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Rural Road Management Guide

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DISCLAIMER

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The Rural Road Management Guide (SD95-16-G3) is part of a three-document series. The other two documents are the Rural Road Condition Survey Guide (SD95-16-G1), and the Rural Road Design, Maintenance, and Rehabilitation Guide (SD95-16-G2).

16. Abstract

This Guide has been developed to introduce the counties of South Dakota to the concept of pavement and gravel road management. The Guide includes background information on pavement management systems, as well as detailed information about a simple and easy-to-use pavement and gravel road management system. Counties that implement the contents of this Guide will be able to start performing pavement management activities.

This Guide has been developed specifically for the counties of South Dakota, based on the needs and requirements that they have expressed, and as such should be particularly well-suited to their needs. In addition, the systems provided herein comply with the data requirements set forth by the SDDOT Local Government Pavement Management System Task Force. Information is also presented that will allow counties whose needs advance beyond the capabilities of the system presented here to add or refine their capabilities.

This Guide is one of three that have been developed to meet the needs of counties. The *Rural Road Condition Survey Guide* presents information on evaluating pavement distresses, which is an integral part of a pavement management system, and the *Rural Road Design, Maintenance, and Rehabilitation Guide* compiles some appropriate pavement and gravel road design and repair information for the needs identified through a roadway management analysis.

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INTRODUCTION

This Guide contains information about the management of paved and gravel roads. The approaches to managing paved versus gravel roads differ in some respects. Both include an inventory of the physical characteristics of the road network and an assessment of the road condition; however, the analysis of the collected information is different for the two road types. Gravel road management typically consists of the identification of standard routine maintenance policies (e.g., blade every 3 weeks, regravel every 5 years) that should be periodically conducted to maintain a gravel road at an acceptable condition level. Paved road management incorporates performance models and life cycle cost analysis to determine the timing of repair and to recommend a specific repair alternative. Because of these differences in management approach, the final section in this Guide is dedicated solely to the management of gravel roads.

Pavement Management

The concept of pavement management was first discussed in the early 1970s. It can be thought of as a set of tools for those who are responsible for making decisions about pavements—such as pavement designers, maintenance staff, public works staff, and even nontechnical decision-makers. These tools enable the individuals to better identify and apply cost-effective strategies to keep their pavements in the best possible condition and to evaluate the long-term impact of their decisions on the entire network.

Many agencies have probably been applying pavement management concepts on an informal basis without even being aware of it. This Guide introduces many of the components of pavement management so that these activities can be done regularly and consistently. The goal, however, is unchanged: to cost-effectively provide the traveling public with pavements that are in the best possible condition.

Network-Level Pavement Management

Pavement management activities can be broken down into two distinct groupings, *network-level* and *project-level*. The pavement network comprises all of the pavements under an agency's jurisdiction, and network-level activities are those that directly address issues that concern the entire network. These include the following:

- Overall funding for pavement maintenance and repair.
- Planning.
- Project scheduling amid conflicting demands.
- Political issues.
- Preservation of an agency's pavement investment.
- Network parameters such as pavement ratings and projections of future condition.
- Representative pavement evaluations to rate the condition of the network.

As noted earlier, in most public works agencies many pavement management actions are being conducted, even among agencies that currently do not have a formal pavement management system. Many of these activities are probably taking place at the network level.

Project-Level Pavement Management

Whereas activities at the network level consider all of the pavements under an agency's jurisdiction, these activities do not look at any specific pavement or group of pavements in detail. Project-level pavement management refers to those activities that take place at a much more basic level, such as individual roads or sections of roads. At this level, attention is paid to the specific deterioration evident in a pavement section. Project-level actions would include or consider the following:

- Distresses on a specific road.
- Repair plans.
- Limits of a repair project.
- Field tests such as California Bearing Ratio (CBR) and materials evaluation.
- Construction of a project.

Some activities might be performed at both the network level and the project level. For example, a network-level survey of pavement condition could be performed. This might involve looking at a representative subset of all pavement sections under an agency's jurisdiction to obtain an indication of the overall condition of the network. A project-level survey, which might be performed as a prelude to a repair project, involves looking at 100 percent of the pavement surface and providing detailed and comprehensive information that could be used to plan, schedule, and budget rehabilitation work.

The differences between network- and project-level activities should become clearer as the reader advances through this Guide. A good rule of thumb is that if the action contributes to a planning function or an understanding of all pavements under an agency's control, it is taking place at the network level; if the action helps the agency to understand the performance of a single road or facilitates the design of a rehabilitation project for a road, it is taking place at the project level.

Why Perform Pavement Management?

Many agencies may rightfully be wondering why they should perform formal pavement management activities. After all, what they are doing now may be working quite well for them, and it has already been acknowledged that much of the decision-making that routinely occurs in a public works agency falls under the heading of pavement management activities. As a partial answer to the question "Why perform pavement management?" the following discussion is offered.

How do you decide which pavements to repair? In the absence of a formal pavement management system, decisions regarding *prioritization* are usually made on a "worst first" basis. This means project funds are allocated to repair those pavements that are in the worst condition, and all other pavements are allowed to deteriorate until they become the worst. This "worst first" approach is very expensive, often well over four times as costly as fixing a pavement at a point in its life cycle when repair alternatives other than reconstruction or a thick overlay are still feasible.

A pavement management system will provide an agency with information about the effects of this strategy on the overall condition of a network and will help to support a move toward repairing those pavements that are in better condition in a timely manner. The overall result of such a strategy is to improve the condition of the network over time.

What repair techniques work? A county may try many different repairs on its roads over the years. Which of these have worked and should be continued and which have not worked? This is not as easy a question to answer as it seems, because two different techniques may both work, but one may provide a longer life or a higher level of service over the same time period. Performance data collected as part of a systematic pavement management system will readily provide information that will allow an agency to determine what repairs work best or are most cost-effective over their life.

How do you replace lost expertise and experience? In many cases, decision-making is in the hands of a few senior staff who know their jobs extremely well and have acquired the skills they need to perform their jobs over a period of many years. When they leave, however, they will take with them a good deal of the knowledge they have accumulated during the course of their time on the job. A pavement management system can serve as an excellent reference source that will enable new or young staff to learn what has been done and how it has worked. The information contained in a pavement management system, in which data have been accumulated for a period of time, can be readily studied to provide the kind of information that less experienced staff can use in their decision-making.

How are budgets for future years developed? How are requests for higher expenditures justified? Most public works staff expend a good deal of effort trying to justify their budgets. This may be due, in part, to the fact that they do not have a good set of tools that can be used to justify their needs. A pavement management system helps to document the condition of an agency's pavements. With the application of the performance prediction tools, the effect of different budgetary levels on the overall condition of an agency's pavements can be readily seen. This allows those with budgetary oversight responsibilities the ability to see exactly what the effect of different funding levels will be on the overall condition.

These examples highlight some of the capabilities of a formal pavement management system. The primary goal of pavement management is for an agency to improve its overall pavement performance. A secondary goal is to improve pavement performance in a cost-effective manner.

Benefits of Pavement Management

By now, some of the benefits of pavement management should be clear. The information available in a pavement management system helps agencies that are responsible for maintaining pavements make better decisions about the pavements under their jurisdiction, including the ability to make more cost-effective choices among a range of alternatives. Thus, not only does the agency benefit, but taxpayers benefit as well. When pavement management concepts are applied to improve the overall condition of a network, the traveling public will also enjoy that benefit.

Some of the benefits of performing pavement management activities are summarized here in part to encourage agencies that are not currently engaged in pavement management to begin the implementation process.

Inventory

The pavement management system contains records of all of the roads under an agency's jurisdiction. Over time it will include construction information, maintenance and rehabilitation records, traffic, and any other elements that are considered desirable. This database is an excellent source of information about what a county has and, with the condition survey information added, the pavement management system also documents the value of a county's pavement investment.

Prioritization

Using the forecasting capabilities of a pavement management system, the effects of different pavement maintenance and rehabilitation strategies can be evaluated. This allows decision makers to consider all possible projects and fund those projects that will provide the greatest benefit.

Funding

Predicting the performance of pavements over time also provides managers with the ability to consider "what if" scenarios. For example, you can consider the condition of your pavement 5 years in the future based on three different funding levels: no funding for maintenance and repairs, minimal funding, and full funding. Looking at the overall pavement condition in this manner provides powerful ammunition to obtain necessary funding or to document the results of funding shortfalls.

Justification

One of the most difficult factors an agency must deal with is justifying the rehabilitation programs it develops each year. Without information that demonstrates the objectivity of the decisions being made, it may be difficult to withstand the pressure from outside sources to limit or even eliminate those funds. A pavement management system will help to provide this justification and reduce the subjectivity inherent in the decision process.

Drawbacks of Pavement Management

Unfortunately, there are some potential drawbacks to a pavement management system. Some agencies have found them to be "data hungry." In addition to all of the background information that is required about the different pavements, the pavement management system requires regular surveys in order to remain up to date and be as useful as possible. The system may also call for additional pavement testing or evaluation. These demands can be burdensome to agencies that have never collected this type of information before or those that cannot release the manpower needed to collect or enter the data.

The system can also be expensive to operate. Pavement management activities may require an additional level of effort, such as extra staff to perform the pavement surveys or to enter the data. If the system is automated, an extra computer may be required.

Another possible drawback is that pavement management activities may be perceived as a threat to the established way of doing things. To someone accustomed to making decisions based on his own interpretation of the data, a pavement management system will likely present a challenge.

In response to these potential drawbacks to a pavement management system, it should be noted that thousands of agencies have implemented these systems, and in almost every case they have found that the benefits far outweigh the potential drawbacks. Many agencies have been able to apply the tools found in their pavement management system to make more cost-effective decisions and improve the overall condition of their pavements. Although, pavement management should not be thought of as a process without problems, there are usually many more positive factors than negative.

Gravel Road Management

The management of gravel roads includes an inventory of the physical characteristics of the road network and an assessment of the road condition. Gravel road management typically involves the identification of standard routine maintenance policies (e.g., blade every 3 weeks, regravel every 5 years) that should be periodically conducted to maintain a gravel road at an acceptable condition level. Major maintenance activities are only indicated when a gravel road falls below some specified acceptable condition level.

GETTING STARTED

In this section, guidance is presented to help set up a pavement management system. Information covered includes defining the pavement network and breaking it down into pavement sections, as well as identifying the types of information that should be collected for each pavement section before the field surveys are conducted.

Your Rural Road Network

The first step in setting up a road management system is to define the road network. Simply put, a county's pavement network consists of all of the roads under its control. If the county is responsible for maintenance, repair, or reconstruction of a road, it belongs in the county's network. Conversely, if some other agency has responsibility for the road, the road is part of the other agency's network. Thus, the network is not defined by road location as much as it is by authority or responsibility for maintenance and rehabilitation. Depending upon the county's needs and approach to management, it may be preferable to separate the paved roads and the gravel roads into different databases.

A convenient way to display the extent or limits of the network is on a map. A simple pavement network can be identified by hand using a highlighter or felt-tip marker to label all roads in the network (or the few roads that are not in the network, if that is easier). Mapping is a capability of many automated management systems and is highly desirable.

The next step is to subdivide the pavement network into manageable, smaller units. This division can be accomplished by first identifying each road in the network and assigning it a five-character identifying name. For example, Dodge Road might be identified as DODGE and Brook Road might be identified as BROOK. Typically, because of the way in which a road's characteristics can change over some distance, it is further subdivided into pavement *sections*.

A pavement section is a portion of pavement that has uniform functional classification, construction history, pavement structure, traffic patterns, and condition throughout its entire length. The basic concept in dividing a network into pavement sections is that sections that are alike should perform similarly. Furthermore, similar sections will likely call for similar treatments. In most counties, a pavement section will be defined as a road running from cross road to cross road. Section numbers are assigned in ascending order from west to east or from north to south. An example of the sectioning of a small group of roads is shown in Figure 1, where sections for Dodge Road, Brook Road, Boot Hill Road, and Goose Pond Road have been identified.

Once the network has been defined, the roads have been classified, and the surface types for each section have been identified, it is possible to create an inventory of the network. The inventory is simply a summary, preferably in table form, of all of

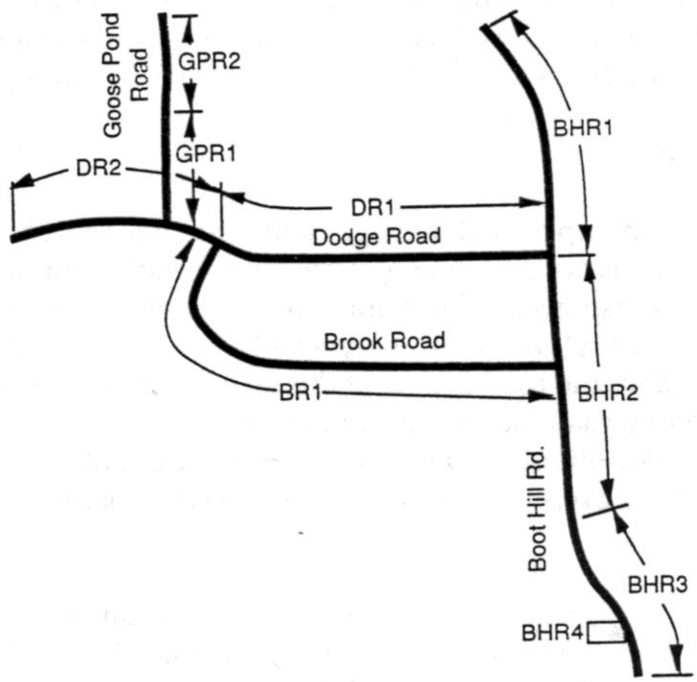

Figure 1. Example of the sectioning of a small group of roads.

the pavement sections in the network. It serves as a useful reference for documenting the miles of pavement under the county's jurisdiction.

Table 1 is provided as an excerpt from a typical network inventory. It should be noted that in this table each section has been assigned a unique identification number. This number provides a means of keeping track of the various sections.

Additional Network Information

To complete the inventory of a pavement network, the collection of additional data is highly desirable. These data can be characterized as information that should be available from office records, either within the agency itself or in the offices of the agency's consulting engineer for pavement work. Typical inventory information that is desired includes the following:

- Section identifier.
- Section length.
- Section width (traveled surface plus shoulder equals total roadway).

- Functional class.
- Curb and gutter information.
- Cross section (layer) information — type, thickness, and date constructed.
- Shoulder information.
- Traffic (ADT).
- Percent heavy trucks.

Table 1. Excerpt of a network inventory of a county's roads.

Road name	Road ID no.	Section ID no.	From	To	Road class	Surface type
Dodge Road	DODGE	DR1	Boot Hill Road	Goose Pond Road	Local	AC
Dodge Road	DODGE	DR2	Goose Pond Road	West End	Local	AC
Brook Road	BROOK	BR1	Dodge Road	Boot Hill Road	Local	Blotter
Boot Hill Road	BOOT	BHR1	North End	Dodge Road	Arterial	AAC
Boot Hill Road	BOOT	BHR2	South End of BHR1	North End of BHR3	Arterial	AAC
Boot Hill Road	BOOT	BHR3	South End of BHR2	South End	Arterial	AAC
Boot Hill Road	BOOT	BHR4	Parking Area off BHR3		Arterial	AAC
Goose Pond Road	GOOSE	GPR1	Dodge Road	North End	Local	Gravel
Goose Pond Road	GOOSE	GPR2	North End of GPR1	North End of Road	Local	Gravel

AC = asphalt concrete; AAC = asphalt pavement with an asphalt overlay.

In addition, section information that some agencies may wish to collect includes the percent cross slope, grade, presence of drainage, manholes, gutters, utilities, signs, and so on. This type of data consists of information about the pavement section that is relatively unchanging (static). Therefore, these items can be assembled once and only updated when a maintenance, rehabilitation, or reconstruction project has resulted in a change in the pavement's characteristics. An example of the additional inventory data desired for each pavement section in the network is shown in Figure 2. This information is not required in a pavement management system, but it can be very helpful in overall operations when it is stored in a computerized database. Most agencies just beginning to implement a pavement management system do not attempt to collect this information at the beginning of their implementation, but do begin to collect it after several years. Table 2 presents a format for storing inventory data for several pavement sections. This table can be used in a paper and pencil system, or it can be readily adapted to a computerized spreadsheet. A full-sized (11 x 17 in) copy of Table 2 is provided in Appendix A. In addition, a computerized copy of Table 2, in both Microsoft Excel and Lotus 1-2-3 formats, is provided on the diskette in Appendix B.

The Field Survey

The field survey should be performed in accordance with the *Pavement Condition Survey Guide for Rural Roads*, which is one of the three documents in this series. In general, the *Pavement Condition Survey Guide for Rural Roads* provides the necessary guidance for determining the condition rating (0 to 100), the average rideability, the railroad crossing rideability (if applicable), the level of rutting (flexible pavements only), and the degree of surface polishing.

The sample pavement condition rating form provided in Figure 3 can be used for organizing, collecting, and storing pavement condition information for each section evaluated. The form accommodates data collected from several surveys. Therefore, a new form does not have to be generated each time a reinspection is performed.

Computerized copies of Figures 2 and 3 are provided on the diskette in Appendix B. Both figures are formatted in WordPerfect, version 6.1 for Windows.

Inventory Data Form

Inventory date ____________________
By ______________________________

Section Identification

Section ID No. ____________________ ____________________
Road name ____________________ Length, m (ft)
From ____________________ To ____________________

Roadway Classification and Traffic Data

Functional classification of road ____________________
Average daily traffic ____________________
Percent heavy trucks ____________________

Roadway Inventory Data

Traveled surface width, m (ft) ________ Shoulder width, m (ft) ________
ROW width, m (ft) ____________________ Number of lanes ____________________
Surface type (circle one): AC, PCC, Blotter, or Gravel
Shoulder type (circle one): AC, PCC, Blotter, Gravel, Turf, None, or Other
Curb and gutter (circle one): Yes/No
Comments ____________________

____

____

Cross Section Information

Layer	Material	Thickness mm (in)	Construction date	Other information
Subgrade				

Figure 2. Illustration of sample inventory data form.

Condition Rating Form

Section Identification

Section ID No. ______________________________ Road name ______________________________

From ______________________________ To ______________________________ Length (ft) ______________

Roadway Surface Type (circle one): AC, PCC, Blotter, or Gravel

Condition Rating Data

Date	Members of rating team	Average pavement condition rating	Pavement rideability rating (0 to 5)	Railroad crossing rideability rating (0 to 5)	AC rut depth rating (0 to 4)	Polished aggregate rating (0 to 2)	Comments

Table 2. Sample network inventory table.

Section ID State	Section ID County	Road Name	From	To	Functional class	Surface type	Section length, m (ft)	Traveled surface width, m (ft)	Section area, sm (sy)	Average daily traffic	Percent heavy trucks	Shoulder type			Date of last construction	Date of last inspection	Condition rating

DEVELOPING A MULTI-YEAR REHABILITATION PROGRAM

This section of the Guide applies only to paved surfaces. Please see the section of the Guide entitled *Gravel Road Management* for information on developing a multi-year rehabilitation program for gravel roads. As illustrated in the *Gravel Road Management* section, both the paved and gravel road systems can be integrated into one system that projects the financial needs for a county roadway network.

Once a pavement management system database has been established, it can be used to develop multi-year rehabilitation programs. Such a program is a very useful tool for planning several years into the future. The following six steps are involved in preparing these programs:

Step 1. Forecast future condition.
Step 2. Develop rehabilitation decision matrix.
Step 3. Identify priority levels.
Step 4. Generate initial multi-year rehabilitation program.
Step 5. Assess network performance.
Step 6. Adjust funding levels and generate new program.

A multi-year rehabilitation program cannot be developed until a basic inventory database has been established for the pavement network. Figure 4 shows the relationship of this activity to the overall pavement management system process.

Throughout this section, preliminary inputs for a pavement management system, called *templates*, are presented for South Dakota's use. These templates were developed using information contained in the Local Road Needs Study published in 1991. For example, a rehabilitation decision matrix template is presented that contains default values for various pavement management system parameters. All templates are preliminary in nature and are designed to provide the counties with a starting point for pavement management system implementation efforts. Initially, a county may have to rely on these preliminary inputs until enough data have been collected to permit their modification. During that period, the county should be cognizant of the limitations of the templates. Each county should review each template carefully and revise or replace them as needed.

Step 1. Forecast Future Condition

To prepare multi-year pavement rehabilitation schedules, a pavement management system must have some means of forecasting the future condition of pavement segments. There are many available methods for predicting future pavement condition, ranging from the simplistic to the advanced. The following approach is simplistic, but it can be used immediately by South Dakota counties, even if resources are limited and historic condition data are unavailable.

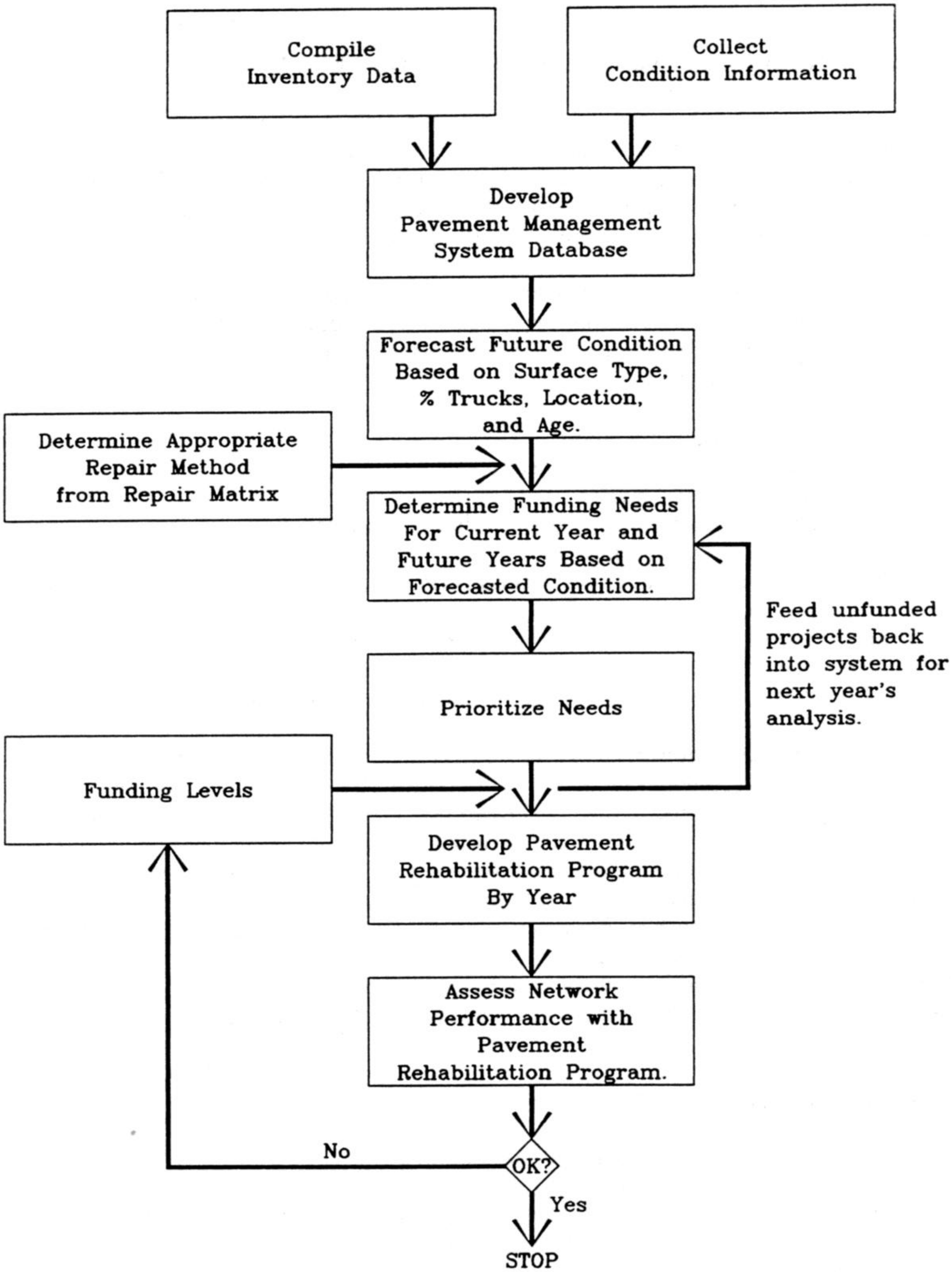

Figure 4. Developing a pavement rehabilitation program.

A very basic approach to modeling pavement condition is to assume specified pavement deterioration rates, depending upon predetermined factors. These factors may include items such as pavement type, pavement age, traffic levels, and geographic location. By identifying the condition index (CI) that signifies major rehabilitation is needed, and estimating how long it takes a pavement under specified conditions to deteriorate to that condition index, an average deterioration rate can be calculated. Figure 5 illustrates this method of predicting future condition, called the *basic forecasting method*.

There are five activities involved in predicting future condition using the basic forecasting method:

- Establish committee.
- Identify families of pavements.
- Establish terminal condition index levels.
- Estimate typical service life of different pavement types.
- Calculate estimated deterioration rates.

These activities are described in greater detail below.

Establish Committee

To apply this modeling approach, a committee should be organized that consists of a group of people familiar with the performance of pavements within an agency's network. This group should work together to estimate pavement deterioration rates. The establishment of a committee at this stage will help to reduce the subjectivity and bias that could result if a single person is responsible for developing the forecasting method.

Identify Families of Pavements

The initial step undertaken by the committee is to identify groups of like performers, called *families*, among the network's pavement sections. For example, different pavement types (asphalt, concrete, asphalt overlays on asphalt pavements, bituminous surface treatments [BST], and so on) are normally separated into different pavement families because they deteriorate at different rates and in different ways. These families can be further subdivided based upon factors such as traffic, functional classification, and geographic location. The goal is to identify families of pavement sections that are expected to exhibit similar deterioration behavior over time.

Establish Terminal Condition Index Levels

After families of pavements have been identified, the committee determines what defines the end of service life for a pavement. For example, one county may determine that a pavement reaching a condition index of 40 is at the end of its useful service life.

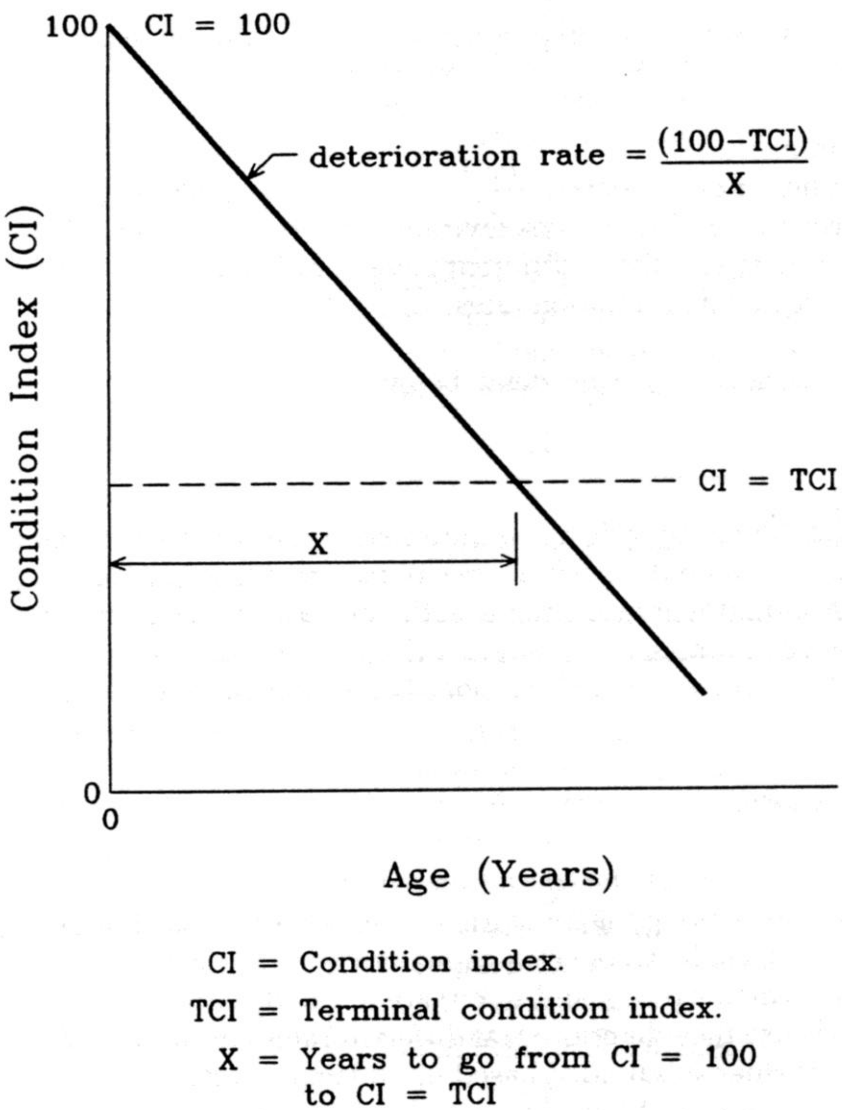

Figure 5. Basic approach to forecasting future pavement condition.

Another county may set this limit at 30 or 50. This number is called the *terminal condition index*.

An easy way to get a feel for the terminal condition index is to go out and look at roads that are currently scheduled for major rehabilitation due to poor condition. (Be careful not to select roads that have been scheduled for rehabilitation due to nonconformance with standards or because widening is required.) Then, determine the condition index of each of these road sections. These values will be in the range of the terminal condition index.

Estimate Typical Service Lives of Different Pavement Types

The next step undertaken by the committee is to estimate, on the average, how long a given pavement type lasts before it requires rehabilitation. The easiest way to obtain this information is to think of past projects within the county. For example, look at a list of recent overlay projects. For each pavement section, determine the family of the original pavement (prior to overlay). Then, estimate how old the existing pavement sections were when they were overlaid. This information will help you estimate typical service lives of different pavement families.

Calculate Estimated Deterioration Rates

The deterioration rate is calculated by subtracting the terminal condition index from 100 and then dividing the result by the estimated service life of the pavement. This calculation assumes a constant (also referred to as *straight line*) deterioration rate throughout the life of the pavement.

<u>Example 1. Using the Basic Forecasting Method to Estimate Deterioration Rates</u>

The following example illustrates the process that is undertaken to estimate deterioration rates for different families of pavements. The example is also illustrated in Figure 6.

***Identify Family**: County A has identified a family comprised of blotter pavements, level terrain, local, and low truck volumes.*

***Determine Terminal Condition Index**: The terminal condition index for this type of pavement has been identified by the committee as 40.*

***Estimate Performance Life**: The committee estimates that a blotter placed under these conditions usually lasts 7 years before rehabilitation is needed.*

***Calculate Deterioration Rate**: (100 - 40) condition points ÷ 7 years = 8.6 condition points/year.*

The basic forecasting method is simple, and it can be used with little historical data. The only elements that need to be stored in the pavement management system database to apply this method are the last construction date and the factors that are used to determine pavement deterioration rates, such as surface type, functional classification, traffic, and terrain. Incidentally, terrain is a category that indirectly encompasses environmental and subgrade conditions. The deterioration rates can, and should, be adjusted as more data become available over time.

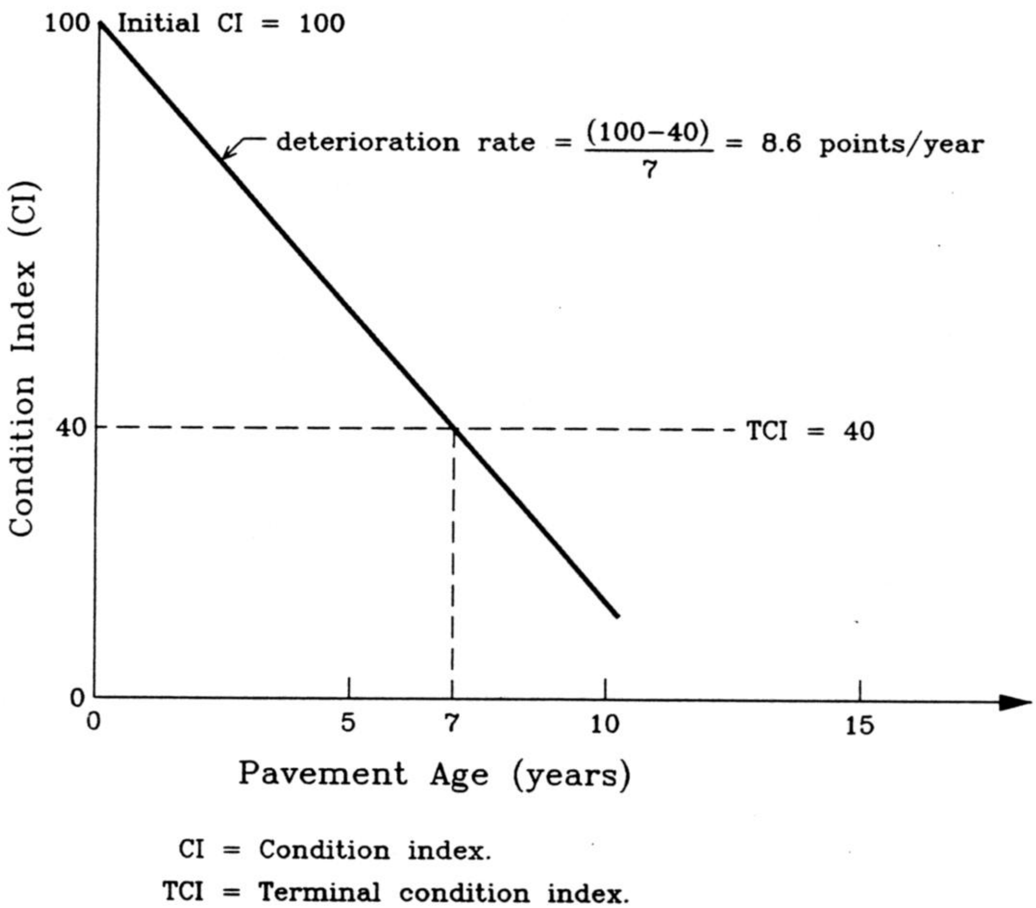

Figure 6. Illustration of a basic pavement deterioration curve (Example 1).

The basic forecasting method does have disadvantages, primarily due to its simplistic nature. First, it relies heavily on subjective expert opinion. This drawback is offset by using a group of people, rather than a single person, to estimate the deterioration rates. In addition, as historical condition versus pavement age data become available, subjective opinion can be supplemented by documented data.

Second, the basic forecasting method assumes pavements deteriorate in a constant manner over time, which is often not the case. This disadvantage can be addressed by dividing the life of the pavement into phases, in order to simulate the non-linear deterioration behavior of most pavements. Each phase of pavement life can be assigned a different deterioration rate, as illustrated in Figure 7. This approach is called a *piecewise linear forecasting method*. It is preferred over the basic forecasting method.

A basic template for forecasting future pavement condition within South Dakota counties, which uses the basic forecasting method, is presented in Table 3. This template was developed by defining pavement families based on surface type and level of truck traffic. Five pavement surface types were used: asphalt concrete (AC) pavements, asphalt pavements with asphalt overlays (AAC), portland cement concrete pavements with asphalt overlays (APC), blotter/chip seals pavements (BST), and portland cement concrete (PCC) pavements. Three levels of truck traffic were used (low, medium, and high).

Table 3. Template for forecasting the future condition of county roads in South Dakota.

Truck traffic level	Forecasted annual change in Pavement Condition Index (Δ)				
	AC	AAC	APC	BST	PCC
Low	Δ = 2.0	Δ = 2.4	Δ = 3.0	Δ = 3.0	Δ = 1.0
Medium	Δ = 2.5	Δ = 3.0	Δ = 3.5	Δ = 4.0	Δ = 1.5
High	Δ = 3.0	Δ = 3.5	Δ = 4.0	Δ = 6.0	Δ = 2.0

Note: The deterioration rates presented in this table are based on the results of interviews conducted during the 1991 Local Road Needs Study and assume a terminal condition index equal to 40. The basic forecasting method was used to estimate these deterioration rates. These deterioration rates are for short term estimating purposes, to be used only until historical information becomes available. These deterioration rates are not to be used for life cycle prediction.

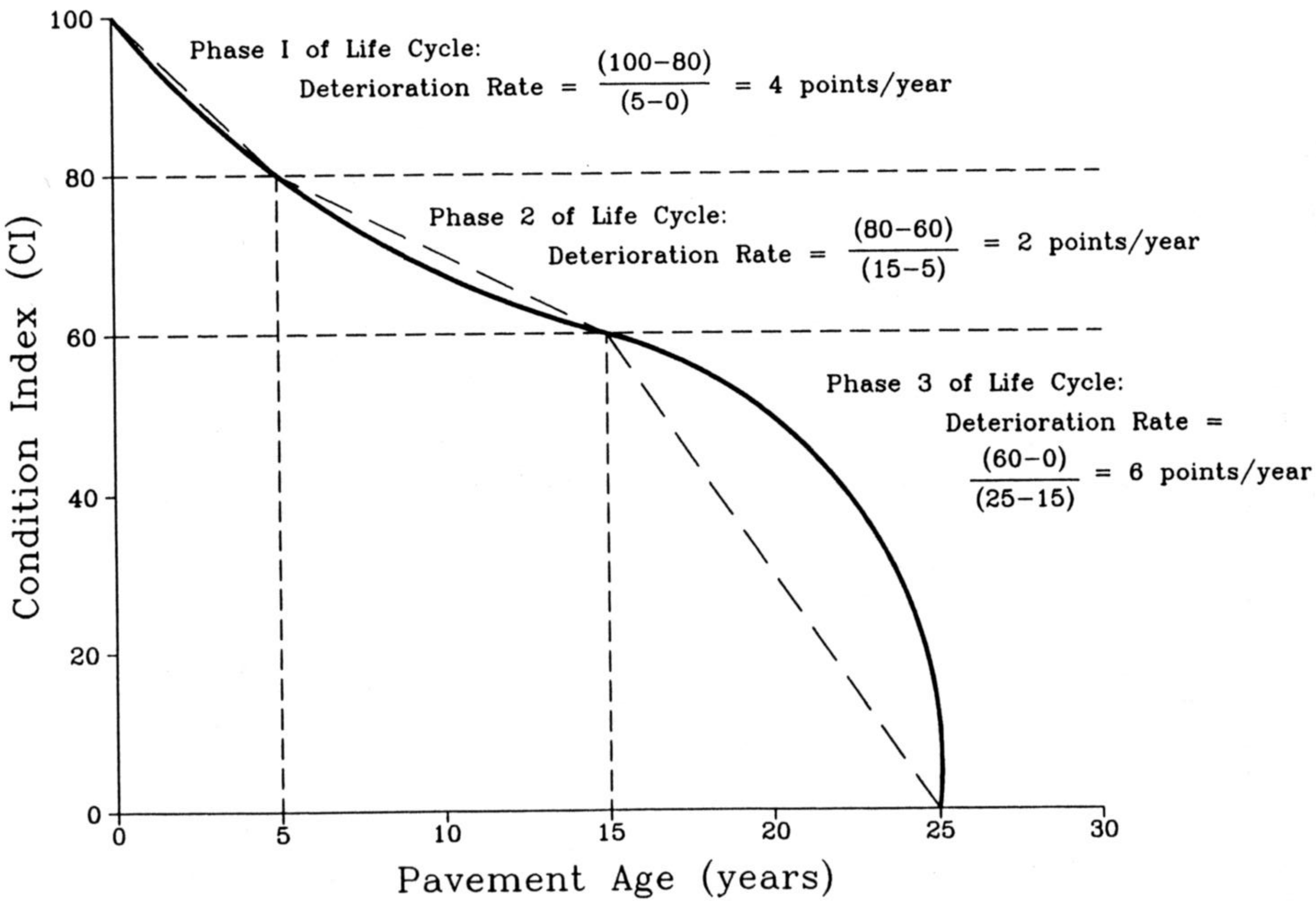

Figure 7. Example of using piecewise linear phased approach to forecasting future pavement condition.

Table 3 should be used only as a starting point for a county that is implementing a pavement management system, because it is basic and limited in its present form. Each county should review the table carefully and modify it as needed. For example, it is expected that geography (level terrain, rolling terrain, and mountainous terrain) may affect the performance characteristics of a pavement. Pavements within different functional classifications may also exhibit different performance characteristics. As a county obtains enough performance data to make these determinations, additional families should be added to the database, and deterioration rate estimates should be refined. In addition, as soon as enough data become available, the piecewise linear approach of forecasting future condition should be evaluated for use in the system.

Step 2. Develop Rehabilitation Decision Matrix

The next step in determining section needs is to develop some type of process for the selection of rehabilitation treatment alternatives. These alternatives are simply the entire range of repairs a county would consider using on its pavements. The technique recommended for South Dakota counties is a decision matrix process. This approach involves identifying feasible rehabilitation alternatives, such as overlays and blotters, and then specifying the parameters that define where these alternatives can be applied. For example, it may not be appropriate to use a blotter on a heavily truck-trafficked road, and the decision matrix should be designed to reflect that fact. A default decision matrix is presented at the end of this section.

The following activities are involved in the development of a rehabilitation decision matrix and are described below in greater detail:

- Establish committee.
- Identify feasible rehabilitation alternatives and associated costs.
- Define under which situations each alternative can be applied.

Establish Committee

To effectively utilize this approach, it is important to involve a group of people familiar with the rehabilitation alternatives that have been tried within the county. The establishment of a committee at this stage will help to reduce the subjectivity and bias that could result if a single person is responsible for developing the rehabilitation decision matrix.

Identify Feasible Rehabilitation Alternatives and Associated Costs

The first task in developing a rehabilitation decision matrix involves identifying which rehabilitation treatments are considered feasible for use within a county and how much these treatments cost. Each county must develop its own list of feasible alternatives and obtain unit cost estimates for each alternative, because these may vary significantly from county to county. For example, one county may consider recycling a feasible alternative for asphalt pavement repair, whereas another county may not have access to the proper equipment and thus would not consider recycling feasible. Another county may have easy access to an asphalt plant, and therefore its asphalt overlay costs are much lower than those of a county that does not have ready access to a plant.

Define Under Which Situations Each Alternative Can Be Applied

After a list of feasible rehabilitation alternatives has been developed, the group must define under what conditions each alternative can be applied. For example, some rehabilitation types are appropriate to repair only certain pavement types, whereas others are only appropriate for pavements in relatively good condition. It is likely that some rehabilitation treatments may not be considered appropriate to use in highly trafficked areas, whereas others could be considered cost-effective only in highly trafficked areas. Once again, each county must make these determinations.

Example 2. Developing a Rehabilitation Decision Matrix

The following example illustrates the process a county may go through to develop a rehabilitation decision matrix.

> ***Establish Committee****: County A assembles a group of experienced maintenance personnel and engineers to develop a rehabilitation decision matrix for use in a pavement management system.*
>
> ***Identify Potential Rehabilitation Alternatives****: The group first discusses all the rehabilitation treatments that had previously been used to repair county roads, or were being considered for future use. The group compiles the following list: reconstruction with asphalt, asphalt overlay, and blotter surface treatment.*
>
> ***Identify Feasible Rehabilitation Alternatives****: After serious discussion, the committee determines that three rehabilitation options are currently feasible for the repair of its road network: reconstruction with asphalt, asphalt overlays, and blotters.*
>
> ***Identify When Each Alternative Can Be Appropriately Applied****: The county personnel identify that these alternatives are applied in the following situations:*
>
> > *Reconstruction with Asphalt: To be used on AC, AAC, APC, and PCC pavements in very poor condition ($CI \leq 25$) or when major rehabilitation is required ($26 \leq CI \leq 55$) and the road is either not meeting current standards or has exceeded the allowable number of overlays.*
> >
> > *Overlays: To be used on AC, AAC, APC, and PCC pavements requiring major rehabilitation ($26 \leq CI \leq 55$), assuming that the allowable number of overlays have not been exceeded. These techniques can also be used to repair pavements that receive heavy*

volumes of truck traffic and require moderate rehabilitation ($56 \leq CI \leq 70$). They can also be used to rehabilitate a blotter road that is in very poor to poor condition ($0 \leq CI \leq 55$) and receives over 100 ADT.

Blotters: To be used on asphalt-surfaced or blotter pavements that require moderate rehabilitation ($56 \leq CI \leq 70$) and are not heavily truck-trafficked roads.

Preliminary decision matrices have been prepared for South Dakota counties and are presented in Tables 4A, 4B, and 4C. These tables address asphalt concrete, portland cement concrete, and blotter pavements and are based on the results of interviews with several South Dakota counties conducted during the 1991 Local Road Needs Study. The costs in these tables represent statewide averages. Separate tables were not generated for pavements that have received overlays. These tables are just templates that are provided as starting points for a county to use. Each county should review these decision matrices carefully and modify them as needed to meet local situations and policies. For example, costs will certainly vary significantly from county to county, and local cost data should be used when possible.

Step 3. Identify Priority Levels

It is rare to have sufficient funds available to address all of the roads that are in need of repair. In order to prioritize projects when there are insufficient funds available to perform all needed projects, a prioritization scheme must be developed. A prioritization scheme can be thought of as a plan of action or a schedule. It spells out rules or guidelines for determining the order in which rehabilitation projects are performed. Different forms of prioritization are available. Projects can be prioritized based upon pavement condition, functional classification, truck traffic, political considerations, and so on. It is up to each county to decide which factors to use in the prioritization process. It is recommended that a group of people familiar with the county's current policies regarding project funding work together to establish priority guidelines for use within the pavement management system.

<u>*Example 3. Identifying Priority Levels*</u>

The following example illustrates the procedure a county might go through to set priority levels.

***Establish Committee**: County A gathers a group of people together representing finance, maintenance, and engineering.*

***Define Priority Levels**: Together, they outline how funding is currently allocated to pavement projects. At the end of a lively discussion, the following guidelines are provided for which roads receive first funding priority.*

Priority Level 1. *Roads in very poor condition ($0 \leq CI \leq 25$) on all functional classifications and receiving high levels of truck traffic are identified as priority 1 due to safety considerations.*

Priority Level 2. *Roads in moderate condition ($56 \leq CI \leq 70$) on all functional classifications and traffic levels are identified as the next highest priority level, because within this condition range repairs can be made cost-effectively.*

Priority Level 3. *Roads in poor condition ($26 \leq CI \leq 40$) on all functional classifications receiving high levels of truck traffic are the third priority level.*

Priority Level 4. *Roads in very poor and poor condition ($0 \leq CI \leq 40$) on all functional classifications receiving low to moderate levels of truck traffic are identified as having the lowest priority. These roads have deteriorated past the point of cost-effective repair and maintenance.*

Priority Level 5. *All remaining roads.*

Table 5 presents a priority policy template for use by South Dakota counties. As with the future condition prediction models and rehabilitation decision matrix previously presented, this table is preliminary in nature and is meant to be used by counties as a starting point when developing their own prioritization scheme. The template policy bases prioritization upon three factors: functional classification, pavement condition, and truck traffic. A county should add and delete prioritization factors as needed.

Step 4. Generate Initial Multi-Year Rehabilitation Program

Using the pavement management system database and the results from steps 1 through 3, an initial multi-year rehabilitation program can be generated. A multi-year rehabilitation program uses the previously discussed tools to project the condition of a county's roads in the future, determine what rehabilitation activities are planned for the roads, and estimate the financial needs to carry out those rehabilitation activities. This is clearly one of the most powerful and useful tools a county can apply to the effective management of its roads. How far into the future this multi-year plan should forecast is up to each county. A 3-year plan is a reasonable starting point and will provide beneficial information; as the forecasting tools become more refined, it may be appropriate to consider a 5-year plan.

Table 4A. Asphalt concrete pavement rehabilitation matrix template.

Condition rating	Functional classification of road	Truck traffic level (L,M,H)	>13 mm (0.5 in) rutting present (yes/no)	Grade constraints (yes/no)	Meets geometric standards (yes/no)	Pavement repair option	Typical costs* ($\$/\text{m}^2$)	Typical costs* ($\$/\text{yd}^2$)
86 to 100	All	All	N/A	N/A	N/A	Rout and seal cracks.	0.22	0.18
71 to 85	All	All	N/A	N/A	N/A	Patch alligator-cracked areas, rout and seal cracks.	0.57	0.48
56 to 70	All	All	No	N/A	N/A	Patch alligator-cracked areas, rout and seal cracks, and apply a surface treatment.	1.34	1.12
56 to 70	All	All	Yes	N/A	No	Patch alligator-cracked areas, rout and seal cracks, and construct a functional AC overlay.	5.43	4.54
56 to 70	All	All	Yes	N/A	Yes	Mill AC surface, construct patches, and place a functional AC overlay.	6.39	5.34
41 to 55	All	L	N/A	No	N/A	Construct patches, rout and seal cracks, and place a functional AC overlay.	8.06	6.74
41 to 55	All	L	N/A	Yes	N/A	Mill AC surface, construct patches, and place functional AC overlay.	8.18	6.84
41 to 55	All	M,H	N/A	No	N/A	Construct patches, rout and seal cracks, and place structural AC overlay.	10.45	8.74
41 to 55	All	M,H	N/A	Yes	N/A	Mill AC surface, construct patches, and place structural AC overlay.	11.47	9.59
26 to 40	All	All	N/A	N/A	N/A	Remove and replace AC layer.	11.47	9.59
0 to 25	All	All	N/A	N/A	Yes	Reconstruct.	15.71	13.14
0 to 25	All	All	N/A	N/A	No	Remove and construct to standards.	15.71	13.14

*Cost figures are for square measurements and are not for volume measurements.

Table 4B. Portland cement concrete pavement rehabilitation matrix template.

Condition rating	Functional classification of road	Truck traffic level (L,M,H)	Grade constraints (yes/no)	Meets geometric standards (yes/no)	Pavement repair option	Typical costs* ($/m²)	Typical costs* ($/yd²)
86 to 100	All	All	N/A	N/A	None required.	0.00	0.00
71 to 85	All	All	N/A	N/A	Rout and seal cracks and reseal joints.	3.47	2.90
56 to 70	All	All	N/A	N/A	Repair spalls, construct full-depth patches, reseal joints, and rout and seal cracks.	5.98	5.00
41 to 55	All	All	Yes	N/A	Replace shattered slabs, repair spalls, construct full-depth patches, and seal cracks and joints.	9.69	8.10
26 to 40	All	All	No	N/A	Replace shattered slabs, construct full-depth patches, and place structural AC overlay. *Option: Crack, break and seat the existing concrete and overlay with asphalt.*	13.33	11.15
26 to 40	All	All	Yes	N/A	Replace shattered slabs, repair spalls, construct full-depth patches, and seal cracks and joints.	15.85	13.25
0 to 25	All	All	N/A	Yes	Reconstruct.	45.45	38.00
0 to 25	All	All	N/A	No	Remove and construct to standards.	45.45	38.00

*Cost figures are for square measurements and are not for volume measurements.

Table 4C. Blotter pavement rehabilitation matrix template.

Condition rating	Functional classification of road	Truck traffic level (L,M,H)	>13 mm (0.5 in) rutting present (yes/no)	Grade constraints (yes/no)	Meets geometric standards (yes/no)	Pavement repair option	Typical costs* ($/m²)	Typical costs* ($/yd²)
71 to 100	All	All	N/A	N/A	N/A	None Required.	0.00	0.00
56 to 70	All	All	N/A	N/A	N/A	Patch alligator-cracked and potholed areas. Apply surface treatment.	0.98	0.82
26 to 55	All	L	N/A	N/A	N/A	Pulverize pavement, regrade crushed material, and apply surface treatment.	2.13	1.78
26 to 55	All	M,H	N/A	N/A	N/A	Pulverize pavement, regrade crushed material, and construct an AC overlay.	5.09	4.26
0 to 25	All	All	N/A	N/A	Yes	Reconstruct.	12.32	10.30
0 to 25	All	All	N/A	N/A	No	Remove and construct to standards.	12.32	10.30

*Cost figures are for square measurements and are not for volume measurements.

Table 5. South Dakota counties priority matrix template.

Condition index	Priority ranking								
	Low truck traffic			Moderate truck traffic			High truck traffic		
	Arterial	Collector	Local	Arterial	Collector	Local	Arterial	Collector	Local
81 to 100	14	14	14	14	14	14	14	14	14
61 to 80	11	13	13	9	10	12	9	10	12
41 to 60	6	6	8	5	5	8	4	4	4
0 to 40	3	3	7	2	2	7	1	1	1

Note: Priority ranking 1 identifies the highest priority ranking and priority ranking 14 the lowest.

The process of generating a multi-year plan includes several activities. A summary of these activities is provided below, and Figure 8 provides a flowchart illustrating this process.

1. Each pavement section is evaluated individually. Initially, the last condition index and associated inspection date are retrieved for each pavement section. The condition prediction models are then used to estimate the current condition of each section and to project the future condition of each pavement section.

2. The treatment rehabilitation decision matrix is then accessed to identify whether rehabilitation is required and which rehabilitation alternative is feasible during the first year of the analysis. If a rehabilitation treatment is recommended, the unit cost of the treatment is multiplied by the section area to determine an estimated project cost.

3. All sections in the network are analyzed for the first year. The available budget is compared to the total needs for the system in that year. If the budget is insufficient to fund all identified projects in that year, the priority policy is used to prioritize the projects. Funded projects are considered to be reset to a condition index of 100, and deterioration in future years is projected from this value using the appropriate deterioration curve. Unfunded sections continue to deteriorate from the Year 1 level.

4. These activities are completed for each year of the analysis period.

This procedure yields cost estimates in current dollars. Repair costs should be updated regularly.

Example 4. Developing an Initial Multi-Year Rehabilitation Program

The following example demonstrates how all the components of a pavement management system are used together to develop a rehabilitation program. The first-year results (1995) of this example are illustrated in Table 6.

Access PMS Database. *County A decides it needs to prepare a rehabilitation program for a subset of its network consisting of road sections S1, S2, and S3. The county accesses the PMS database to obtain the following information for those road sections: surface type, last construction date, last inspection date and associated condition index, functional classification, truck traffic levels, and section area. The following information is obtained for each section*:

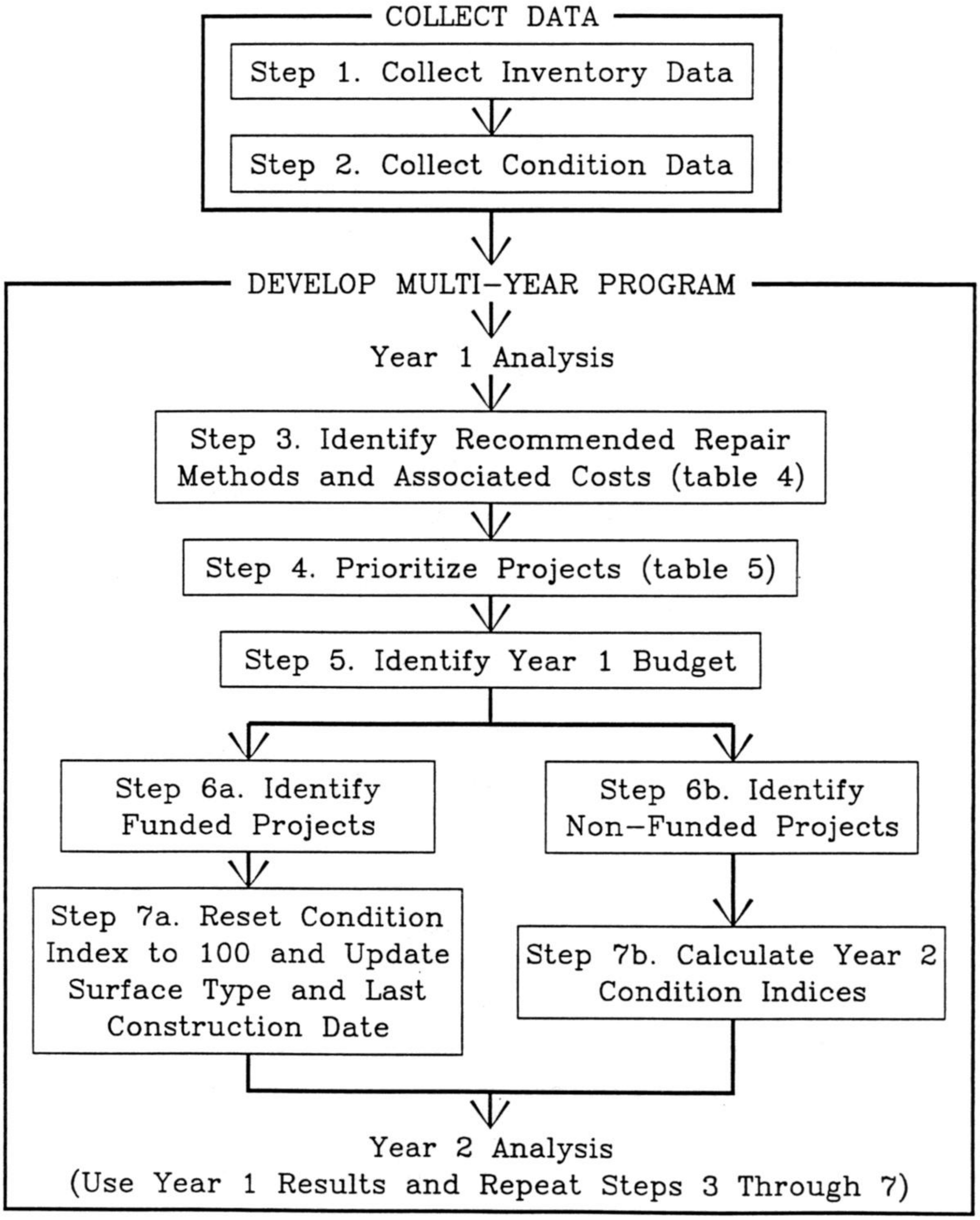

Figure 8. Process for generating a multi–year rehabilitation program.

***Road Section S1**: S1 was originally an asphalt pavement that received an asphalt overlay in 1985. It was last inspected in May 1991, when its CI was 80 and rutting in excess of 13 mm (0.5 in) (rut-depth rating of 2) was prevalent. It receives high truck traffic levels and is an arterial. S1 has an area of 4,180 m^2 (5,000 yd^2), and it meets current geometric standards. The rideability rating was 3.5, and the railroad crossing rating is 3.0.*

***Road Section S2**: S2 was originally constructed in 1970. It is a blotter pavement and was last inspected in May 1992, when its CI was 29, its rideability rating was 1.5, and its rut depth index was 3. This section receives moderate truck traffic levels, sufficient to warrant an AC surface. S2 is a local and has an area of 4,180 m^2 (5,000 yd^2). S2 does not meet geometric standards.*

***Road Section S3**: S3 is a blotter pavement placed in May 1990. It has not been inspected since its construction, and it receives low truck traffic levels. S3 is classified as local, has an area of 8,360 m^2 (10,000 yd^2), and meets current geometric standards.*

***Estimate Deterioration Rates.** The county estimates that AC pavements deteriorate at a rate of 4 points per year under moderate and high truck traffic levels. Blotter pavements are estimated to deteriorate at a rate of 8 points per year under moderate truck traffic conditions. Blotter surfaces are estimated to deteriorate at a rate of 6 points per year under low and moderate truck traffic levels.*

***Perform Year 1 (1995) Analysis**:*

***Estimate 1995 Condition Index.** Using the deterioration rates discussed above, the county estimates the 1995 condition index of each section.*

***Section S1** will have a CI of 64 [80 - (4 years x 4 points/year)].*
***Section S2** will have a CI of 5 [29 - (3 years x 8 points/year)].*
***Section S3** will have a CI of 70 [100 - (5 years x 6 points/year)].*

***Identify Feasible Rehabilitation Alternative and Associated Cost.** Using the rehabilitation matrices provided in Tables 4A, 4B, and 4C, the county identifies a rehabilitation alternative and cost for each section.*

***Section S1**: Mill AC surface, construct patches, and place a functional AC overlay. \$26,710 (4,180 m^2 x \$6.39/m^2)*

***Section S2**: Pulverize and construct an AC overlay. \$21,276 (4,180 m^2 x \$5.09/m^2)*

***Section S3**: Patch alligator-cracked and potholed areas. Apply surface treatment. \$8,193 (8,360m^2 x \$0.98/m^2)*

Prioritize Projects. *Using table 5, the county prioritizes the identified projects.*

Section S1*: Priority 9*
Section S2*: Priority 7*
Section S3*: Priority 13*

Identify Available Funding and Compare to Project Cost. *The county has $25,000 for work in 1995. Because Section S2 has the highest priority, it is funded first. There is not enough money remaining to fund work on Section S1 or S3.*

Perform Year 2 (1996) Analysis*:*

Section S1: *S1 continues to deteriorate from its 1995 condition level. In 1996, it is estimated to reach a CI of 60. The triggered treatment is to mill the AC surface, construct patches, and place a functional AC overlay at a cost of $26,710.*

Section S2: *S2 is assumed to have a CI of 100 at the beginning of 1995 when it is overlayed. After one year of deterioration, using the AC pavement deterioration rate, the 1996 CI is estimated to be 96. No treatment is triggered for this section in 1995.*

Section S3: *S3 continues to deteriorate from a 1995 CI of 70 to a 1996 CI of 64. The triggered treatment is to patch alligator-cracked and potholed areas and apply a surface treatment at a cost of $8,200.*

The budget permits funding the Section S1 project in 1996.

Perform Year 3 (1997) Analysis:

Section S1: *S1 is assumed to have a CI of 100 at the beginning of 1995 when it receives a blotter course. After one year of deterioration, using the 6 points per year deterioration rate for AAC pavement, the 1996 CI is 94. No treatment is triggered for this section in 1996.*

Section S2: *The 1997 CI for S2 is estimated to be 92. No treatment is triggered for this section in 1995.*

Section S3: *S3 continues to deteriorate from a 1996 CI of 64 to a 1997 CI of 58. The triggered treatment is to patch alligator-cracked and potholed areas and apply a surface treatment. The rehabilitation matrix indicates that patching and application of a surface treatment is recommended to repair this section, at a cost of $8,200.*

The county is able to fund the Section 3 surface treatment in 1997.

This process is continued for as many years as desired.

Step 5. Assess Network Performance

Once the initial program has been generated, the estimated condition of the network is evaluated to determine whether it is acceptable. The condition of each section in the network is calculated as if all the repairs identified in the initial program had been performed.

Example 5. Assessing Network Performance

The following example illustrates the process a county may undergo to assess a network's condition if a given rehabilitation program is followed. This example uses the data presented in Example 4 and is illustrated in Figure 9.

Calculate Year 1 (1995) Condition Before Work Program. *An area-weighted condition is calculated for the network. (Note that this example is a subset of a network and only consists of three road sections.)*

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 64.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 5.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 70.

Network Area-Weighted CI:

$$= \frac{[(64x4,180)+(5x4,180)+(70x8,360)]}{(4,180+4,180+8,360)}$$

$$\mathbf{= 52.3}$$

Calculate Year 1 (1995) Condition After 1995 Work Program.

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 64.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 100.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 70.

Network Area-Weighted CI*:*

$$= \frac{[(64x4,180)+(100x4,180)+(70x8,360)]}{(4,180+4,180+8,360)}$$

$$\mathbf{= 76.0}$$

Calculate Year 2 (1996) Condition Before 1996 Work Program.

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 60.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 96.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 64.

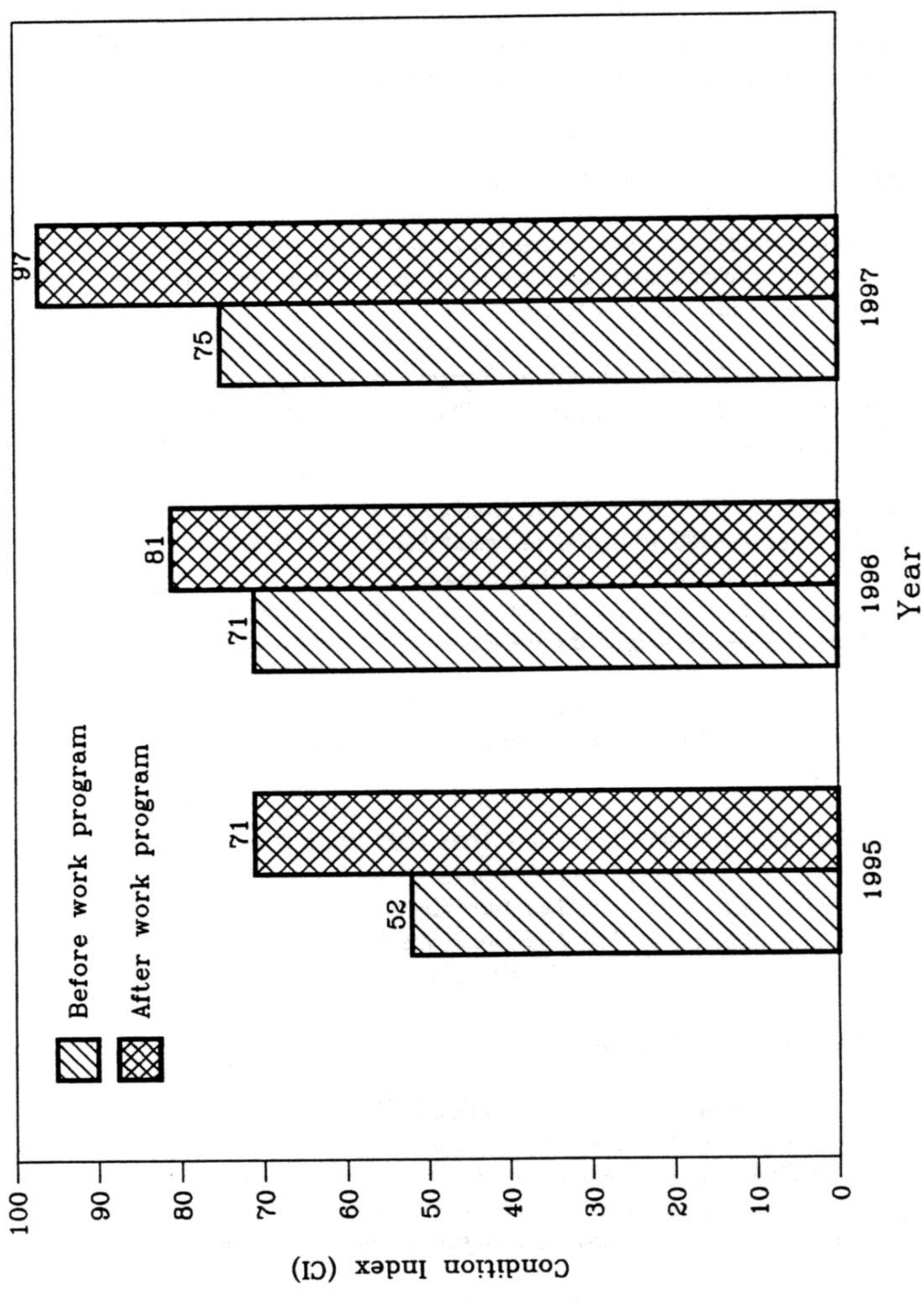

Figure 9. Summary of network area-weighted condition index (Example 5).

Network Area-Weighted CI:

$$= \frac{[(60x4{,}180)+(96x4{,}180)+(64x8{,}360)]}{(4{,}180+4{,}180+8{,}360)}$$

= 71

Calculate Year 2 (1996) Condition After 1996 Work Program.

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 100.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 96.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 64.

Network Area-Weighted CI: 81

Calculate Year 3 (1997) Condition Before 1997 Work Program.

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 94.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 92.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 58.

Network Area-Weighted CI: 75.5

Calculate Year 3 (1997) Condition After 1997 Work Program.

S1: Area is 4,180 m^2 (5,000 yd^2) and CI is 94.
S2: Area is 4,180 m^2 (5,000 yd^2) and CI is 92.
S3: Area is 8,360 m^2 (10,000 yd^2) and CI is 100.

Network Area-Weighted CI: 96.5

Step 6. Adjust Funding Levels and Generate New Program

The resulting network condition is then compared to the county's requirements. If the network condition is unacceptable, the funding levels can be adjusted and the rehabilitation program can be generated again. This is an iterative process that does not end until the county accepts the final recommended program. Table 6 contains a sample worksheet for generating a multi-year rehabilitation program. The worksheet can be used in a paper and pencil system or within a computerized spreadsheet. The first three rows of this table show the 1995 calculations from Example 4. A full-sized (11 x 17 in) copy of Table 6 is provided in Appendix A. In addition, a computerized copy of Table 6, generated using both Microsoft Excel and Lotus 1-2-3, is provided on the diskette in Appendix B.

Table 6. Sample worksheet for generating a multi-year rehabilitation program (paved roads only).

Section ID	Road name	Functional Classification	Pavement type	Pavement area, sm (sy)	Truck traffic level	Date of last Construction	Date of last inspection	Pavement condition rating	Rut depth rating	Rideability rating	Railroad Rideability rating	Polished Aggregate rating	Meets Geometric standards (yes/no)	Deterior-ation rate (CI/year)	Repair priority	Year of analysis	Projected condition index	Projected repair technique	Unit Cost of repair Techni-que ($/sm)	Projected repair cost ($)	road monthly blading frequency	oannual gravel road blading cost ($)
S1	Example 4	Arterial	AAC	4,180	High	1985	1991	80	2	3.5	3.0	2	yes	4.0	9	1995	64	Mill & Overlay	6.39	26,710	n/a	n/a
S2	Example 4	Local	Blotter	4,180	Medium	1970	1992	29	3	1.5	n/a	2	no	8.0	7	1995	5	Overlay	5.09	21,276	n/a	n/a
S3	Example 4	Local	Blotter	8,360	Low	1990	1990	100	not meas-ured	not meas-ured	n/a	not meas-ured	yes	6.0	13	1995	70	Surface Treat-ment	0.98	8,193	n/a	n/a

UPDATING A PAVEMENT MANAGEMENT SYSTEM

This section of the Guide applies only to paved surfaces. Please see the section of the Guide entitled *Gravel Road Management* for information on developing a multi-year rehabilitation program for gravel roads.

The pavement management system implementation process is not over after a county has developed its initial inventory and condition database. For a pavement management system to provide realistic and useful recommendations, it must base these decisions on current data that accurately reflect the conditions of the pavement network being managed. Therefore, it is important that a pavement management system be updated frequently with new inspection data. In addition, a pavement management system should be reevaluated regularly to make sure that pavement performance models, rehabilitation alternatives, prioritization guidelines, and cost models do not become outdated. If the system is not kept current, it will provide unrealistic recommendations, become discredited in the eyes of its users, and fall into disuse.

The following components of a pavement management system should be reevaluated on a periodic basis: inventory database, pavement condition database, pavement condition versus age models, cost models, applicable repair alternatives, and priority arrays. Each of these components is discussed in more detail below.

Inventory Database Update

The inventory database contains basic information on the pavement network, such as road network dimensions, pavement surface types, segmentation, construction and maintenance history, and so on. As pavement projects are conducted within a county, these database fields should be updated as needed. For example, if a road segment is partially overlaid, the original segment needs to be divided into two segments (one overlaid and one original). In this case, the segment dimensions also need to be revised, as does the last construction date of the overlaid section. Work history records need to be updated as well.

Pavement Condition Database Update

The condition of the pavement is the basic information a pavement management system draws upon to make rehabilitation recommendations. The pavements need to be periodically reinspected to make sure the condition information stored in the database realistically reflects the current condition of the pavements. A variety of reinspection schedules and approaches can be used; it is up to each agency to choose the approach that best fits its budget and needs.

Inspection Intervals

Reinspections are recommended every 1 to 3 years. However, the actual frequency of inspections should depend upon the anticipated change in condition of the pavements. For example, heavily truck-trafficked roads may need to be reinspected more frequently than low-volume rural roads. Staff availability and budget constraints will also influence the length of the reinspection cycle.

All the pavement sections in a network can be inspected in a single year, or a portion of the network can be inspected each year. This latter approach permits the distribution of staff and budget allocations. It also can help keep inspectors familiar with the rating procedure, because they do not have a 1- or 2-year hiatus between inspection periods. If such a lull period does occur, consider inspection training prior to conducting reinspections.

If only a portion of a network's sections are to be inspected in a year, the sections that should be reinspected and in what year the reinspections should occur can be determined by considering the following factors (adapted from the Army Corps of Engineers Technical Report M-86/04): minimum condition index inspection value, rate of deterioration, and maximum reinspection interval. This technique, described below, allows for a reasonable reinspection interval for all sections.

The minimum condition index inspection value should be established at a level higher than the level at which the rate of deterioration begins to increase (see Figure 10). By adopting this approach, a county will be able to identify the point in a pavement section's life when rehabilitation will be most beneficial and cost-effective. The M-86/04 report states that "one of the objectives of pavement management is to identify, monitor, and repair sections early while the repairs are less expensive."

A section with a high rate of deterioration should be inspected more frequently than one with a constant, low rate of deterioration. Each county must determine what deterioration rate is considered normal, and what is considered low and high. In addition to the minimum condition index and deterioration rate, a maximum reinspection interval should also be established. This will ensure that even a section exhibiting low deterioration rates and a high condition index, will not go too many years without reinspection.

Inspection Personnel

If full-time county personnel will conduct the pavement reinspections, then the inspections can be conducted in conjunction with other annual inspection activities. If full-time personnel are not available or are too costly to utilize, reliable inspections can be obtained by training part-time or temporary personnel. In addition, inspection work can be contracted out if needed.

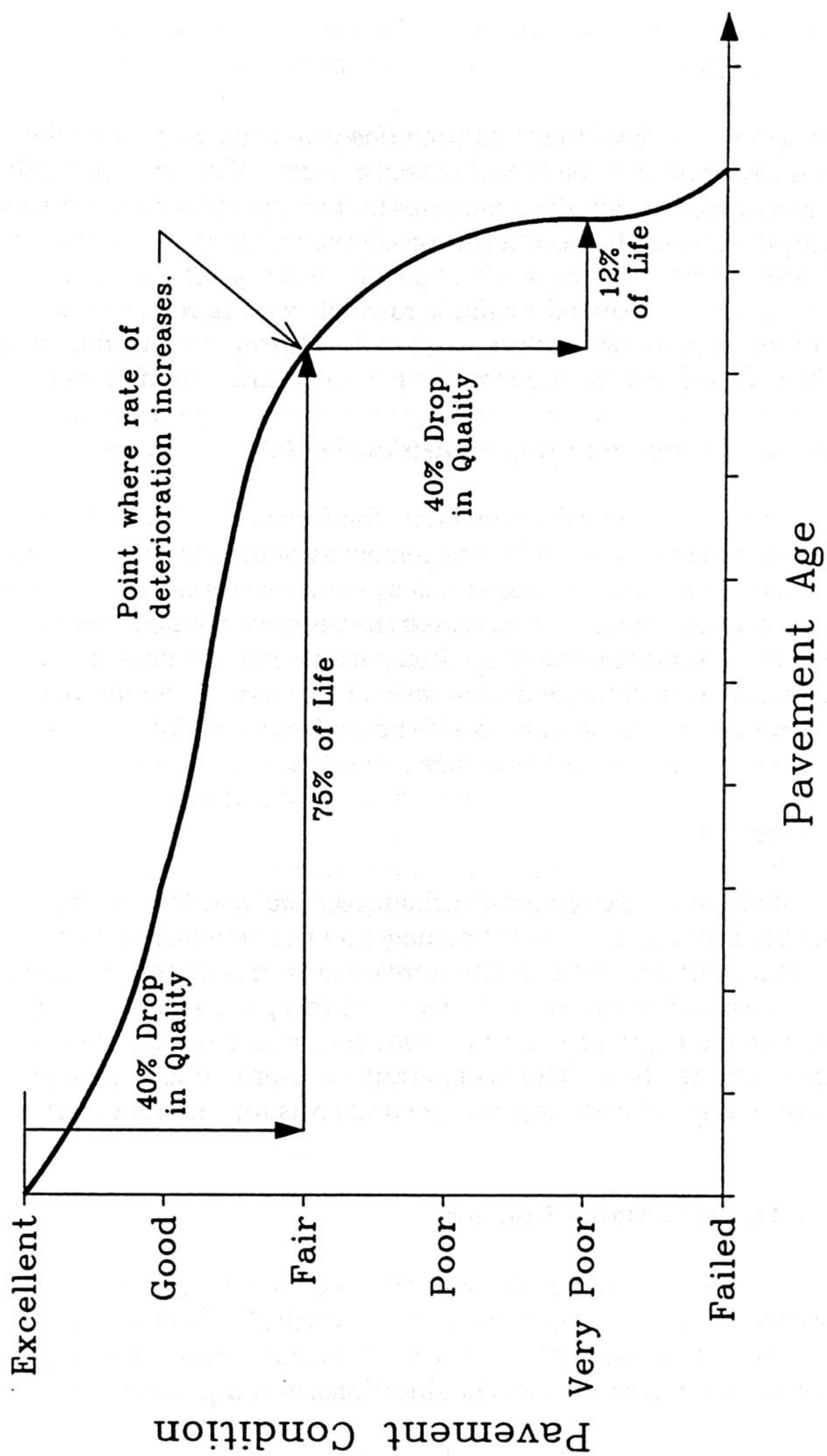

Figure 10. Illustration of a typical pavement deterioration curve.

Reinspecting Sample Units

If a low inspection rate was used in previous years, it is recommended that the same sample units inspected before be inspected again. This will permit the county to estimate pavement section deterioration rates more accurately than if different pavement sample units are inspected during different inspection years. If different sample units are inspected during each inspection year, differences in the calculated condition index could be due to the sample unit selection rather than the actual change in condition of the section. By resurveying the same sample units, this variable is eliminated. This will lead to improved pavement condition prediction estimates.

Refine or Replace Future Condition Prediction Models

A county needs to periodically reevaluate the future condition prediction models that are being used in the pavement management system. During the initial implementation of a pavement management system, these models are often based upon a limited set of data. As successive pavement inspections are performed, the additional data obtained can be used to refine the initial performance models so that they more accurately reflect actual pavement deterioration behavior. A county may also decide to select a different method of condition prediction when more data are collected and are available for the development of performance models.

Cost Models Updates

It is a fact of life that little remains unchanged from year to year, particularly economic factors. Because a pavement management system estimates costs based on unit cost factors for different rehabilitation treatments, it is important that these costs be reviewed on at least an annual basis. To facilitate this process, it is recommended that as projects are bid and completed, cost information should be stored in the pavement management system database. This will permit the user to track cost factors over time and to more accurately estimate appropriate unit costs for different treatment alternatives.

Rehabilitation Decision Matrix Updates

The initial set of rehabilitation alternatives a pavement management system considers may include such items as overlays, reconstruction, chip seals, and so on. The county defines when each of these alternatives may be appropriately applied, in terms of condition ranges, functional classifications, existing standards, and truck traffic.

Over time, it is likely that these parameters will change, and the county must update the pavement management system to reflect these changes. In addition, it may be found that a treatment alternative should be eliminated from the list due to high cost or poor performance, or that a new alternative has shown potential and should be added to the list. At least once a year, the rehabilitation decision matrix being used in the pavement management system should be reviewed.

A life-cycle cost analysis is a very good tool for evaluating the effectiveness of a county’s rehabilitation decision matrix. A life-cycle cost analysis considers not only the initial cost of each rehabilitation option, but also incorporates subsequent maintenance and rehabilitation costs that are expected to be incurred. For instance, the periodic patching of potholes and sealing of cracks in a blotter pavement may be an effective form of maintenance for blotter pavements in good or better condition. However, as the quantity of patching and sealing increases and the frequency at which they are performed decreases, the cost-effectiveness of this repair technique is reduced. In some instances, the cost of patching and sealing may be so great that it is more cost effective (in terms of life-cycle costs) to overlay the blotter pavement with AC.

Priority Models Updates

Normally, only a portion of identified project needs can be addressed within a given year. Those that are not programmed will need to wait another year, adding to the backlog of projects. A prioritization model may have been established during the initial implementation of the pavement management system. This model assists the program in determining which projects to fund first when budget allocations are insufficient to fund all triggered projects. Often, these priority models are based on such criteria as functional classification and condition.

The priority model needs to be reviewed annually to ensure that it reflects the implementing county's policies with respect to project prioritization.

ENHANCING A PAVEMENT MANAGEMENT SYSTEM

The pavement management system presented in this guide is a basic paper and pencil system. There are several activities a county can undertake to enhance this system, including the following:

- Computerize the pavement management system.
- Build comprehensive database.
- Develop and refine pavement performance models.
- Implement more powerful programming analysis routines.
- Link the pavement management system to maps.
- Add other infrastructure elements to the pavement management system.
- Interface with other management systems.
- Use detailed condition survey approach.
- Refine rehabilitation strategies.

Computerize the Pavement Management System

The basic system presented in this guide can be utilized manually using paper and pencil. Although a manual system may be possible for a small network, the efficiency and cost-effectiveness of storing data on a computer makes an automated database a very practical alternative. As a county's database grows and additional pavement management system requirements are identified, it is likely that computerization of the system will be required. Initially, a simple computerized system in the form of a spreadsheet can be used to facilitate the retrieval and analysis of data. Eventually, a full-scale pavement management system software program may be desired.

Build Comprehensive Database

During the initial implementation of a pavement management system, the pavement information collected generally includes, at a minimum, physical dimensions, pavement surface type, pavement last construction date, and pavement condition. Although this information provides a firm foundation for a pavement management system, there are other data elements that can be collected and stored in a pavement management system database that will provide significant benefits to a county.

Additional data elements that would enhance an existing pavement management system database include the following:

- Construction history.
- Maintenance history.
- Soils information.
- Climatic data.
- Past evaluation data.
- Past and anticipated future traffic information.

A comprehensive review of existing records may be conducted to collect this information. The records information usually needs to be supplemented by information obtained through interviews with engineers and maintenance personnel, and often a limited coring program is conducted. This task culminates in the preparation of a historical record for each pavement section in the database.

The collected information is used to accurately divide the pavements into distinct pavement sections and to identify pavement performance trends on which future maintenance and rehabilitation requirements can be based. In addition, this information provides valuable insight into pavement behavior. Through an analysis of the successive rehabilitation treatments that have been applied to the pavements within the county's network, it is possible to determine how long different rehabilitation alternatives have lasted before a subsequent rehabilitation was required.

Analyzing the data helps engineers and planners determine which designs and repair methods have been the most successful in the past, and which have not been as cost-effective. Although many of the findings resulting from this activity may not be surprising to those who work closely with a county's pavements, it is extremely important to document the results. Over time, practices often come full circle, and unsuccessful approaches could be implemented again without the historical inventory information at hand.

Develop and Refine Performance Models

As mentioned earlier, a county needs to periodically reevaluate the future condition prediction models that are being used by the system. This reevaluation may result in developing new curves, refining existing curves, or adopting a new method of modeling pavement performance.

During the initial implementation of a pavement management system, pavement performance models are often based on a limited set of data. As successive pavement inspections are performed, the additional data obtained can be used to refine the initial performance models so they more accurately reflect actual pavement deterioration behavior. In addition, as more data become available it may be possible to generate additional performance models. For example, during an initial implementation there may only be sufficient data to develop one model for asphalt-surfaced roads and one model for concrete roads. Over time, as more information is collected, the asphalt-surfaced road model can be further broken down into original asphalt, asphalt overlay on asphalt pavement, asphalt overlay on concrete pavement, and so on.

As a county collects condition data over time and establishes a historical pavement management system database, it may be possible to adopt more sophisticated methods of predicting future pavement condition than the one described previously in this guide. The following is a description of selected pavement performance modeling techniques that a county may want to consider using as its pavement management system evolves.

Section-Specific Deterioration Rates

One method that is available for predicting future pavement condition involves tracking a given pavement section's condition over time. Initially, performance modeling is based upon two data points. The first data point assumes that the condition index was 100 at the time of construction or rehabilitation. The second data point represents the condition and age of the pavement at the time of condition inspection. A straight line is then drawn through the two points, and the equation of this line is used to predict future pavement condition. After additional historical condition versus age data are available for a section, straight lines can be drawn through the last two data points, or a curve can be developed using all data points, to predict future condition.

This method uses section-specific data upon which to base performance models. It should be noted that maintenance (crack sealing, patching, fog seals, and so on) often leads to intermittent increases in pavement condition without resetting the last construction date of a section. This effect may mask the overall deterioration trend of an individual pavement section and may result in misleading pavement performance models. In addition, during the time when only two data points are available and straight-line predictions are made, there is the disadvantage that pavements rarely display constant, linear deterioration behavior in real life. Finally, this method almost mandates the use of a computer, because each section is modeled individually.

Multiple Linear Regression Modeling

A more complex method for developing pavement performance models is to place all variables used in determining pavement condition on the right-hand side of an equation. Every pavement section then has its own unique performance pattern. This technique is an example of a multiple linear regression model. The performance of each pavement section is a function of individual items relating to each section. Individual items in the prediction equations could include truck traffic levels, subgrade strength, maximum surface deflection, and climate. This method often produces relatively complicated models and requires complex and comprehensive data. This type of section-specific modeling is data intensive.

Family Condition Prediction Modeling

Another modeling technique that has been used successfully to predict future performance is a natural outgrowth of the basic approach presented early in this chapter. This method, like the one described previously, involves organizing the pavement network into groups of pavements, called *families*, that perform in a similar manner. The sections within a family have similar characteristics, such as surface type, traffic, and pavement structure. For example, asphalt pavements that have never received an overlay and are subjected to heavy traffic may be grouped into a family. This approach makes a basic assumption that pavements within the same grouping will perform similarly throughout their life.

By plotting the condition and age of all pavement sections that fit within a given family description, a curve can be generated that represents the performance trends of that particular family. Individual section predictions are made using the relative position of a section to the prediction curve that represents it. This is based on the assumption that the decline in pavement condition is similar on all sections represented by a particular curve. Thus, the categorization of pavements into like-performance groups is very important. The future condition of a section is a function of its current condition relative to age. A curve is drawn through the index (age point for the section being predicted) parallel to the representative prediction curve. This method is advantageous in that it is easy to understand and modify in the future. In addition, it does not require complex data. This modeling technique is illustrated in Figure 11.

Augmenting Performance Models

Pavement condition prediction models must make sense and follow the traditional line of how the county would expect pavement sections to perform based on past experience. It is probable that augmentation of historical data by incorporating expert opinion will be required during the development of performance models. Augmentation may also be required to supplement limited historical data, to accommodate for maintenance effects, and to define a terminal age.

There may be performance models where data points are either missing or are insufficient to successfully model pavement behavior. In these instances, an expert's opinion is needed to determine whether the curve is reasonable and to provide alternate or additional points. In some performance models, the performance curves may be based on data collected over a relatively narrow range of pavement life. Again, expert opinion is required in this situation to accurately develop a performance model.

Expert opinion is also needed to account for the effect of maintenance on pavement performance. Several of the performance curves will probably slope downward initially but flatten out over time. The performance curves based solely on historical data will show the effect of the maintenance effort, because the condition of road sections is often not allowed to fall below certain levels through maintenance effort.

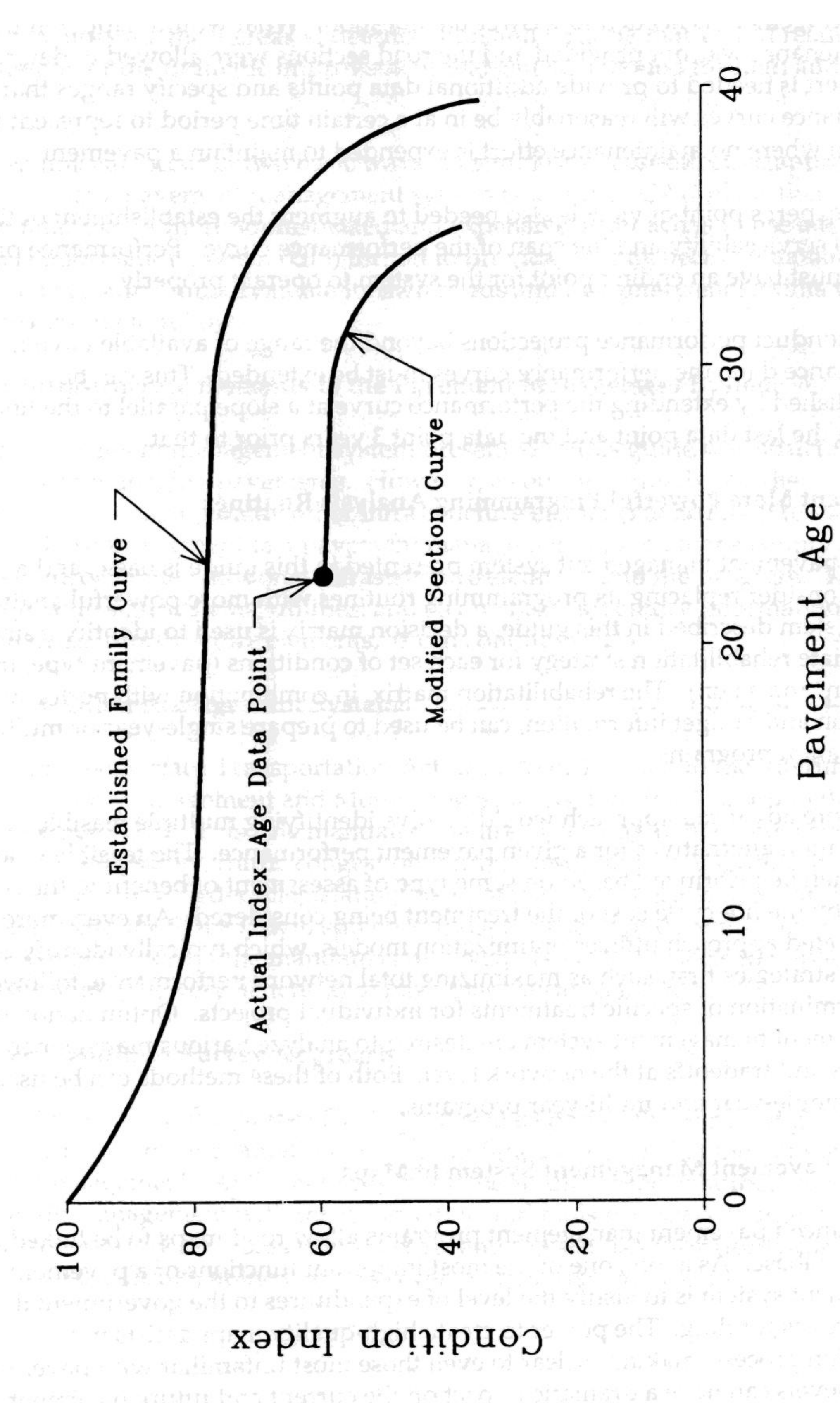

Figure 11. Illustration of the family curve modeling technique.

Expert judgment is needed to answer the question, "What would happen if this level of maintenance was not provided and the road sections were allowed to deteriorate?" The expert is needed to provide additional data points and specify ranges that the performance curves will reasonably be in at a certain time period to represent the situation where no maintenance effort is expended to maintain a pavement.

An expert's point of view is also needed to augment the establishment of the terminal serviceability and life span of the performance curve. Performance prediction curves must have an ending point for the system to operate properly.

To conduct performance projections beyond the range of available pavement performance data, the performance curves must be extended. This can be accomplished by extending the performance curve at a slope parallel to the line between the last data point and the data point 3 years prior to that.

Implement More Powerful Programming Analysis Routines

The pavement management system presented in this guide is basic, and a county should consider replacing its programming routines with more powerful analysis tools. In the system described in this guide, a decision matrix is used to identify a single appropriate rehabilitation strategy for each set of conditions (pavement type, traffic condition, and so on). The rehabilitation matrix, in combination with performance prediction and budget information, can be used to prepare single-year or multi-year rehabilitation programs.

A more advanced approach would involve identifying multiple feasible rehabilitation alternatives for a given pavement performance. The feasible strategies would then be prioritized based on some type of assessment of benefit to the county, divided by the life-cycle cost of the treatment being considered. An even more sophisticated approach utilizes optimization models, which typically identify optimal network strategies first, such as maximizing total network performance, followed by the determination of specific treatments for individual projects. Optimization models in a pavement management system are desired to analyze various management strategies and tradeoffs at the network level. Both of these methods can be used to prepare single-year and multi-year programs.

Link the Pavement Management System to Maps

Advanced pavement management programs allow road maps to be linked to the system database. As a tool, one of the most important functions of a pavement management system is to justify the level of expenditures to the governmental body that approves funding. The power to create high-quality maps assists in the justification process, making it clear to even those most unfamiliar with pavements that funding levels can have a dramatic impact on the current and future pavement condition and can significantly affect expenditures in the future. A good pavement management system has the capability to examine any number of funding scenarios, using maps to illustrate the increased deterioration and backlog that would result if the budget were cut, or the dramatic improvement that can be obtained through additional funding.

The map link can occur in two basic ways. A simple and cost-effective approach to linking maps with a pavement management system is to utilize CAD maps that can be linked to a database. A more sophisticated and expensive approach is to use a true geographical information system (GIS) format to provide the link between database and maps. Each county must evaluate its own needs and budgetary constraints when electing which route to follow.

Add Other Infrastructure Elements to the Pavement Management System

The basic pavement management system presented in this guide was structured to assist a county in managing pavements. However, a county normally has the responsibility for managing many other infrastructure elements in addition to pavements. One enhancement of a pavement management system that a county should consider is to incorporate additional infrastructure elements into the program. These items may include sign systems, utilities, and so on. Basic inventory information can be collected on these infrastructure elements, as can condition data.

Interface With Other Management Systems

The Intermodal Surface Transportation Act (ISTEA) of 1991 led to the interim final rule (CFR Part 614: Management and Monitoring Systems; Interim Final Rule) that was issued in December 1993. This rule mandated the use of several management systems, including pavement, safety, traffic congestion, bridge, and public transportation facilities. However, new Federal legislation may not mandate these systems at the local level. Nevertheless, the SDDOT will still encourage the use of pavement management by local government, even if the mandate is removed. If a county elects to implement other systems, it may be very beneficial to have these systems interact.

Use Detailed Condition Survey Approach

The *Rural Roads Condition Survey Guide*, prepared as part of this series of guides, presents a visual pavement evaluation method designed to be used at the network level of pavement management. At the network level, the results of the condition survey are used to provide management with the information and tools necessary to monitor the condition of the network, to assess future needs, and to establish the priority for timely rehabilitation. Specifically, at the network level, distress data are used to:

- Assess overall network condition.
- Determine cause of distress.
- Identify candidate repair projects.
- Provide general indicator of type of repair work needed.
- Determine whether preventive maintenance is feasible.
- Schedule reinspection.
- Provide a rational method for prioritization.
- Define M&R backlog and accruing needs.
- Monitor pavement performance.

A more detailed inspection procedure should be considered if the collected data are to be used at the project level. Distress data have many applications at the project level, including the following:

- Define project limits.
- Determine mechanisms of pavement deterioration.
- Determine rate of deterioration.
- Compute repair quantities and cost.
- Provide necessary information to select rehabilitation alternatives.
- Provide a guide for further testing.

A condition survey that involves physically identifying distress types and measuring distress severities and quantities is recommended for project-level evaluations.

Refine Rehabilitation Strategies

During initial implementation of a pavement management system, it is very likely that only a few rehabilitation strategies, such as overlays and blotter courses, are programmed into the system. As time goes on, these rehabilitation strategies can be refined. Other activities, such as recycling or other repair techniques, can be incorporated into the rehabilitation decision matrix for consideration in the pavement management system.

GRAVEL ROAD MANAGEMENT

As mentioned earlier in this Guide, the approach to gravel road management differs in some respects from the approach used for paved road management. As in paved road management, gravel road management involves the collection of inventory data to define the road network and the conduct of a visual inspection of the pavement to determine condition. However, the way the collected information is used to manage the roads differs.

Paved road management involves the use of performance models to predict pavement condition in the future. Different maintenance and rehabilitation alternatives are identified that are appropriate to fix pavements within given condition levels. The use of the performance models allows you to predict in time when a given section of paved road will require a certain level of rehabilitation.

Gravel road management does not necessarily involve the prediction of performance in the future in order to plan maintenance and rehabilitation. This is due to the fact that, unlike paved roads, gravel roads do not exhibit predictable long-term deterioration rates. The condition of gravel roads can fluctuate weekly, if not daily, depending upon weather and traffic. For example, significant rainfall or a sudden increase in heavy traffic can change the condition of a gravel road in a matter of hours. Washboarding, loose rock, and dust are examples of distress types that can change quickly due to weather. Often, the type of deterioration caused by these short-term effects can be corrected by routine maintenance.

Gravel road deterioration can also be due to long-term problems. Material deficiencies or structural inadequacy are typically associated with long-term problems that cannot be easily corrected with routine maintenance techniques. A primary consideration in gravel road performance is the depth of the gravel layer and the quality of material. The gravel road must be thick enough to accommodate actual traffic levels. This thickness will be dependent upon the existing soils and the amount of heavy traffic. The gradation and durability of the gravel are also important and a proper mixture of larger aggregate, sand sized aggregate, and fines are needed. Distresses such as ruts and potholes indicate structural and material related problems.

To address the frequent change in condition of gravel roads, a different approach to management is used. Minimum cycles for routine maintenance activities are defined. For example, it may be determined that gravel roads under a certain traffic level need to be bladed 4 times per month and will require regraveling every 5 years. With this information, you can develop a multi-year maintenance plan for your gravel roads.

The information collected during the visual condition inspection procedure is used to determine whether routine maintenance activities are appropriate. A gravel road may have such a low condition index, or be exhibiting such a high deterioration rate, that routine blading or regraveling will no longer successfully address the problem. In this situation, where the condition rating falls below the minimum acceptable condition rating, you should identify the primary form(s) of distress using the *Rural Road Condition Survey Guide* and determine the appropriate repair method using the *Rural Road Design, Maintenance, and Rehabilitation Guide*.

Table 7 contains a preliminary decision matrix for gravel road maintenance. It should only be used as long as the road is maintained above the specified minimum condition rating. This table is based on the results of interviews with several South Dakota counties conducted during the 1991 Local Road Needs Study. The costs in this table represent statewide averages. This table is just a template and is provided as a starting point for a county to use. Each county should review this decision matrix carefully and modify it as needed to meet local situations and policies. For example, costs will certainly vary significantly from county to county, and local cost data should be used when possible.

Example 6. Gravel Road Management

The following example illustrates the process a county may go through to manage a gravel road system. The first year of this example, 1995, is shown in Table 8. To illustrate how the paved road management system is integrated with the gravel road management system, the first-year (1995) results of example 4 are also illustrated in Table 8. A full-sized (11" × 17") copy of Table 8 is included in Appendix A. A computerized copy (in both Microsoft Excel and Lotus 1-2-3 formats) is also provided on the diskette in Appendix B.

Collect inventory information: *County A gathers the following information about the gravel roads in its jurisdiction.*

Road Section S4: *S4 is a gravel road which receives greater than 50 ADT and high levels of truck traffic. It crosses level terrain. The area of S4 is 8,360 m^2 (10,000 yd^2). It was last regravelled in 1992. S4 meets current geometric standards.*

Road Section S5: *S5 is a gravel road that receives less than 50 ADT. It crosses mountainous terrain. The area of S5 is 4,180 m^2 (5,000 yd^2). It was last regravelled in 1990. S5 meets current geometric standards.*

Road Section S6: *S6 is a gravel road that receives greater than 50 ADT and low levels of truck traffic. It crosses rolling terrain. The area of S6 is 8,360 m^2 (10,000 yd^2). It was last regravelled in 1990. S6 meets current geometric standards.*

Collect condition information: *The county inspects the gravel roads using the methodology outlined in Pavement Condition Survey Guide for Rural Roads, which is one of the three documents in this series. The results are the following:*

Road Section S4: *Condition rating of 45, rideability rating = 1.8.*

Road Section S5: *Condition rating of 35, rideability rating = 1.5.*

Road Section S6: *Condition rating of 70, rideability rating = 2.5.*

Develop multi-year maintenance plan: *The county uses the collected information, in conjunction with table 7, to develop a multi-year maintenance plan.*

Perform Year 1 (1995) Analysis:

S4. *The condition rating of 45 falls below the minimum condition rating acceptable for routine maintenance. The county identified the primary forms of distresses present using the Survey Guide, and determined that the road needed to have the crown corrected, drainage improved, and gravel re-applied. This work was completed in 1995. A regimen of blading 4 times per month was then initiated.*

S5. *Blading is performed 2 times per month.*

S6. *Blading is performed 3 times per month.*

Perform Year 2 (1996) Analysis:

S4. *Blading is performed 4 times per month.*

S5. *Regravel. Continue blading 2 times per month.*

S6. *Blading is performed 3 times per month.*

Perform Year 3 (1997) Analysis:

S4. *Blading is performed 4 times per month.*

S5. *Blading is performed 2 times per month.*

S6. *Regravel. Continue blading 3 times per month.*

Table 7. Gravel road maintenance guidelines.

ADT	ADTT	Type of terrain	Minimum condition rating[a]	Gravel frequency (years)	Cost of gravel[b]		Blade frequency (per month)	Cost of blading[**]	
					$\$/\text{m}^2$	$\$/\text{yd}^2$		$\$/\text{m}^2$	$\$/\text{yd}^2$
> 50	H	Level	55	4	1.70	1.42	4	0.0024	0.002
		Rolling	55	5	1.70	1.42	4	0.0024	0.002
		Mountainous	55	4	1.70	1.42	4	0.0024	0.002
	L	Level	40	7	1.70	1.42	3	0.0024	0.002
		Rolling	40	7	1.70	1.42	3	0.0024	0.002
		Mountainous	40	6	1.70	1.42	3	0.0024	0.002
< 50	L	Level	25	5	1.70	1.42	2	0.0024	0.002
		Rolling	25	7	1.70	1.42	2	0.0024	0.002
		Mountainous	25	6	1.70	1.42	2	0.0024	0.002

[a]Minimum condition rating allowed for routine maintenance to be appropriate. If the condition rating falls below the minimum condition rating, identify the primary form(s) of distress using the Survey Guide and determine the appropriate repair method using the Design, Maintenance, and Rehabilitation Guide.

[b]Cost figures are for square measurements and are not for volume measurements.

Table 8.   Sample worksheet for generating a multi-year rehabilitation program (gravel and paved roads).

Section ID	Road name	Func-tional classifi-cation	Pave-ment type	Pave-ment area, sm (sy)	Truck traffic level	Date of last construc-tion	Date of last inspec-tion	Pave-ment condi-tion rating	Rut depth rating	Ride-ability rating	Rail-road ride-ability rating	Polished aggre-gate rating	Meets geo-metric stan-dards (yes/no)	Deterior-ation rate (CI/year)	Repair priority	Year of analysis	Projected condition index	Projected repair technique	Unit Cost of repair techni-que ($/sm)	Projected repair cost ($)	Gravel road monthly blading frequency	Projected annual gravel road blading cost ($)
S1	Example 4	Arterial	AAC	4,180	High	1985	1991	80	2	3.5	3.0	2	yes	4.0	9	1995	64	Mill & Overlay	6.39	26,710	n/a	n/a
S2	Example 4	Local	Blotter	4,180	Medi-um	1970	1992	29	3	1.5	n/a	2	no	8.0	7	1995	5	Overlay	5.09	21,276	n/a	n/a
S3	Example 4	Local	Blotter	8,360	Low	1990	1990	100	not meas-ured	not meas-ured	n/a	not meas-ured	yes	6.0	13	1995	70	Surface Treat-ment	0.98	8,193	n/a	n/a
S4	Example 6	Local	Gravel	8,360	High	1992	1995	45	n/a	1.8	n/a	n/a	yes	n/a	4	1995	n/a	correct crown, improve drainage, and regravel	1.7	14,212	4	963
S5	Example 6	Local	Gravel	4,180	Low	1990	1995	35	n/a	1.5	n/a	n/a	yes	n/a	8	1995	n/a	blading	n/a	n/a	2	241
S6	Example 6	Local	Gravel	4,180	Low	1990	1995	70	n/a	2.5	n/a	n/a	yes	n/a	13	1995	n/a	blading	n/a	n/a	3	361

Note: Gravel road blading cost is estimated to be \$0.0024 per square meter.

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GLOSSARY

ADT: Average Daily Traffic.

Asphalt concrete (AC): Aggregate mixture with an asphalt cement binder.

Asphalt concrete overlay on an asphalt concrete pavement (AAC): Asphalt concrete pavement that has received one or more asphalt concrete overlays.

Asphalt concrete overlay on a portland cement concrete pavement (APC): Portland cement concrete pavement that has received one or more asphalt concrete overlays.

Basic forecasting method: A basic approach to modeling pavement condition in which specified deterioration rates are assumed.

Blading: Regrading of gravel surface to restore proper pavement crown and remove minor corrugations, potholes, and ruts.

Blotter: A gravel road that has received a surface treatment consisting of a uniform application of asphalt to the road surface, followed immediately by a layer of aggregate chips.

BST: Blotter or chip seal pavements.

Condition data: Quantified description of the condition of the pavement.

Family: Group of pavements with similar performance characteristics, such as surface type and traffic levels.

Functional class: The classification of pavements based on function.

Gravel road: The structure of a gravel road usually consists of a gravel layer overlying the subgrade.

Inspection intervals: Frequency of field inspection.

Inventory data: The definition of all the physical elements of a pavement network.

Multiple linear regression modeling: A mathematical representation of the performance of the pavements in which the pavement condition is linearly correlated to multiple parameters like the age, traffic, strength and surface thickness.

Multi-year rehabilitation program: Establishment of maintenance and rehabilitation requirements and priorities based on inspection data and other relevant information, such as traffic.

Network definition: Process of dividing road network into manageable sections for conducting surface inspection and determining maintenance and rehabilitation requirements and priorities.

Network-level management: Management of an entire network of pavements.

Paved road: A road with a paved surface like AC, PCC, AAC, and APC.

Pavement distress: External indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or any combination thereof.

Pavement management: A set tools or methods that can assist decision makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition.

Performance modeling: A mathematical approach to define the deterioration of a pavement.

Piecewise linear forecasting method: A linear modeling approach in which the performance of a section is modeled.

Portland cement concrete (PCC) pavement: Aggregate mixture with portland cement. In this document, refers to both reinforced and nonreinforced jointed pavement.

Prioritization: Ranking of projects to be used in case of limited funding.

Prioritization scheme: The criteria for prioritization of projects.

Project-level management: Management of a specific section or a group of pavements that are part of a network.

Rehabilitation decision matrix: Definition of feasible rehabilitation alternatives and the conditions under which they can be applied.

Section: A section is part of the network that has certain consistent characteristics, such as structural composition, construction history, and traffic levels.

Service life: The time span from construction to the terminal condition of a pavement section.

Terminal condition index: The condition index of a pavement beyond which it is considered to be not functional.

"Worst-first" approach: Prioritization based on the condition of the pavements, with the pavements in worst condition receiving the highest priority for repair.

APPENDIX A – EXCEL SPREADSHEETS (TABLES 2, 6, AND 8) AND WORD (FIGURES 2 AND 3)

APPENDIX B – DISKETTE NOT INCLUDED IN THIS VERSION. SEE APPENDIX A

Table 2. Sample network inventory table.

Section ID State	Section ID County	Road Name	From	To	Functional class	Surface type	Section length, m (ft)	Traveled surface width, m (ft)	Section area, sm (sy)	Average daily traffic	Percent heavy trucks	Shoulder type			Date of last construction	Date of last inspection	Condition rating

Table 6. Sample worksheet for generating a multi-year rehabilitation program (paved roads only).

Section ID	Road name	Functional classification	Pavement type	Pavement area, sm (sy)	Truck traffic level	Date of last construction	Date of last inspection	Pavement condition rating	Rut depth rating	Rideability rating	Railroad rideability rating	Polished aggregate rating	Meets geometric standards (yes/no)	Deterioration rate (CI/year)	Repair priority	Year of analysis	Projected condition index	Projected repair technique	Unit Cost of repair technique ($/sm)	Projected repair cost ($)	Gravel road monthly blading frequency	Projected annual gravel road blading cost ($)
S1	Example 4	Arterial	AAC	4,180	High	1985	1991	80	2	3.5	3.0	2	yes	4.0	9	1995	64	Mill & Overlay	6.39	26,710	n/a	n/a
S2	Example 4	Local	Blotter	4,180	Medium	1970	1992	29	3	1.5	n/a	2	no	8.0	7	1995	5	Overlay	5.09	21,276	n/a	n/a
S3	Example 4	Local	Blotter	8,360	Low	1990	1990	100	not measured	not measured	n/a	not measured	yes	6.0	13	1995	70	Surface Treatment	0.98	8,193	n/a	n/a

Table 8. Sample worksheet for generating a multi-year rehabilitation program (gravel and paved roads).

Section ID	Road name	Functional classification	Pavement type	Pavement area, sm (sy)	Truck traffic level	Date of last construction	Date of last inspection	Pavement condition rating	Rut depth rating	Rideability rating	Railroad rideability rating	Polished aggregate rating	Meets geometric standards (yes/no)	Deterioration rate (CI/year)	Repair priority	Year of analysis	Projected condition index	Projected repair technique	Unit Cost of repair technique ($/sm)	Projected repair cost ($)	Gravel road monthly blading frequency	Projected annual gravel road blading cost ($)
S1	Example 4	Arterial	AAC	4,180	High	1985	1991	80	2	3.5	3.0	2	yes	4.0	9	1995	64	Mill & Overlay	6.39	26,710	n/a	n/a
S2	Example 4	Local	Blotter	4,180	Medium	1970	1992	29	3	1.5	n/a	2	no	8.0	7	1995	5	Overlay	5.09	21,276	n/a	n/a
S3	Example 4	Local	Blotter	8,360	Low	1990	1990	100	not measured	not measured	n/a	not measured	yes	6.0	13	1995	70	Surface Treatment	0.98	8,193	n/a	n/a
S4	Example 6	Local	Gravel	8,360	High	1992	1995	45	n/a	1.8	n/a	n/a	yes	n/a	4	1995	n/a	correct crown, improve drainage, and regravel	1.7	14,212	4	963
S5	Example 6	Local	Gravel	4,180	Low	1990	1995	35	n/a	1.5	n/a	n/a	yes	n/a	8	1995	n/a	blading	n/a	n/a	2	241
S6	Example 6	Local	Gravel	4,180	Low	1990	1995	70	n/a	2.5	n/a	n/a	yes	n/a	13	1995	n/a	blading	n/a	n/a	3	361

Note: Gravel road blading cost is estimated to be $0.0024 per square meter.

Inventory Data Form

Inventory date ______________________
By ______________________

Section Identification

Section ID No. ______________________
Road name ______________________ Length, m (ft) ______________________
From ______________________ To ______________________

Roadway Classification and Traffic Data

Functional classification of road ______________________
Average daily traffic ______________________
Percent heavy trucks ______________________

Roadway Inventory Data

Traveled surface width, m (ft) ________ Shoulder width, m (ft) ________
ROW width, m (ft) ______________________ Number of lanes ______________________
Surface type (circle one): AC, PCC, Blotter, or Gravel
Shoulder type (circle one): AC, PCC, Blotter, Gravel, Turf, None, or Other
Curb and gutter (circle one): Yes/No
Comments ______________________

Cross Section Information

Layer	Material	Thickness mm (in)	Construction date	Other information
Subgrade				

Figure 2. Illustration of sample inventory data form.

Condition Rating Form

Section Identification

Section ID No. ______________________ Road name ______________________

From ______________________ To ______________ Length (ft) ______________

Roadway Surface Type (circle one): AC, PCC, Blotter, or Gravel

Condition Rating Data

Date	Members of rating team	Average pavement condition rating	Pavement rideability rating (0 to 5)	Railroad crossing rideability rating (0 to 5)	AC rut depth rating (0 to 4)	Polished aggregate rating (0 to 2)	Comments

Figure 3. Illustration of sample condition rating form.