRUCTURE PAVEMENT	TYPE	THICKNESS	DATE CONSTRUCTED

FIGURE 7 Sample comprehensive pavement inventory form (*2*).

Drainage can also be given a score of 1 to 3; the formula would then be as follows:

$$P = PC \times (TV + TT) \times D \qquad (2)$$

where

D = an index of drainage.

Any relevant measure of adequacy can be included in the ranking scheme in this manner.

Other items on the expanded inventory can be used for other purposes. Records of utilities and structures, for instance, are helpful in determining the most appropriate maintenance alternative and cost, and the remaining life of the pavement.

Great care should be taken to include any information that could be important to the program, and, at the same time, to avoid the collection of data that will not be utilized.

Details of Pavement Condition

In many cases it is desirable to go beyond the simple A to F classification of pavement conditions in order to ensure rating consistency. This is especially true if several individuals will be rating the pavement. A more objective measure can be achieved by rating the pavement quantitatively on each of several aspects of pavement condition. A sample of commonly surveyed distress types follows:

- Alligator Cracking — a series of interconnecting cracks resembling alligator skin or chicken wire.
- Bleeding — a film of bituminous material on the pavement surface which creates a shiny or glasslike appearance.
- Block Cracking — cracks which divide the surface into approximately rectangular pieces.
- Corrugation — ripples across the asphalt surface resulting from plastic movement.
- Joint Reflection Cracking — cracks in asphalt concrete which coincide with joints of underlying PCC slabs.
- Longitudinal Cracking — cracks which are parallel to the pavement centerline or laydown direction.
- Polished Aggregate — aggregate which has lost its rough irregular texture.
- Pothole — a bowl-shaped hole in the pavement surface.
- Pumping — ejection of water and fine materials through cracks under pressure of moving loads.
- Rutting — a surface depression in the wheel paths.
- Slippage Cracking — crescent or half-moon shaped cracks resulting from sliding or deformation of the pavement.
- Swell — an upward bulge in the pavement.
- Transverse Cracking — cracks perpendicular to pavement centerline.

Several excellent catalogues of pavement distress are also available, and are identified in the appendix of the manual. These references provide both descriptions and photographs of each type of pavement distress or failure. In some cases, causes and repair techniques are also addressed. The literature includes three authoritative methods for condition surveys, each of which is described briefly here, and more extensively in the manual.

The Asphalt Institute method includes a condition rating that ranges from 0 to 100 (*4*). Thirteen different types of distress are evaluated, each on a scale of 0 to 5 or 0 to 10, and then subtracted from 100 to yield the condition rating. This technique is easy to use, but is somewhat subjective. It also assumes that each type of distress should be weighted equally in every situation. For example, shoving and pushing are always responsible for 10 percent of the overall condition rating.

The Federal Highway Administration method assesses eight different forms of distress and overall riding quality (*2*). Visual estimates are required for each distress type to characterize the severity of the distress as slight, moderate, or severe and the extent of the distress as a percentage of roadway area. This approach is far more objective than others, but it also requires more survey time. Furthermore, the scoring key to translate this data into a distress condition rating is not provided but must be developed by the user.

The Army Corps of Engineers method uses physical measurements of 19 types of distress at low, medium, and high levels of severity (*5*). This method entails the greatest amount of data collection and is the most precise method of the three described here. It has been adopted and computerized by the American Public Works Association and is offered to member communities on a time-sharing basis at cost.

A comparison of the three methods just described is shown in Figure 8. One of the attributes shown is roughness, or rideability. Rideability is a measure of riding comfort and is measured subjectively on a scale from 0 to 5. Roughness is a corresponding mechanical measure that is made by a wheel suspension device. Other mechanical devices can also be used to make measurements more precisely, such as the Benkelman Beam and deflection meters.

Automation of the road survey is also possible through the use of a computerized van with optical or laser scanning capabilities. References to literature and consultants are provided in the manual.

Most communities will begin with visual surveys of distress, and possibly take advantage of the methods provided by the Asphalt Institute, Federal Highway Administration, or American Public Works Association. Mechanical and automated methods may be more appropriate to larger networks, in which the expense of such techniques is spread over more miles and the advantages of standardization are greatest.

Many other methods are available through the literature, engineering consultants, and computer software vendors. A review of these resources is recommended before beginning an elaborate pavement management system.

Maintenance Alternatives

The most appropriate maintenance and the timing of the work are both critical in maximizing cost-effectiveness. The highway superintendent is undoubtedly aware that many pavement treatment options are available. The manual includes a description of alternative seals and mixes, and comments on their performance and service life. Although it is practical to work with just a few of these in any one community, a continued effort should be made to evaluate their performance and the potential of alternative treatments.

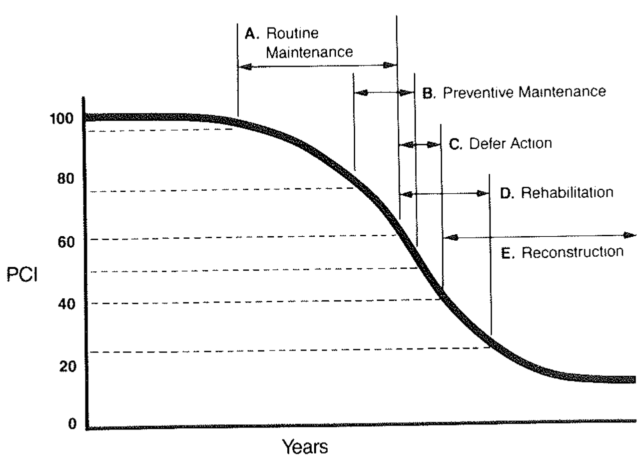
Timing of maintenance treatments is critical, as shown in Figure 9. Note that routine and preventive maintenance are appropriate on the most comfortable part of the curve, in which the pavement is still in good condition. When the pavement begins to deteriorate more quickly, rehabilitation or even reconstruction is usually required.

In order to develop systematic assignments of treatment, cost, and value for elements of the street network, it is convenient to describe the menu of maintenance treatments in the five categories shown in Figure 9 and described below. The following is an excerpt from *Road Surface Management for Local Governments* (*2*).

> *Routine Maintenance*—For roads in reasonably good condition, routine maintenance is generally the most cost-effective use of funds. If at all possible, all routine maintenance needs should be funded each year. Routine maintenance usually includes local patching, crack sealing, and other relatively low-cost actions. Distresses such as isolated medium or high severity bumps or potholes that may have a considerable negative impact on the performance of a section are usually corrected first.
>
> *Preventive Maintenance*—This strategy is a more expensive activity designed to arrest deterioration before it becomes a serious problem. Surface seals are excellent examples of preventive maintenance. A common source of poor performance of seals is inadequate repair of existing distress before sealing, so extensive repair work may also be included in preventive maintenance. Repair and seal needs will probably have to be programmed over several years in order of priority because of the expense. Routine maintenance should be performed on those sections that are not programmed for the current budget year.
>
> *Deferred Action*—The road sections which fall into this category receive minimum funds for the current budget year. These sections are beyond the point where preventive maintenance will be effective but have not yet deteriorated to the point of needing rehabilitation. Selecting this strategy is deferring action, so an agency must be prepared to fund rehabilitation or reconstruction when it becomes necessary. This strategy is normally not appropriate for aggregate surfaced roads.
>
> *Rehabilitation*—Rehabilitation usually includes overlays or extensive recycling. Funding for completion of these major projects may depend upon federal or other outside sources. The established priorities should be followed if possible, although managers should realize that priorities may change for a variety of reasons. For example, estimates for a particular job may exceed available funds, or insurmountable administrative restrictions on funds may exist, or very valid political reasons to change priorities may occur. Sections that fall into this strategy category that are not programmed for the current budget year should fall into the deferred action strategy.
>
> *Reconstruction*—The comments on rehabilitation projects also apply to reconstruction projects. The main difference is in the costs that might be expected. Reconstruction would involve complete removal and replacement of a failed pavement and might also involve features other than just pavement, such as widening, realignment, traffic control devices, safety hardware, and major drainage work. Lead times of five to ten years might be required because of the significant nature of required investments and the time necessary to develop plans, acquire right-of-way, and other funding.
>
> There is considerable overlap of possible strategies on the performance curve. In the example shown, there are two or three possible strategies for any point in the mid-range of pavement conditions. This is a very realistic approach because the deterioration of pavements is a gradual process. A small change will not usually make one strategy preferable over another.
>
> The following priority groups should constitute the program developed from these five treatment strategies:

Technique	Asphalt Institute	Federal Highway Administration	Army Corps of Engineers
Pavement Characteristics			
• Number observed	13	9	19
• Cracking	transverse longitudinal alligator shrinkage	transverse longitudinal alligator	longitudinal & transverse alligator block edge joint reflection slippage
• Shifting	rutting corrugation shoving or pushing	rutting corrugation	rutting corrugation shoving depression swell bumps & sags
• Separation	raveling excess asphalt polished aggregate pot holes	raveling flushing	raveling & weathering bleeding polished aggregate pot holes lane/shoulder drop-off
• Patching		patching	patching & utility cut
• Roughness	overall riding quality	riding quality	
• Drainage	deficient drainage		
• Other			railroad crossing
Method of Rating Severity of Distress	Scales of 0 to 5 or 0 to 10	slight, moderate, severe	low, medium high
Method of Rating Extent of Distress	Reflected in estimate of severity	1-15%, 16-30% 31%+ (of area)	square feet linear feet # of pot holes
Combining Measures of Distress to Yield an Index of Pavement Condition	Simple addition gives index with range from 0 to 100	Sample scoring Key is provided (Not necessarily appropriate to the system being evaluated)	Scoring is complex and more appropriate to mainframe computer than hand calculations
Adopting the Rating System	Distress items can be added or deleted, and scales expanded for emphasis	Scoring is complex and adaption requires experience with the model	Scoring is complex and adaption requires experience with the model

FIGURE 8 Comparison of pavement condition rating techniques.



Source: *Road Surface Management for Local Communities Course Workbook.* U.S. Department of Transportation and Federal Highway Administration, May, 1985.

FIGURE 9 Maintenance strategies and timing (*2*).

A. Routine Maintenance (It is probably not worthwhile to determine priorities but rather just list sections in this strategy.)
B. Preventive Maintenance
   Priority Group 1
   Priority Group 2
   Priority Group 3
C. Deferred Action: No priorities are necessary, just a list of sections.
D. Rehabilitation
   Priority Group 1
   Priority Group 2
   Priority Group 3
E. Reconstruction
   Priority Group 1
   Priority Group 2
   Priority Group 3.

Economic Analysis

Economic analysis is a powerful technique for the objective evaluation of alternatives. It can be used in pavement management to establish the most cost-effective maintenance treatments and to compare the relative priority, or value, of alternative projects. The measurement of a variety of factors by a common unit, the dollar, makes possible an objective, quantitative comparison of treatments, projects, and schedule alternatives. Unfortunately, these comparisons require a number of assumptions about the future value of today's dollar, the expected life of capital, and the value of time.

A summary of the methods often used in economic analysis is included in the appendix of the manual. These techniques are especially appropriate to large systems, in which the savings from a complete analysis make the added complexity worthwhile.

Computerization

If the superintendent has, or is planning to have, access to a personal computer, it is worthwhile to think about using it for pavement management. The programming process involves repetitious sorting and arithmetic. Once the process is set up, the computer can make revisions and updates a simple matter.

Two options are available. The first is to use commonly available spreadsheet software to manipulate the data as described earlier. The second is to use software specifically designed for pavement management. Both methods are effective. A list is provided in the manual of popular spreadsheets and the hardware on which they operate. Most of these software packages are priced between $100 and $500.

The spreadsheet is basically a large table with rows and columns of cells. The computer user can place a number, a label, or a formula in each cell. If the cell entry is a formula, it is defined as a function of the current values in certain other cells. The spreadsheet can calculate new values for each function as the input values of the table change.

A brief example of a pavement management spreadsheet is shown in Figure 10. Each row corresponds to a street segment and each column to data or results of the program. A key at the bottom indicates the meanings of the codes for surface type, traffic, and so forth. Once the data are entered as shown, unit costs for each type of maintenance can be entered for the six traffic and treatment categories and automatically assigned to street segments. The computer can then multiply these unit costs by street length to derive project costs.

The remainder of the programming could be very time-consuming if done by hand, but is trivial on the computer. Projects can be sorted by year of treatment, surface type, treatment, or any other category desired. If some projects must be deferred to a later year, the entire process can then be easily repeated after the recommended treatment and year are revised.

The second option is to use a data base manager tailored to the pavement management process. A list of pavement management software encountered in this study is shown in Figure 11. These powerful programs are capable of handling large data bases and producing useful statistics and graphics.

CASE STUDIES

The experiences of five communities were reported in the manual, and each took a very different approach to the

HILTON
Pavement Management Survey
cem 07-10-86

STREET NAME	SURFACE TYPE	LENGTH	WIDTH	TRAFFIC	CONDITION	RECOMM. TREAT.	YEAR	UNIT COST	TOTAL COST
Monument St.	1	0.41	30	3	3	2	4	$129,000	$52,890
Linden St.	1	0.07	28	1	2	2	1	98,000	6,860
Rubbly Rd.	1	0.28	26	1	2	1	1	39,000	10,920
Hill Top Dr.	1	0.70	25	2	1	2	1	109,000	76,300
Bruce Lane	1	0.16	30	1	4	1	7	66,000	10,560
Porter St.	1	0.43	20	2	2	1	4	66,000	28,380
Grapevine Rd.	1	0.61	24	3	4	1	3	86,000	52,460

KEY:

Surface Type:
1. Bituminous pavement
2. Aggregate

Traffic:
1. Low
2. Medium
3. High

Condition:
1. F Failure
2. E Very Poor
3. D Poor
4. C Fair
5. B Good
6. A Excellent

Recommended Treatment:
1. Resurface
2. Reconstruct

Unit Costs (per mile):

	Resurfacing	Reconstruction
Low Traffic	$39,000	$98,000
Medium Traffic	66,000	109,000
Heavy Traffic	86,000	129,000

FIGURE 10 Sample of pavement management spreadsheet.

Name of Software	Type of System	Operating System	Supporting Software	Phys. Storage	Mass Data Required	Other Hardware	Data I/O	Cost	Date	Ref.	Comments
COMPAVE	Radio Shack Model 16	TRS-DOS	Radio Shack BASIC	64k	2 floppies		interact. prn	$7,500	10/85	Allan Davis	
IMS	IBM-pc & compat.	MS-DOS	RUN-TIME D-Base (incl.)	256k	1 floppy 1-10MB hard disk	132colprn	interact. prn graphics	$1,995 SW + modif.	10/85	Gordon Derring	
PAVER	see comments	Control Data	Comm. SW for PC	128 to 256k	2 floppies	Mainframe Computer	file, prn graphics	approx. $3-6/SY	10/85	Mike Hill	Entry of field data with PC, to Mainframe Output to PC
PMI	most Micros	MS-DOS CP/M	RUN-TIME D-Base (incl.)	64k min.	1 floppy 1-10MB hard disk		interact. prn	$3,000 $6,000 $9,000	10/85	Harris & Assoc. Texas A&M	Costs are Econ., Reg., & Deluxe
PMS	most Micros	MS-DOS CP/M	RUN-TIME DATAFLEX (incl.)	256k	1 floppy 1-10MB hard disk		interact. prn	$1,500 to $11,000	10/85	Vanasse-Hangen	
FPMS	IBM-pc	MS-DOS	Advanced BASIC	256k	1 floppy		interact. prn	Public Domain	10/85	CALTRANS	
STAMPP PMS	IBM-pc & compat.	MS-DOS	Advanced BASIC	128k	2 floppies min.		interact. prn	Public Domain	10/85	Penn.DOT	

FIGURE 11 Pavement management software (*6*).

problem. One survey was very simple and gathered only the following information for each street:

- Street name,
- Segment,
- Length and average width,
- Surface type and area in yd^2, and
- Condition and recommended action.

This information was sufficient to assemble a 3-year program of rehabilitation. The total cost of this effort, including field work and record-searching, was about six person-weeks of staff time. The result was a documented list of needs for the annual budget proposal. The next step for this community is to program each road into a long-range plan to make the costs of deferring maintenance obvious.

Another community that evaluated private roads developed several innovative factors to measure the significance of each road and its condition:

Housing Factor—This factor indicates service to homes:

1—Fifteen houses or less
2—More than 15 but not exceeding 30
3—More than 30 but not exceeding 45
4—More than 45

Artery Factor—This factor indicates the road function:

1—Minor Residential — Road provides access to houses primarily on that street.
2—Residential Collector — Road feeds into "subdivision" providing primary access to houses on other streets.
3—Thru Connector — Road serves as primary connector between two major roads.

Surface Factor—This factor indicates the road surface condition:

1—Very Good — Road surface generally smooth, can travel at legal speed without damage or loss of control.
2—Good — Road surface somewhat rough, can travel at legal speed with moderate care.
3—Fair — Road surface rough in many locations, can travel at slightly below legal speed with moderate care.
4—Poor — Road surface rough in many locations, can travel only at speeds substantially below legal limit.
5—Very Poor — Road surface very rough throughout, travel on road must be very slow and erratic to avoid damage or loss of control.

The five case studies presented in the manual were for road systems that varied in size from 33 miles to over 100 miles. Although three studies were completed by town highway department staff, two were performed by consultants (for the largest and smallest of the road systems). None used automated road survey equipment, but the consultant studies used a microcomputer. The methodologies of these studies varied widely, but in each case the needs of the road system were clarified.

CONCLUSION

Pavement management is effective in both reducing road maintenance costs and improving road conditions. Although resources for planning low-volume roads may be limited, pavement management is important to these facilities. The simplified methods presented make it possible for any road maintenance agency to implement a system of pavement management programming. The goal for that system is to document road maintenance needs to the point at which the costs of deferring maintenance are clear.

Some jurisdictions may still confront the obstacle that the funds needed for the programmed maintenance projects are simply not available. The Metropolitan Area Planning Council is currently researching this problem. By comparing local estimates of need with statistics on recent expenditures, the MAPC will attempt to ascertain whether there is a shortfall and, if so, to quantify it at the regional level for a group of 101 communities. Alternate sources of funding will be explored.

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