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NHI Course No. 13154

Pavement Preventive Maintenance

Instructor Guide

National Highway Institute

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Pavement Preventive Maintenance

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Prepared by:
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National Highway Institute

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This training course is the product of the efforts of many people. Five states willingly agreed to share their pavement preventive maintenance experience with the project team and serve as case studies for this manual. Those states, and the representatives listed below, gave generously of their time and knowledge so that their agencies' experience could be more broadly disseminated.

Case Study State	Contact Person(s)
California	Randell H. Iwasaki, Deputy Director–Maintenance and Operations
	Larry H. Orcutt, Program Manager–Maintenance
Georgia	Wouter Gulden, State Materials and Research Engineer
Michigan	Larry Galehouse, Pavement Maintenance Engineer
New York	Ed Denehy, Transportation Maintenance Division
Texas	Joe S. Graff, Director–Maintenance Section

This entire project came about as a result of a joint initiative among several AASHTO states, the Federal Highway Administration (FHWA), and the Foundation for Pavement Preservation (FPP). FPP is a non-profit industry organization whose purpose is to promote research and training in preventive maintenance. Their assistance was supplemented by financial support from the Asphalt Emulsion Manufacturers Association (AEMA), the Asphalt Recycling & Reclaiming Association (ARRA), and the International Slurry Surfacing Association (ISSA). In addition to financial contributions to the project, FPP staff helped organize and coordinate meetings and facilitate the distribution and evaluation of preliminary draft reports. In that regard, the efforts of John Fiegel, FPP Executive Director, are especially appreciated.

Throughout the course of assembling the technical material for this project, input, feedback, and evaluations have been provided by a Preventive Maintenance Expert Task Group (ETG) and members of FPP. Specifically, input was provided by the following individuals:

Member	Affiliation
Mr. Bill Ballou	FPP and Koch Materials Company
Mr. Jim Chehovits	CRAFCO
Mr. Barry Dunn	International Slurry Surfacing Association
Mr. John Fiegel	FPP
Mr. Larry Galehouse	Michigan DOT
Mr. Jose Garcia	FHWA
Mr. Kent Hansen	National Asphalt Pavement Association
Mr. Jack Hardin	Mariani Asphalt Company
Dr. Gary Hicks	FPP and Oregon State University
Mr. Denny Jackson	FPP and Washington State DOT
Ms. Pat Lees	National Highway Institute
Mr. Bob McQuiston	FHWA
Mr. Jim Moulthrop	Koch Materials Company
Mr. Richard Nelson	Consultant
Mr. John Roberts	ACPA
Mr. Jim Sorenson	FHWA
Mr. Jim Stevenson	Montana DOT

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David G. Peshkin
Kurt D. Smith
Kathryn A. Zimmerman

Applied Pavement Technology, Inc.

Donald N. Geoffroy

Consultant

September 1999

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INTRODUCTION

About the Course

This training course, *Pavement Preservation: The Preventive Maintenance Concept*, provides an introduction to the concept of pavement preventive maintenance, including a description of currently available tools and technology that make the implementation of a pavement preventive maintenance program feasible. Targeting an audience of upper management and policy makers in highway agencies, the course focuses on the information needed to develop or improve a preventive maintenance program and illustrates the steps that five states have gone through in the development of their own preventive maintenance programs. Considerably less emphasis is given to the actual pavement preventive maintenance techniques themselves, although an extensive listing of pertinent references is provided for each technique.

An accompanying *Reference Manual* has been prepared to serve as the technical basis for the course. This training course presents the information contained in that document in a series of six modules, each focusing on a specific topic:

- Module 1—Overview
- Module 2—Benefits and Challenges
- Module 3—Techniques
- Module 4—Cost Analyses
- Module 5—Case Studies
- Module 6—Implementing Preventive Maintenance as Part of a Pavement Preservation Program

As part of the training course, a series of four workshops are conducted. These workshops underscore some of the key points of the presentation material and allow course participants the opportunity to work together to establish objectives and program components for their own preventive maintenance programs.

Overall Course Objectives

The overall objectives for this training course are as follows:

1. Become familiar with the concepts of a Pavement Preventive Maintenance (PPM) program.
2. Define potential pavement preventive maintenance techniques and materials.
3. Describe the interrelationships between pavement management and PPM.
4. Explain cost/benefit concepts to decision makers.

About This Instructor's Guide

This *Instructor's Guide* has been assembled to assist instructors in presenting the *Pavement Preservation: The Preventive Maintenance Concept* training course. This course material is challenging, and new instructors are encouraged to thoroughly familiarize themselves with its contents before braving the classroom. Doing so will better arm them to present the training material and effectively facilitate interaction among the participants. Reading the material will also help instructors to learn from the accumulated knowledge and experience gained from those who have gone before them.

This *Guide* is organized into two sections. This first section provides general guidance on the logistics involved in running this course. While experienced instructors will find most of this material to be quite familiar, there is still a lot of new information provided.

The second section of the material in this guide relates to the technical presentation. Each module begins with an introduction, which discusses the approximate instruction time for each module, pitfalls and typical questions that might arise during the presentation, and the workshop(s) that are associated with the module. This section also contains a "hard copy" of the slide presentation, in which the slide is shown on the left side of the page and suggested presentation text is shown on the right side.

Information From Participant's Workbook

Accompanying this training course is a *Participant's Workbook* that is distributed to all of the participants. To assist the instructors in responding to participant questions in the *Workbook*, and to eliminate the need for instructors to carry a copy of the *Workbook*, the front matter contained in the *Participant's Workbook* is reproduced in the following sections.

About the Workbook

This *Participant's Workbook* has been assembled to augment the formal presentations of the *Pavement Preservation: The Preventive Maintenance Concept* training course. It has been developed to assist participants in following the presentation of the course materials and to facilitate the comprehension of the information. However, it is not intended as a replacement for the technical reference manual, which provides more detailed information on the various course topics.

This *Participant's Workbook* contains a section corresponding to each training session. These sections consist of the following items:

- Cross reference information to the applicable pages of the *Reference Manual.*
- A brief overview of the information to be presented in the session.
- An outline of the information to be presented.
- A list of review questions applicable to the session.

- A list of key references for additional information on the topic.
- A reproduction of the presentation graphics used in the session, presented in two-column format to allow note-taking by the participants during the presentation.

The above information is provided for each of the six training sessions. With these features, participants should have no trouble following along during the technical presentations and will more easily recognize the key discussion points of each session. To further aid the participant, a glossary of key technical terms used in the training course and in the *Reference Manual* is found at the end of the *Participant's Workbook.*

Course Schedule

This training course is intended to be completed over 2 days of instruction. A generic course schedule for this training course is found on the next page. This schedule provides the approximate starting and ending times for each session or workshop, as well as anticipated break and lunch times. The actual times for each of these will undoubtedly vary depending upon the flow of the course.

Key Technical References

The *Reference Manual* serves as the primary source of information for this training course. It provides an excellent overview of pavement preventive maintenance concepts and pavement preventive maintenance techniques. In the development of that manual, the following key references were noted as being particularly useful, and interested participants may wish to refer to these documents for more detailed information:

Asset Management/Pavement Management

1. Federal Highway Administration (FHWA). 1997. *Asset Management: Advancing the State of the Art Into the 21st Century Through Public-Private Dialogue.* FHWA-RD-97-046. Federal Highway Administration, Washington, DC.

2. Federal Highway Administration (FHWA). 1996. *Pavement Management Analysis Multi-Year Prioritization.* Demonstration Project No. 108. FHWA-SA-97-071. Federal Highway Administration, Washington, DC.

3. Zimmerman, K. A. and ERES Consultants, Inc. 1995. *Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments.* NCHRP Synthesis of Highway Practice 222. Transportation Research Board, Washington, DC.

Pavement Preventive Maintenance Typical Course Schedule

Suggested Duration	Topic
1:00 to 1:15	Welcome and Course Introduction
1:15 to 1:45	Module 1: Overview
1:45 to 2:45	Module 2: Benefits and Challenges
2:45 to 3:00	*Break*
3:00 to 4:30	*Workshop 1: Defining Your Pavement Maintenance Strategies*
8:00 to 8:15	Review of Day 1
8:15 to 10:00	Module 3: Techniques, Part 1
10:00 to 10:15	*Break*
10:15 to 11:30	Module 3: Techniques, Part 2
11:30 to 12:30	*Lunch*
12:30 to 1:30	*Workshop 2: Identifying Your Preventive Maintenance Program Treatment Strategies*
1:30 to 2:45	Module 4: Cost Analyses
2:45 to 3:00	*Break*
3:00 to 4:30	Module 5: Case Studies
8:00 to 8:15	Review of Day 2
8:15 to 9:15	*Workshop 3: Demonstrating the Importance of Your Preventive Maintenance Program to Management*
9:15 to 10:15	Module 6: Implementing Preventive Maintenance as Part of a Pavement Preservation Program
10:15 to 10:30	*Break*
10:30 to 11:45	*Workshop 4: Integrating the Preventive Maintenance Program Into the Agency*
11:45 to 12:00	Course Summary

Cost Analysis

4. Peterson, D. E. 1985. *Life-Cycle Cost Analysis of Pavements.* NCHRP Synthesis of Highway Practice No. 122. Transportation Research Board, Washington, DC.

5. Walls, J. and M. R. Smith. 1998. *Life Cycle Cost Analysis in Pavement Design—Interim Technical Bulletin.* FHWA-SA-98-079. Federal Highway Administration, Washington, DC.

Pavement Preventive Maintenance—Concepts and Implementation

6. Denehy, E. J. 1997. "Implementing New York State Department of Transportation's Pavement Preventive Maintenance Program." *Transportation Research Record 1597.* Transportation Research Board, Washington, DC.

7. Galehouse, L. 1998. "Innovative Concepts for Preventive Maintenance." *Transportation Research Record 1627.* Transportation Research Board, Washington, DC.

8. Geoffroy, D. N. 1996. *Cost-Effective Preventive Pavement Maintenance.* NCHRP Synthesis of Highway Practice 223. Transportation Research Board, Washington, DC.

9. O'Brien, L. G. 1989. *Evolution and Benefits of Preventive Maintenance Strategies.* NCHRP Synthesis of Highway Practice 153. Transportation Research Board, Washington, DC.

10. Shober, S. F. and D. A. Friedrichs. 1998. "Pavement Preservation Strategy." *Transportation Research Record 1643.* Transportation Research Board, Washington, DC.

Pavement Preventive Maintenance—Flexible Pavement Treatments

11. Asphalt Institute. 1996. *Asphalt in Pavement Maintenance.* Manual Series No. 16, Third Edition. Asphalt Institute, Lexington, KY.

12. Asphalt Institute. 1997. *A Basic Emulsion Manual.* Manual Series No. 19, Third Edition. Asphalt Institute, Lexington, KY, and the Asphalt Emulsion Manufacturers Association, Annapolis, MD.

13. Button, J. W., D. N. Little, and C. K. Estakhri. 1994. *Hot In-Place Recycling of Asphalt Concrete.* NCHRP Synthesis of Highway Practice 193. Transportation Research Board, Washington, DC.

14. Epps, J. A. 1990. *Cold-Recycled Bituminous Concrete Using Bituminous Materials.* NCHRP Synthesis of Highway Practice 160. Transportation Research Board, Washington, DC.

15. Federal Highway Administration. 1995. *Pavement Maintenance Effectiveness/ Innovative Materials Workshop—Participant's Manual.* FHWA-SA-96-007. Federal Highway Administration, Washington, DC.

16. Federal Highway Administration. 1998. *Techniques for Pavement Rehabilitation.* Participants Manual. Federal Highway Administration, Washington, DC.

17. Joseph, P. E. and G. J. Kennepohl. 1996. "Crack Sealing in Flexible Pavements: A Life-Cycle Cost Analysis." *Transportation Research Record 1529.* Transportation Research Board, Washington, DC.

18. Kandhal, P. S. and R. J. Mallick. 1997. *Pavement Recycling Guidelines for State and Local Governments—Participants Reference Book.* FHWA-SA-98-042. Federal Highway Administration, Washington, DC.

19. Raza, H. 1992. *An Overview of Surface Rehabilitation Techniques for Asphalt Pavements.* FHWA-PD-92-008. Federal Highway Administration, Washington, DC.

20. Raza, H. 1994a. *State-of-the-Practice Design, Construction, and Performance of Micro-Surfacing.* FHWA-SA-94-051. Federal Highway Administration, Washington, DC.

21. Raza, H. 1994b. *An Overview of Surface Rehabilitation Techniques for Asphalt Pavements—Instructor's Guide.* FHWA-SA-94-074. Federal Highway Administration, Washington, DC.

22. Smith, H. A. 1992. *Performance Characteristics of Open-Graded Friction Courses.* NCHRP Synthesis of Highway Practice 180. Transportation Research Board, Washington, DC.

23. Zaniewski, J. P. and M. S. Mamlouk. 1996. *Preventive Maintenance Effectiveness–Preventive Maintenance Treatments, Participant's Handbook.* FHWA-SA-96-027. Federal Highway Administration, Washington, DC.

Pavement Preventive Maintenance—Rigid Pavement Treatments

24. American Concrete Pavement Association. 1990. *Diamond Grinding and Concrete Pavement Restoration 2000.* Technical Bulletin TB-008.0 CPR. American Concrete Pavement Association, Arlington Heights, IL.

25. American Concrete Pavement Association. 1993. *Joint and Crack Sealing and Repair for Concrete Pavements.* Technical Bulletin TB-012.0. American Concrete Pavement Association, Skokie, IL

26. American Concrete Pavement Association. 1994. *Slab Stabilization Guidelines for Concrete Pavements.* Technical Bulletin TB-018P. American Concrete Pavement Association, Skokie, IL.

27. Federal Highway Administration. 1995. *Pavement Maintenance Effectiveness/ Innovative Materials Workshop—Participant's Manual.* FHWA-SA-96-007. Federal Highway Administration, Washington, DC.

28. Federal Highway Administration. 1998. *Techniques for Pavement Rehabilitation.* Participants Manual. Federal Highway Administration, Washington, DC.

29. Federal Highway Administration and American Concrete Pavement Association. 1998. *Concrete Pavement Rehabilitation, Guide for Load Transfer Restoration.* FHWA Report No. FHWA-SA-97-103, ACPA Report No. JP001P. Federal Highway Administration, Washington, DC, and American Concrete Pavement Association, Skokie, IL.

30. McGhee, K. H. 1995. *Design, Construction, and Maintenance of PCC Pavement Joints.* NCHRP Synthesis of Highway Practice 211. Transportation Research Board, Washington, DC.

31. Zaniewski, J. P. and M. S. Mamlouk. 1996. *Preventive Maintenance Effectiveness–Preventive Maintenance Treatments, Participant's Handbook.* FHWA-SA-96-027. Federal Highway Administration, Washington, DC.

For More Information

To obtain more information on this course, to request specific technical documents, publications, or computer software, or to secure additional information on a specific maintenance technique, interested participants may contact the following governmental, professional, and industry associations.

Course Scheduling and Information

National Highway Institute
4600 North Fairfax Drive, Suite 800
Arlington, VA 22203
(703) 235-0500
http://www.nhi.fhwa.dot.gov

Technical Information

Federal Highway Administration
Office of Asset Management
400 Seventh Street, S.W.
Washington, DC 20590
(202) 366-1333
http://www.fhwa.dot.gov

Foundation for Pavement Preservation

Foundation for Pavement Preservation (FPP)
1200 19th Street, NW, Suite 300
Washington, DC 20036
(202) 429-5146

Publications

AASHTO
P.O. Box 96716
Washington, DC 20090-6716
(800) 231-3475
http://www.aashto.org

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
(703) 605-6000
http://www.ntis.gov/index.html

Transportation Research Board
P.O. Box 289
Washington, DC 20055
(202) 334-3213
http://www.nas.edu/trb/ *(general)*
http://www2.nas.edu/trbbooks *(bookstore)*

Asphalt Pavement Industry Associations

Asphalt Emulsion Manufacturers Association (AEMA)
3 Church Circle, Suite 250
Annapolis, MD 21401
(410) 267-0023
http://www.aema.org

Asphalt Institute
Research Park Drive
P.O. Box 14052
Lexington, KY 40512
(606) 288-4960
http://www.asphaltinstitute.org

Asphalt Recycling and Reclaiming Association (ARRA)
3 Church Circle, Suite 250
Annapolis, MD 21401
(410) 267-0023
http://www.arra.org

International Slurry Surfacing Association (ISSA)
1200 19th Street NW, Suite 300
Washington, DC 20036
(202) 857-1160
http://slurry.org *[Note: does not include "www"]*

National Asphalt Pavement Association (NAPA)
NAPA Building
5100 Forbes Boulevard
Lanham, MD 20706
(301) 731-4748
http://www.hotmix.org

Concrete Pavement Industry Associations

American Concrete Institute (ACI)
P.O. Box 9094
Farmington Hills, MI 48333-9094
(248) 848-3800
http://www.aci-int.org

American Concrete Pavement Association (ACPA)
5420 Old Orchard Road, Suite A100
Skokie, IL 60077-1083
(847) 966-2272
http://www.pavement.com

Portland Cement Association (PCA)
5420 Old Orchard Road
Skokie, IL 60077-1083
(800) 868-6733
http://www.portcement.org

Professional Organizations

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
(610) 832-9585
http://www.astm.org

American Society of Civil Engineers (ASCE)
P.O. Box 79404
Baltimore, MD 21279-0404
(800) 548-2723
http://www.pubs.asce.org

Other Web Sites

AASHTO Innovative Highway Technologies
http://leadstates.tamu.edu

Course Developer

Applied Pavement Technology, Inc.
http://www.pavementsolutions.com

NOTES

COURSE ADMINISTRATION

Pre-Course Activities

Preparations for the presentation started long before the first day of class. The host agency was informed about the class requirements, including the need for sufficient class space to spread out and hold workshops, the need for an overhead projector during the workshops, and something to write on during the presentation, such as a whiteboard or flip chart. Manuals and other forms were sent to the class site; the computer and presentation equipment are carried by one of the instructors. If anything is amiss with any of these arrangements, contact Applied Pavement Technology, Inc. (APTech) immediately (at either 630-268-8483 or 217-384-0817).

During preliminary conversations with the host agency, there may have been some guidance provided regarding the desire for the host agency to have a customized presentation, such as presenting the current status of their preventive maintenance program. If such a request has not been communicated, the instructors should still try to find out what the interests of the class participants are and orient the presentations and workshops so that they address those interests.

Prior to the start of the course, the classroom should be arranged so that the view of the screen is unobstructed and so that participants have sufficient room to spread out and take notes. The projector should be checked to ensure that it is properly functioning, and instructors should familiarize themselves with the location of the lights and the lighting combinations that provide for the best viewing of the slides. Both the *Reference Manual* and the *Participant's Workbook* should also be distributed before the start of the course.

The Start

One of the instructors (typically the one who will be teaching the first module) should assume responsibility for starting the class. This instructor handles any preliminary "housekeeping" chores, such as handing out a revised schedule and instructor biodata, distributing the manuals, confirming daily starting and ending times, and taking care of initial introductions. This is described in greater detail below.

Introductions

Each instructor should briefly introduce themselves. This introduction reinforces the informality of the course and should help to provide participants with some valid reasons why the instructors should be respected and listened to for the next 2 days. Instructors might state their background, their technical interests, their current employer, their experience in NHI training courses, and anything else that they believe might be of interest to the participants that is not covered in the short bio sketch. Next, have the class participants introduce themselves. Ask each participant to give their name, their employer and job responsibilities, and what they hope they will learn from the class. Any information on their backgrounds will also help instructors to know how to aim the course so that it is well received.

For many courses, a course coordinator or contact person from the host agency will kick off the course and take care of housekeeping details. However, in the absence of someone from the host agency to play the part, the instructors will have to take care of this. To begin with, a class sign-in sheet needs to be passed around. This should be part of the package of manuals and other course material that NHI sent to the host agency. Ask each attendee to print their name legibly, and provide their job title and their employer. This sheet is forwarded to APTech after the course is completed. Many State agencies also use this form to keep track of employee training, so confirm this with the local coordinator. The course schedule and instructor's bios also need to be handed out at this time. These documents will be provided by APTech.

There are several things to establish at the beginning of the class, including the class schedule and the overall manner of presentation. It is a good idea to stress the informal nature of the class. Encourage participation at all times; participants should feel free to interrupt, ask questions, and learn from the class what it is they would like to know. No formal time has been set aside for class participation or question and answer periods; these should occur throughout the course. A generic schedule is bound with the notes and gives a general idea of what will be taught when. However, instructors should also be prepared to deviate from this, based on local schedules, interest, or differing levels of experience. As a final item, the instructor should also take a moment to point out the exit locations.

Start Time

There are at least 12 hours of material to cover in this course and there usually ends up being less than 12 hours to pull this off. In setting up the course, APTech will try to ascertain what the agency's normal hours are. That time should be communicated to the class and instructors will then be expected to start at that time. In the absence of any constraints, the normal start time will be 8:00 a.m.

Flexibility is admirable, but you must consider both the need to present all of the information and the tendency of participants to want to start as late as possible and finish as soon as possible. Try to cater to the true interests and wishes of the group and not to those of the most vocal, who may be in the minority.

Break Policy

Perhaps the hardest part of teaching adults, many of who will have not spent any prolonged time in a classroom in the past 10 or 15 years, is maintaining their attention. Remember that the more technical the material being presented, the more the mind seems to wander, and fairly frequent breaks can actually help maintain a high level of interest and attentiveness. A formal break is scheduled for both the morning and afternoon. However, most instructors will find that the students need about 5 minutes an hour to stand up and stretch their legs. The downside of taking informal breaks is that instructors will find themselves fighting the class to get participants back to their seats in a timely manner. Please make an effort to keep short breaks short. Try leading by example—that is, by being at the front of the class ready to teach at the time that you announced the break would be over. It is especially important to establish the policy of short breaks during the first day to get the students in the habit.

Lunch Time

The schedule will usually call for a 1-hour break at lunch. However, some agencies may only take 30 or 45 minutes. This is more likely to be the case where meals are readily available at the training site. In any case, it is up to the instructors to identify any local variations in schedule or circumstances that might affect the prepared timetable and decide on the appropriate modifications as needed.

Ending Time

A normal daily ending time is 5:00 p.m. There may be cases, however, in which circumstances dictate that the class end earlier. APTech will try to identify an ending time with the course coordinator before the course starts, but instructors should be receptive to valid needs of course participants. For the second day of the course, an ending time of 12 noon is targeted.

Equipment Guide

This course uses a laptop computer and data show to present the visuals. Information is presented here that should help new instructors to become familiar with the equipment used in this class; nonetheless, there is no substitute for a "hands on" approach. As soon as possible, instructors who are unfamiliar with the equipment should try it out so they know how to use it.

Presentation Equipment

Presentations are made via a data show with built-in display capabilities, hooked up to the instructor's laptop computer running Microsoft PowerPoint.

Using PowerPoint®

PowerPoint® is easy to use, but instructors should not wait until the course starts to learn how to use it with the data show. PowerPoint® is a program that runs in Windows and thus operates in the same manner as do all other Window programs. A few "tricks" to note:

- When you open PowerPoint® it comes up with a preliminary screen. Choose "Work on an existing presentation" to continue.
- Select the appropriate file corresponding to the module being presented.
- To start a screen show presentation for the selected module, select the Slide Show pull-down menu and select View Show. The Slide Show will always go the first slide of the presentation, so if you need to start up elsewhere, simply advance through the slides to the slide that you need. The screen show can also be started by clicking on the appropriate icon in the toolbar.
- Slides are advanced by clicking the first button (left or top) on the mouse. You can back up by clicking the second (right or bottom) button on the mouse. The PgUp and PgDn keys on the keyboard will also advance and backup the slides. If you chose to draw on

the slide (you have to have extraordinary hand-to-eye coordination to pull this off) you can click the first button and move the track ball or mouse. This will cause a line to appear on the screen.

- If you would like to leave the screen show before the end of the presentation, hit the ESC key and click on the "Quit" option. This will bring you back to the regular PowerPoint® screen. Otherwise, PowerPoint® will automatically kick you out to regular screens at the end of the screen show.

Display Equipment

The display equipment will be furnished by the host agency, by NHI, or by APTech. While features and characteristics of different types of display equipment will vary, there are several commonalities to their hook-up and operation.

The major "pieces" of the display equipment with which you will need to become familiar include the projector itself, the power cable, the cable that connects it to the laptop's monitor, the remote, and perhaps a wide angle lens. There are also often buttons on top of the device that control horizontal and vertical position, contrast, reverse image, and so on. Focus is controlled by screwing the lens in and out.

Use the wide-angle lens when the projector must be close to the front of the room. This will happen quite a bit, as the instructor, the computer, and the projection equipment must all be in about the same place.

How to hook up the cables is fairly self-evident. There is a power cord and a cable to connect the computer to the projector. The cable has been labeled to assist in connecting it. Due to the short lengths of the cables, there is not a lot of flexibility as to where the instructor can stand and still reach the equipment. Room configurations, projection screens, and lighting will also have a large effect on what is possible in terms of efficient placement and operation of the equipment. It is highly recommended that at least one of the instructors get to the classroom early and set up and test the projection equipment.

Usually the computer should be on before the projector, and once turned on and connected the projector should automatically project the image. However, if after connecting the equipment it doesn't work, you may need to push the monitor switch function key (generally either F3 or F5, and often denoted on the function keyboard with a small computer monitor icon), which will send the image from the screen to the projector. If this still doesn't work, you may wish to try rebooting the computer. Note that the display equipment will take a few minutes to warm up.

Whether the projector is provided by the host agency, by the FHWA, or by APTech, always ensure that a back-up bulb is available. Failure of the bulbs in the projectors is generally not an abrupt failure, but rather a gradual and increasingly noticeable loss in the intensity of the screen projections. Check the user's manual of the projector for guidance on changing the bulb.

Housekeeping on the Last Day

At the start of the last day, one instructor should hand out the course evaluations. These are four-page forms that can be filled out at the participant's leisure during the last day and handed in at the end of the class. Providing this extra time helps to ensure that the forms aren't being filled out at the end of the class when everyone is anxious to leave. This is important because the more information that is collected, the better we can make this class.

The following instructions about the evaluations should be provided to the participants:

- Names and addresses are optional.
- For the instructor's ratings, please write out the names of Instructor A and Instructor B on the board. If everyone uses the same Instructor A and B it will help us to keep track of the responses.
- Participants should be encouraged to take extra space to provide additional feedback. It is this feedback that helps us to improve the course and we pay close attention to it.
- Filled out forms can be left at the back of the class at the end of the presentation.

CEU Credits

Continuing Education Unit (CEU) credits are available through the NHI by filling out the computer coded forms supplied by NHI. In some states, CEUs are required to maintain licensing. On the last day, one of the instructors should read the instructions for filling out the forms to the participants and hand out the forms that are provided. The number for this course is 013154. Participants who complete the course will receive 1.6 CEUs. Pick up the CEU forms at the end of the class and return them to APTech along with the other paperwork.

Certificates

Course certificates are part of the package sent by NHI to the host agency several weeks before the course. At the end of the first day of the course, instructors should provide a copy of the course roster to the host agency so that they may begin preparing the certificates. After the certificates have been prepared, instructors then sign in the appropriate place prior to the end of the class. These certificates are then distributed after the class is over in as formal or informal a ceremony as the situation warrants.

Final Responsibility

As a reminder, one of the instructors needs to be responsible for sending the completed course roster, CEU forms, and course evaluation to APTech. This should be done immediately, as they must be processed and submitted to NHI within 15 days. Instructors will be sent a copy of their course evaluations once they have been processed.

A checklist of instructor duties is provided on page 18.

Updates to the Course Material

While a good deal of effort has gone into the development of this training course, it is inevitable that both instructors and participants will find errors, omissions, or other shortcomings that need to be addressed. Instructors should encourage the class participants to bring any problems with the course that they identify to the instructors' attention. Any problems that are identified should be noted and communicated to APTech at the end of each class. These corrections can be made in subsequent versions of the course, or handed out on an errata sheet. This is especially true for the instructor's guide, which can be improved over time through the combined input of instructors and with the feedback received from participants. Instructors may also be provided technical information that could be used to improve the course material, with a copy forwarded to APTech.

About Teaching

Over the years, a number of observations have been made about the successful presentation of a NHI course. While all of the information is undoubtedly familiar to the course instructors, it is repeated here.

1. Try to make frequent eye contact with course participants. Refer to your notes, but don't read from your notes or the book. Also, don't read verbatim each slide that is shown; instead, try to add information that supports or highlights the points being made in the slide.

2. Don't be afraid to admit what you don't know. There may be a lot of questions to which you don't immediately know the answer. Ask the other instructor, see if anyone in the class has an idea, or suggest that you'll find the answer and get back to them. The worst possible approach is to try to hide your ignorance with an incorrect answer, as it will have the opposite effect.

3. Encourage classroom participation. This can be accomplished by asking questions, and by recognizing participants who look like they want to ask questions. However, try not to let the class be dominated by a few people who want to talk all the time. Also, try to minimize discussion at the back of the classroom, as it is disruptive to those who are trying to pay attention. Finally, side discussions should be discouraged: if someone has something to say, it should be said to the class.

4. Encourage participants to speak so that everyone can hear. Try not to engage in a dialogue with just one or two participants sitting in the front row, as you run the risk of losing the rest of the class that can't hear what's going on.

5. Encourage participants to follow along in the *Participant's Workbook.* Become familiar with what is in the Reference Manual and refer to the book whenever possible.

6. At the end of a session, ask the participants what they remember about the topic. Let them provide feedback on what the major instructional points were.

7. Keep the classroom atmosphere informal so that the participants are comfortable asking questions, participating in the workshops, and sharing their concerns. This will help to make the class a success for everyone.

8. Put yourself in the class' place. There is a lot of technical material to be presented and it may have been many years since participants have had to sit still in a class for that long. No one likes to sit for long periods, it's hard to stay awake, and even harder to pay attention. Do what you can to minimize the effect of this.

Training Course Checklist

DAY 1 CHECKLIST

The following checklist is provided as a reminder of the topics that should be covered during the first day.

Before Class

- ☐ Instructor's computer set-up and check
- ☐ Projection equipment set-up and check
- ☐ Arrangement of classroom
- ☐ Course notes distribution

Start of Class

- ☐ Introductions
  –Instructors
  –Participants
  –Others, where applicable
- ☐ Discuss schedule
  –Start Time
  –End Time
- ☐ Discuss break policy

LAST DAY CHECKLIST

- ☐ Course evaluations handed out, collected, and returned
- ☐ CEU forms
- ☐ Certificates signed and distributed
- ☐ Hardware repacked and shipped back
- ☐ Recommendations for course changes returned to APTech

MODULE 1

OVERVIEW

NOTES

MODULE 1
OVERVIEW

Instructional Time: 30 minutes
Presentation File: Mod 1 Overview.ppt
Reference Manual: Module 1, "Overview," p. 1-6

Overview

This module provides an overview of pavement preventive maintenance. It is noted that the manual and the associated presentation are intended to provide to interested state highway agencies (SHAs) the currently available tools and technology that make the implementation of a pavement preventive maintenance program feasible.

Learning Objectives

The learning objectives for this training course are as follows:

1. Become familiar with the concepts of a Pavement Preventive Maintenance program.
2. Define potential pavement preventive maintenance techniques and materials.
3. Describe the interrelationships between pavement management and PPM.
4. Explain cost/benefit concepts to decision makers.

Participant Review Questions And Answers

1. What benefits are expected to be derived from timely pavement maintenance?

   Reduced travel delays, reduced costs, increased safety, improved traveling comfort, and increased pavement performance are a few of the benefits that can be realized from timely pavement maintenance.

2. What is meant by the saying "there are no ribbon cuttings for pavement maintenance"?

   The construction of new pavement facilities always receives much attention, applause, and acclaim and are perceived as a significant achievement. In contrast, maintenance activities, while essential to the performance of the pavement, are often neglected or ignored because there is little or no short term recognition or reward.

3. What is the current FHWA initiative in preventive maintenance?

   The most recent FHWA initiative is titled Transportation System Preservation (TSP). TSP represents a coordinated effort in the maintenance area to develop long-term policies, technology, research initiatives, and technology transfer under the Federal-Aid Highway Program.

4. What is asset management? What are the FHWA objectives in asset management?

   Asset management is defined as "a systematic process of maintaining, upgrading, and operating physical assets cost-effectively." The objectives of asset management are to:

   - *Bring better and more objective information to the decision making process.*
   - *Consider the implications of all investment alternatives.*
   - *Improve decision making and enhance productivity.*
   - *Derive the maximum benefit from whatever funding is provided.*

Pitfalls

None.

Discussion Points

Begin by asking the group about their knowledge of and experience in pavement preventive maintenance.

Go over the modules for the course and briefly discuss each. Emphasize that this course is not a design/construction course on pavement maintenance activities.

Discuss briefly the FHWA initiatives in pavement preventive maintenance. These are discussed in module 2 in more detail.

Areas To Reduce If Time Constraints Exist

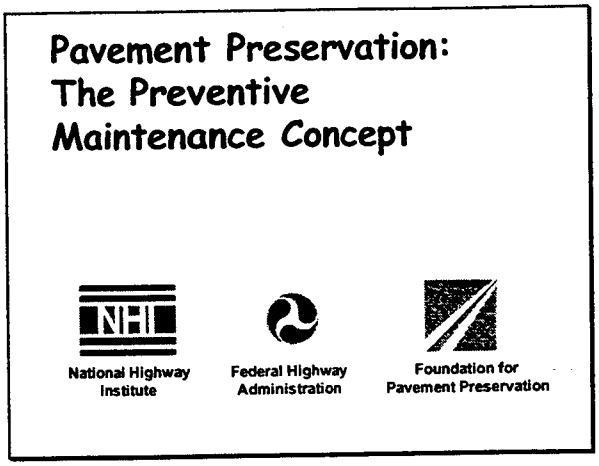
None. This is the introductory module and is intended to provide a brief overview of the course.

Associated Workshop

There is no workshop for this session.

Presentation Graphics and Instructor Notes

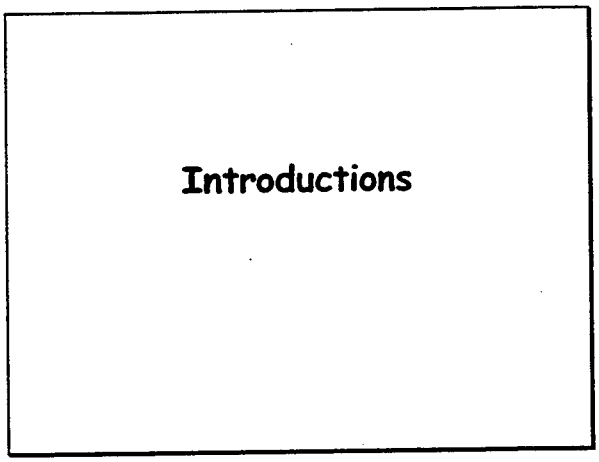
Slide 1



This course presents the fundamental principles beyond the concept of pavement preventive maintenance. Furthermore, it provides guidance for agencies interested in implementing a preventive maintenance program.

The course was developed under the joint sponsorship of the National Highway Institute (NHI) of the Federal Highway Administration (FHWA) and the Foundation for Pavement Preservation (FPP). The partnership between a public agency and industry has been formed as both parties recognize that "there is a growing and significant need to develop and deliver a comprehensive training program in the area of pavement preservation policy, programming, and techniques."

Slide 2



At this point, the instructors should initiate the introductions. The instructors should first introduce themselves, providing some information on their background and interests. The participant should then introduce themselves, revealing their agency and department assignment and also describing what they hope to get out of the course.

Slide 3

Course Format

- Lecture/Discussion
- Workshops
- Protocol
  - Informal
  - Questions are encouraged
  - Class participation is essential

Most of the information will be presented in lecture-discussion format. However, we will also feature several workshops to help apply some of the concepts presented and drive home some of the important points.

We want the course to be as informal as possible. We encourage questions and class participation so that the course meets the needs of the group.

Slide 4

Module 1

Overview

Let's now begin by looking at module 1. This module provides an overall overview of the course. It describes the content and objectives of the course.

Slide 5

Course Objectives

- Explain components of a Pavement Preventive Maintenance program
- Define techniques and materials
- Describe relationships between pavement management and PPM
- Explain cost/benefit concepts

The overall course objective is to provide the currently available tools and technology to agencies interested in implementing a pavement preventive maintenance program.

Much of the information within the course was taken from states that have successfully implemented a preventive maintenance program. This is the most valuable tool for agencies trying to implement their own program.

Slide 6

Course Objectives (cont'd)

- **Not** meant to serve as a guide to preventive maintenance techniques
- Rather, focus is on how to implement or improve a preventive maintenance program

Again, the focus is on implementation. Although some information is given regarding the cost and performance of the treatments themselves, it is not the focus of this course.

Slide 7

Future Direction

As we move towards the 21st century, it is clear that the Federal-Aid highway program is undergoing a significant transition from its original focus on new construction to that of preservation of the highway system.

- FHWA Program Development Office

With the majority of the pavement infrastructure in place, it is now time to turn to preserving that investment. Recent FHWA initiatives, such as ISTEA and TEA-21 (discussed in detail in Module 2), have supported a change toward preservation of the pavement system. AASHTO is also committed to preventive maintenance. Approximately 20 percent of their program is devoted to preventive maintenance. Preventive maintenance definitely falls within the future plans.

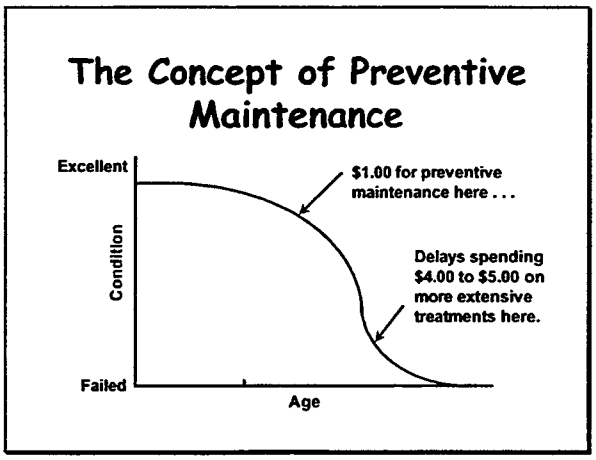
Slide 8

Importance of Preventive Maintenance

- Maintenance has always had a role
- Focus is no longer on new construction but on preserving the existing system
- Preventive maintenance plays an essential role in this preservation
- We can't afford to keep doing things the same way

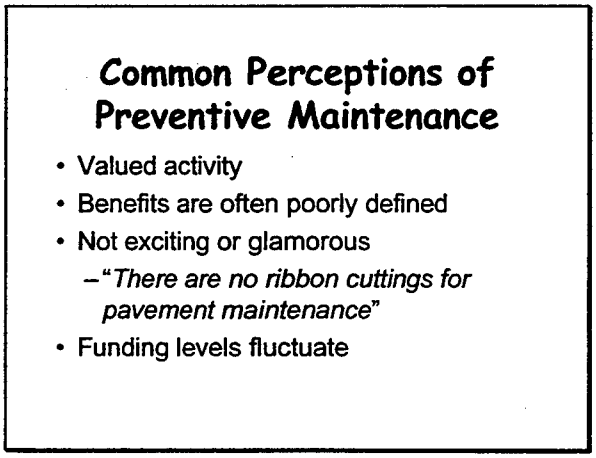
Maintenance has long been acknowledged as playing an essential and integral role in the life of a pavement. Over 80 years, it was recognized that the attention paid to maintenance seems to rise and fall. Now the focus is again directed toward maintenance and its role in pavement life. The major goals of preventive maintenance are to improve customer satisfaction and to extend the service life of the pavement.

Slide 9



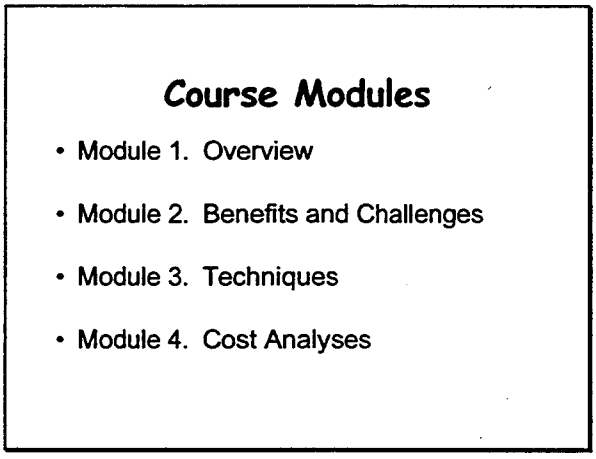
This chart illustrates why we can not afford to keep doing things the same old way. As the pavement first begins to deteriorate, the cost of repair is relatively inexpensive (like an oil change or tune up). However, as the progression deteriorates further, the costs increase exponentially (like an engine overhaul).

Slide 10



The importance of preventive maintenance is not the issue. The issue is the priority given to preventive maintenance activities. Funding for preventive maintenance is often the first to be cut during times of fiscal restraint. Why? For one, the benefits are often poorly defined. It is difficult to quantify the exact benefits of preventive maintenance. Also, it is difficult to justify spending money for maintenance on a pavement in good condition when other pavements are in poor condition.

Slide 11



This course is comprised of seven modules. Module 1 presents an overview of the course content and objectives.

Module 2 introduces the terminology associated with preventive maintenance and provides background information.

Module 3 discusses the treatments for AC and PCC pavements. The purpose is to familiarize the reader with the techniques.

Module 4 provides an introduction to the tools that are used to perform cost analyses, shows how the results of the analyses are used for making decisions, and presents means to compare alternative strategies.

Slide 12

Course Modules (cont'd)

- Module 5. Case Studies
- Module 6. Implementing Preventive Maintenance as Part of a Pavement Preservation Program
- Module 7. Workshops
- Executive Overview

Module 5 presents case studies from five states that have implemented a preventive maintenance program. Each state was visited as part of the course development.

Module 6 ties together the various concepts of preventive maintenance. It serves as a road map to agencies and individuals charged with either creating a new program or improving an existing one.

Module 7 includes four workshops that will be conducted throughout the course. These group activities allow the participants to apply the information.

The Executive Summary was developed to be a quick overview to be presented to decision makers and upper management.

Slide 13

Related FHWA Initiatives

- Preventive Maintenance
- Maintenance Effectiveness
- Maintenance Materials
- QC/QA in Maintenance
- Asset Management

FHWA recognizes their responsibility in this overall effort and has undertaken several initiatives to accomplish their goal. These initiatives also tie into their focus on asset management.

FHWA has taken over the SHRP pavement maintenance studies and is sponsoring two SHRP showcase presentations. Their most recent initiative, Transportation System Preservation, represents a coordinated effort to develop long-term policies, technology, research initiatives, and technology transfer under the Federal-Aid Highway Program. These initiatives also tie in with FHWA's focus on asset management

Slide 14

Summary

- The benefits of preventive maintenance are being recognized
- FHWA and industry are now promoting benefits
- This course focuses on implementation of a PPM program

This course focuses on the implementation or improvement of a preventive maintenance program. Although information is provided about the techniques themselves, that information is secondary to the objectives of this course. This course is the first of a series of FHWA courses on pavement preventive maintenance.

NOTES

MODULE 2

BENEFITS AND CHALLENGES

NOTES

MODULE 2
BENEFITS AND CHALLENGES

Instructional Time: 60 minutes
Presentation File: Mod 2 Benefits and Challenges.ppt
Reference Manual: Module 2, "Benefits and Challenges," p. 7-28

Overview

This module reviews basic information about pavement maintenance and provides background information on preventive maintenance. The terminology associated with preventive maintenance is introduced and several definitions are presented. An overview of the advantages of a preventive maintenance program, both conceptually and as actually realized, is presented. Finally, the barriers to implementation of a pavement preventive maintenance program are also reviewed.

Learning Objectives

The learning objectives for this module are as follows:

1. Become familiar with the various definitions for pavement maintenance, preventive maintenance, and pavement preservation.
2. List some of the advantages of a preventive maintenance program.
3. Understand how pavement maintenance is viewed under the TEA-21 legislation.
4. Identify common barriers to the implementation of a preventive maintenance program.

Participant Review Questions And Answers

1. Define "pavement preventive maintenance." How is it different than routine or reactive maintenance?

   AASHTO defines it as the planned strategy of cost-effective treatments that preserves, retards future deterioration, and maintains or improves the functional condition of the pavement. This is different from routine maintenance in that it is planned, cost-effective, and anticipates and addresses deterioration before it is severe.

2. What is pavement preservation? What activities are included in pavement preservation?

   The sum of all activities that are undertaken to provide and maintain serviceable roadways. Pavement preservation includes preventive maintenance, as well as rehabilitation projects.

3. List some of the benefits associated with preventive maintenance.

   Reduced travel delays, reduced costs, increased safety, improved traveling comfort, and increased pavement performance are a few of the benefits that can be realized from timely pavement maintenance.

4. How is maintenance viewed in the latest Federal highway legislation (TEA-21)?

   The latest highway bill goes the furthest of any funding legislation to supporting state maintenance activities on the NHS. Projects can receive up to 80 percent funding, eligible treatments only need to be shown to be cost effective, and safety can be addressed later.

5. What are some challenges facing pavement preventive maintenance programs?

   These programs face many challenges, including public perception, management perceptions, lack of relevant research demonstrating the claimed benefits, shortage of appropriate training in the concepts and techniques, poor management of important maintenance data, and the challenge of obtaining dedicated funding support.

Pitfalls

None.

Discussion Points

What would participants need to see or know to be convinced of the merits of a preventive maintenance program? Is the information available to them? Why or why not? The workshop will further develop some of these ideas, including local challenges and barriers, so don't pursue this topic too much.

Areas To Reduce If Time Constraints Exist

None.

Associated Workshop

Workshop 1, *Defining Your Preventive Maintenance Program.*

Presentation Graphics and Instructor Notes

Slide 1

Module 2

Benefits and Challenges

This module provides background information and introduces the concepts of pavement preventive maintenance. The information includes:

--Review of basic information.

--Introduction of terminology.

--Overview of advantages of a preventive maintenance program.

--Barriers to implementation.

Slide 2

Learning Objectives

- Become familiar with terminology
- Describe advantages of PPM
- Understand TEA-21 legislation
- Identify barriers to implementation

These are the learning objectives of this module. The participants should be familiar with these concepts upon completion of this presentation.

Slide 3

Issues

- What is pavement preventive maintenance?
- How does it differ from other pavement preservation activities?
- When should it be applied?
- Is it effective?
- If so, then why isn't everyone doing it?

There are many issues when it comes to preventive maintenance. This course attempts to answer these and other questions about pavement preventive maintenance. Use this slide to establish dialog with the students.

Slide 4

Definitions

- Pavement preservation
- Pavement rehabilitation
- Pavement reconstruction

Don't lose the audience with these definitions. These are some common terms that need to be introduced so we can differentiate them from preventive maintenance.

Preservation is the sum of all activities undertaken to provide and maintain serviceable roadways, including corrective maintenance, preventive maintenance, and minor rehabilitation.

Rehabilitation may include partial recycling, placement of additional surface materials, or other work necessary to return an existing pavement to a condition of structural or functional adequacy.

Reconstruction involves complete removal and replacement of the existing pavement structure including new and/or recycled materials.

Slide 5

Routine Maintenance

- Reactive in nature (not planned)
- Performed on pavements that are failing
- Does not contribute to long-term performance
- Often performed under harsh conditions
- Repairs perform poorly

When most people think of pavement maintenance, what they are really thinking of is routine or corrective maintenance. Routine maintenance is reactive in nature. Routine maintenance is simply fixing defects as they occur. It is a stopgap approach that keeps traffic moving. By this stage, it is often beyond the point of preventive maintenance; it just needs to be done.

The Ohio legislature is now telling the highway agency when and where rehabilitation and maintenance activities should be conducted. This is by no means a cost-effective approach. A more effective approach would be to warrant pavements (i.e., make the contractor responsible for building and maintaining the pavement).

Slide 6

Preventive Maintenance

A program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for routine maintenance and service activities.

- Louis O'Brien (NCHRP 153)

Preventive maintenance is a completely different approach to pavement preservation. It is a concept that has really only come into light in this country within the last decade or so. This definition of preventive maintenance was developed by AASHTO's Standing Committee on Highways.

Slide 7

Preventive Maintenance

An organized, systematic process for applying a series of preventive maintenance treatments over the life of the pavement to minimize life-cycle costs.

- Don Geoffroy (NCHRP 223)

Geoffrey offers a somewhat simpler definition. It suggests that planning is essential and that a treatment's costs, effectiveness, and performance must be considered.

Slide 8

Preventive Maintenance

The planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing structural capacity).

- AASHTO's Standing Committee on Highways

Preventive maintenance is a completely different approach to pavement preservation. It is a concept that has really only come into light in this country within the last decade or so. This definition of preventive maintenance was developed by AASHTO's Standing Committee on Highways.

Slide 9

Philosophy of Preventive Maintenance

Applying the right treatment

. . . To the right pavement

. . . At the right time

This is the basic philosophy behind pavement preventive maintenance. This definition, developed by AASHTO's Lead State Team on Maintenance, will be the definition that is used in this course. The objective of preventive maintenance is keeping good roads in good condition.

Slide 10

Challenges

- Safety issues
- Americans with Disabilities Act (ADA)
- Training to wrong people
- Restructuring within agencies to implement preventive maintenance

Two issues that agencies have to deal with are safety and ADA. In order to receive Federal funding, projects must also meet Federal safety requirements. Preventive maintenance projects must also address these issues, which can result in substantial costs. This is a barrier to preventive maintenance.

In order to be successful, agencies may need to change their philosophy regarding preventive maintenance. Agencies need to make a commitment in terms of funding and other resources.

Slide 11

Benefits of a Preventive Maintenance Program

- Higher customer satisfaction
- Better informed decisions
- Improved strategies and techniques
- Improved pavement condition
- Costs savings
- Increased safety

Why would an agency consider implementing a preventive maintenance program?

There are many reasons that may vary from agency to agency and we'll look at each one in a little more detail.

Slide 12

Customer Satisfaction

- Roads exist to serve the traveling public
- Decisions should be made to improve customer satisfaction
- Roads are merely a product

A PPM program should focus on customer satisfaction

Occasionally the connection between decisions about pavements and their effect on the public are forgotten. Customer satisfaction should be the primary goal because the roads are there to serve the public. Customers are demanding more. They want to see their tax dollars spent in a cost-effective manner.

Slide 13

NQI Survey of Users

- Moderate level of satisfaction with highway system
- Considerable opportunity to improve customer satisfaction
- Prefer permanent over temporary repairs
- Complete construction in a timely fashion

A nationwide survey of public opinion performed as part of the National Quality Initiative (NQI) showed only a "moderate level of satisfaction with the highway system" and noted that "there is considerable opportunity for improving public satisfaction with the highway system." The public is concerned that their tax dollars are used in a cost-effective manner.

Slide 14

Washington State Survey

- Roadway surface maintenance is the highest priority maintenance activity
- Public is willing to pay more:
  - to achieve desired levels of maintenance
  - to reduce future costs

Washington DOT commissioned a study to evaluate maintenance management and administration. These findings support pavement maintenance.

They developed an approach to understand and improve customer satisfaction. Bonds were issued to help compensate the program but a tax increase was not needed.

Slide 15

Arizona Survey

- #1 priority: safety (85 %)
- #2 priority: preservation (74 %)
- Over 60 % would be willing to pay more taxes to improve maintenance service levels
- 90 % would be willing to spend more now to save money in the long term

An Arizona DOT survey also showed a concern for maintenance. The findings are presented here. The public doesn't perceive that the government will spend the money well.

A focus on customer satisfaction should be a part of every preventive maintenance program.

Slide 16

California Survey

- Ranking of public priorities
  - Maintenance response to accidents/disasters
  - Safety
  - Pavement conditions
  - Traffic flow

An Arizona DOT survey also showed a concern for maintenance. The findings are presented here. The public doesn't perceive that the government will spend the money well.

A focus on customer satisfaction should be a part of every preventive maintenance program.

Slide 17

Better Informed Decisions

- Program relies on proper treatment selection and treatment timing
- Need information to make decisions
- Successful programs have been integrated with PMS

To select the right treatment for the right pavement at the right time, the following questions must be answered:

--What is the structure and condition of the existing pavement?

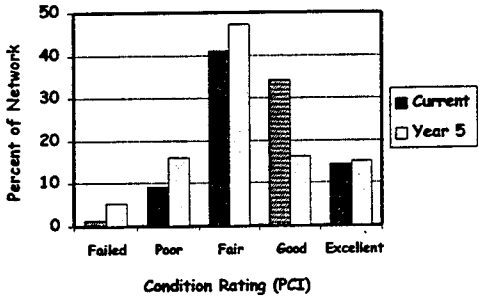
--What is the expected performance of the pavement?

--How will different treatments affect this performance?

--What other factors affect how the treatments will perform?

Slide 18

Use of PMS Information



This figure illustrates an example of how pavement management data can be used to support preventive maintenance decisions very effectively. The example is from the City of Bedford, Texas.

With capital improvement projects only and no preventive maintenance, the percent of pavements in excellent condition increases slightly, but the overall network condition declines.

Slide 19

Montana's Experience

- Began integration with PMS in 1992
- Use PMS data to identify maintenance needs (increased funding from $2 to $13 million)
- Provide feedback into PMS database
  - Track location, type, and cost of treatment
  - Helps to identify cost effectiveness

PMS ⟷ PPM

Montana's objectives included making maintenance a full partner in the pavement preservation process and maximizing the use of resources for maintenance and construction.

Lack of accurate tracking has often been a major shortcoming of agencies. Montana has found this information to be crucial to identifying the cost effectiveness of treatments.

Slide 20

Continuous Improvement of Strategies and Techniques

- Develop new and improved treatments
- Correct observed deficiencies in existing protocols
- Apply treatments while pavement is still in good condition
- Minimize traffic disruptions

Higher quality, more durable materials and new application methods are being tried by many agencies. Innovation comes from industry, agencies, and researchers.

Initial treatment costs may be higher, but the expected life of the treatment is greater than conventional applications.

Slide 21

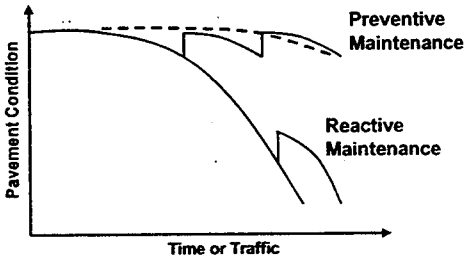
Improved Pavement Condition

- Preventive maintenance helps to preserve a pavement and extend its performance
- Overall condition of network improves

A reasonable expectation of preventive maintenance is that over time the agency and the traveling public can expect improved pavement performance.

Slide 22

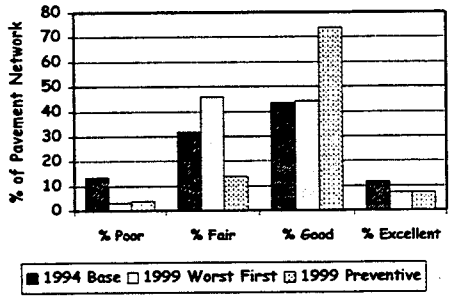
Pavement Condition



The difference between the effect of preventive and reactive maintenance is significant. Not only is the timing of application different, but the effect (represented by the slopes of the after-treatment performance curves) is also different.

Slide 23

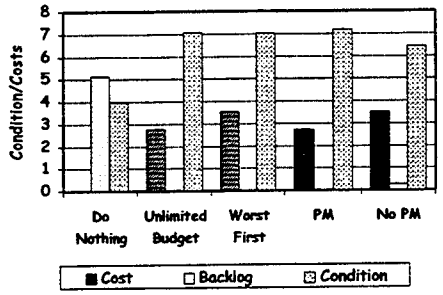
Effect of Preventive Maintenance



This figure was developed from a study by the New York DOT. The overall condition for a preventive maintenance strategy was much better than for a worst-first strategy. The most noticeable difference is the large increase in the percent of pavements in good condition.

Slide 24

Comparison of Funding Strategies



This study was conducted by Wisconsin and involved a simulation on a 400 segment, 110-km (68-mi) portion of their network. Pavements are rated on a scale of 1 to 10. These strategies were examined over a 5-year period. The strategy in which preventive maintenance is applied first with remaining funds applied to pavement rehabilitation is the most cost effective. The unlimited budget scenario is effective but impractical. The worst-first and no preventive maintenance strategies ignore good performing pavements and will create backlogs if adequate funding is not available. The do nothing strategy creates a tremendous backlog.

Slide 25

Cost Savings

- Most persuasive argument for shifting to preventive maintenance strategies
- Forms of cost savings
  - Less expensive treatments
  - Longer pavement life
  - Reduction of user delay costs

Cost savings is certainly an intended benefit but sometimes hard to prove. Savings can be in terms of less expensive treatments, longer pavement lives, and/or cost benefits to the user such as fewer delays. The real benefit is in terms of the cost effectiveness of the treatments; they extend the life of the pavement.

Slide 26

Cost Comparison of Options

- Preventive maintenance: $ 10,270
- Rehabilitation: $ 45,570
- Reconstruction: $ 574,000

Costs obtained from City of Bedford (Texas) on a per-lane mile basis

Cost of preventive maintenance treatment is much less than rehabilitation or reconstruction. Based upon this study, the timely use of maintenance treatments was recommended.

Slide 27

Reported Cost Savings

- Michigan
  - Initial preventive maintenance costs 14 times less than rehabilitation or reconstruction
  - $700 million savings from 1992 to 1996
  - Overall LCCA appears to be 6:1
- California
  - 4:1 to 6:1 overall cost benefit with preventive maintenance treatments

Agencies that have been active in preventive maintenance have realized benefits after a relatively short period of time. Michigan reports $700 million in savings to keep the same level of service over 5 years. This slide illustrates cost differences; another component is cost effectiveness.

Slide 28

Increased Safety

- Safety is the #1 priority of users
- Explicit benefits
  - Improved surface friction
  - Fewer defects
- Implicit benefits
  - Better pavement condition
  - Fewer and less disruptive repairs

Safety appears over and over in surveys of users as their most important concern. The FHWA has a Strategic Plan Goal to reduce fatal and injury crash rates by 20 percent over 10 years.

Safety can be improved by using treatments that are safer to operate on, by having better operating conditions, and by reducing or eliminating repairs.

Slide 29

Additional Benefits of Preventive Maintenance

- Agencies have a stable budget
- Agencies have stable workforce
- Contractors have stable workforce
- Not affected by upswings and downswings

Here are some additional benefits of a preventive maintenance program. It can provide greater stability to both agencies and contractors.

Slide 30

Current Funding Status

- In the past, eligibility for Federal funding required that the pavement be improved structurally
- Recent highway bills have changed the way preventive maintenance is funded

Success of any pavement program is in some part dependent upon the type and level of funding support it receives. We will provide a brief history of the recent developments in Federal funding.

Slide 31

ISTEA

- First highway bill to allow Federal funds for preventive maintenance activities
- Restrictions
  - Demonstrate that treatments are a cost-effective means of extending pavement life
  - Projects must address safety deficiencies

Has not become a widespread practice

The Intermodal Surface Transportation Efficiency Act (ISTEA) was passed in 1991. Provisions make it necessary to concurrently address safety deficiencies such as grades, guard rails, signs, and so on. It is not widespread practice due to a combination of factors, including unclear policy, limited available funds, and many competing demands for those funds.

Slide 32

TEA-21

- Barriers have been removed
  - Greater flexibility to address safety concerns
  - More funding with fewer strings attached
- Federal funding increased to 80 percent

The Federal Government is encouraging preventive maintenance programs

The Transportation Equity Act for the 21st Century (TEA-21) indicates that pavement work can be performed initially and safety improvements addressed in subsequent stages.

There are still issues. For instance, some agencies cannot come up with funding for the remaining 20 percent. Other agencies use only state funds so they do not have to meet additional safety requirements.

Slide 33

Challenges to Implementation

- Agencies that have implemented a preventive maintenance program report extremely positive results.
- Why isn't everyone doing it?
- Barriers, both real and perceived...

There are several success cases among State highway agencies. In addition, funding is now available at the Federal level (up to 80 percent reimbursement). So why isn't it more successful? What are the barriers that are holding states back?

Slide 34

Public Perceptions

- Public averse to steering maintenance dollars toward pavements in good condition
- Agencies more likely to receive complaints about specific defects than overall network
- Need to educate the public about new philosophy

One barrier is public perception. The public may not accept the move away from the worst-first strategy. Put another way, the concern is that the public is unable to place the general good above their own personal interests. Agencies only receive complaints about failed roads.

Slide 35

Management Perceptions

- Need commitment from management to succeed
- Maintenance not traditionally given a high priority
- Need to create awareness of benefits
- Personnel changes disrupt continuity

A preventive maintenance program needs a product champion that supports the change. The engineering climate may be right today to support a shift to preventive maintenance, although management support must still be fostered and strengthened. Often times, champions (or others involved in the decision making process) move up or out and must be replaced with someone with similar beliefs and enthusiasm in order to keep the program moving forward.

Management also faces resistance from contractors who would rather receive the bigger paving contracts than the small preventive maintenance contracts.

Slide 36

Research Needs

- More data are needed to support the advantages of preventive maintenance
  - Treatment timing
  - What treatments are appropriate
  - Life extension gained

Most of the prior research has addressed the performance of specific treatments. There are other issues as listed here. For example, if the treatment is not used appropriately, one may report that the technique doesn't work when in fact it will work under the right conditions.

Slide 37

Training

- Confusion exists about what preventive maintenance is and how best to apply it
- Previous training efforts have focused on different aspects
  - Specific materials
  - Specific methods
- This course is a starting point

More detailed information is needed on the treatments themselves and their optimum timing. Training should extend to contractors and agency forces alike.

Slide 38

Data Management

- Historically, performance monitoring only done as part of research projects
- Must become a standard practice of highway agencies
- Could be incorporated in pavement management system

Information that is useful to track includes the road condition prior to treatment, environmental conditions at time of placement, type of treatment, design details, and material properties, performance data after treatment application, cost data, and traffic data.

Maintenance has applied treatments to address needs, but they have not documented anything for research. Tracking of this information will help agencies identify what works and what does not work. Engineering support is needed in the maintenance area.

Slide 39

Dedicated Funding Challenges

- Preventive maintenance programs are particularly susceptible to funding variability
- Makes it difficult to project long-term benefits of the program

If funding for these programs is not dedicated, or if projected needs are not met, the overall benefits are not realized.

There are many steps to overcome these challenges, including innovative contracting, shorter programming cycles, and simplification of the design and procurement process.

Slide 40

Safety Issues

- TEA-21 requires the development of a plan to address safety issues
- Should not affect decisions for preventive maintenance (need to address safety anyway)

TEA-21 includes provisions regarding improvements to meet safety requirements in order to receive Federal funding. However, the improvements do not have to be made at the time preventive maintenance activities are conducted; a plan must be in place to address the safety requirements.

Regardless, safety requirements will need to be met. An agency should not let these issues control their decisions to perform preventive maintenance. The safety improvements will have to be done anyway.

Slide 41

Summary

- Anticipated benefits
  - Higher customer satisfaction
  - Better informed decisions
  - Improved strategies and techniques
  - Improved pavement condition
  - Cost savings
  - Increased safety
  - Stability

Agencies that have implemented preventive maintenance programs have done so in a desire for one or more of these benefits. As agencies become customer oriented there will be an even greater shift toward achieving these.

Slide 42

Summary (cont'd)

- Challenges are widespread
  - Public perception
  - Management perception
  - Shortage of applicable research
  - Absence of relevant training
  - Poor data tracking
  - Dedicated funding
  - Safety

The remaining modules are aimed at addressing some of the challenges and laying the groundwork for implementing or improving a preventive maintenance program.

NOTES

MODULE 3

TECHNIQUES

NOTES

MODULE 3
TECHNIQUES

Instructional Time: 180 minutes
Presentation File: Mod 3 Techniques.ppt
Reference Manual: Module 3, "Techniques," p. 29-86

Overview

This module describes the most commonly used pavement maintenance techniques and provides information regarding their use and application, performance, and costs. The pavement maintenance techniques are presented for both AC pavement surfaces (including composite [AC/PCC] pavements) and PCC pavement surfaces. The purpose is to familiarize the reader with the techniques without getting into details regarding design and construction.

Learning Objectives

The learning objectives for this module are as follows:

1. Become familiar with the various preventive maintenance techniques available for asphalt-surfaced pavements.

2. Become familiar with the various preventive maintenance techniques available for concrete-surfaced pavements.

3. Understand the steps involved in the selection of maintenance techniques.

Participant Review Questions And Answers

1. What is the distinction between slurry seals and microsurfacing? When is each appropriate to use?

   The binder in microsurfacing is polymer modified and the aggregate is higher quality than that typically used in slurry seals. Slurry seals perform best when placed on pavements in good condition, with relatively little cracking. They provide raveling resistance and improve skid resistance. Microsurfacing applications are similar, but are also used to fill ruts and other surface depressions.

2. What benefits are provided by chip seals? What are the differences between chip seals, sand seals, cape seals, and sandwich seal?

   Chip seals are used to seal the surface of a pavement which is experience cracking not caused by loads. They also improve surface friction, and are used as a wearing course on some low-volume roads. Sand seals use a much smaller aggregate and are primarily used on weathered or oxidized surfaces. Cape seals are made by covering a chip seal with a slurry seal; the resultant surface is smoother than a conventional chip seal. Sandwich seals consist of a conventional chip seal topped with a second application of emulsion and a layer of smaller aggregate. Both of these surfacings are denser than a chip seal alone and should provide a more waterproof layer.

3. Differentiate between cold in-place recycling and hot in-place recycling.

   In CIR, a portion of the existing pavement is reworked in place, mixed with new binder and virgin materials, and then replaced as a base for an overlay. No heat is used in the recycling process. There are a number of HIR techniques, but all rework some of the surface using heat, and then replace the material after it is mixed with a recycling agent. In some cases, virgin asphalt cement or aggregate may be added to the recycled material prior to laydown.

4. What advantages are offered by an open-graded friction course?

   OGFC have a voids content around 15 percent, permitting the rapid drainage of surface water. They are an effective means of facilitating the rapid removal of water from surfaces and thus contribute to a safer pavement structure.

5. How are diamond grinding and diamond grooving different?

   Diamond grinding uses closely spaced saw blades to remove surface roughness and other irregularities. In a preventive maintenance application this technique improves rideability and can be used to redress mild transverse joint faulting. In diamond grooving, the purpose is to create channels on the PCC surface which will keep water from standing on the pavement surface. The result is better tire-pavement contact in wet weather and a reduction in wet weather accidents. The saw blade spacing for grooving is about 19 mm.

6. When might load transfer restoration be considered in preventive maintenance?

   LTR is appropriate for jointed concrete pavements that were constructed without load transfer devices. It is also occasionally used on transverse cracks. It is most effective where transverse joint load transfer is poor, but the pavement still has significant remaining life.

7. List some of the benefits associated with preventive maintenance.

   Preventive maintenance treatments restore rideability and correct other functional deficiencies, such as poor skid resistance. Treatments are available to seal the surface and prevent or retard further deterioration. Treatments are also applied in anticipation of

pavement deterioration, and if applied in a timely manner can extend the useful life of the pavement.

8. What steps are recommended for the selection of maintenance treatments?

   The Reference Manual recommends a series of steps to follow to select appropriate treatments. These include identifying the existing pavement's condition (including measures of importance in triggering treatments), obtaining construction and other project information, determining the cause(s) of any existing distresses, developing feasible alternatives that address the existing problems, performing a LCCA, constructing the treatment, and monitoring performance to improve the process.

Pitfalls

None.

Discussion Points

What resources are available to get more information regarding available treatments? Has a partnership with industry been tried? What are the obstacles to partnering? Has this agency tried any other techniques that they believe to be successful or promising? What are the typical performance problems with your maintenance treatments? How is the monitoring process?

Areas To Reduce If Time Constraints Exist

Depending on the highway agency and the interest, portions of the preventive-maintenance treatments for concrete-surface pavements can be reduced or eliminated.

Associated Workshop

Workshop 2, *Identifying Your Preventive Maintenance Program Treatment Strategies*.

NOTES

Presentation Graphics and Instructor Notes

Slide 1

Module 3
Techniques

Pavements deteriorate due to load-related forces and environmental forces. Many techniques are available for the preservation and maintenance of existing pavements. This module describes the most commonly used maintenance techniques for AC- and PCC-surfaced pavements and provides general information regarding their use and application, performance, and cost.

Slide 2

Learning Objectives

- Become familiar with preventive maintenance techniques
  - AC-surfaced pavements
  - PCC-surfaced pavements
- Understand selection process

Will not get into design and construction details

These are the learning objectives of this module. Each technique will be discussed, with the focus on the use and effectiveness of the technique rather than on the design and construction aspects. Some guidelines for selecting the most appropriate techniques will be provided at the end of this module.

Slide 3

Benefits of Preventive Maintenance Treatments

- Retard future deterioration
- Maintain or improve the functional condition of the pavement system
- Preserve the pavement system and extend the life

But no structural improvement

Successful preventive maintenance treatments provide the following benefits, as discussed in Module 2. However, it should be kept in mind that preventive maintenance treatments provide little or no structural enhancement to the existing pavement.

Slide 4

Techniques for AC-Surfaced Pavements

- Maintenance of drainage features
- Crack filling/sealing
- Fog seals
- Slurry seals
- Microsurfacing
- Chip seals
- Cold in-place recycling
- Hot in-place recycling
- Milling
- Thin HMA overlays

We will be discussing preventive maintenance techniques for both AC-surfaced pavements (including asphalt overlays of concrete pavements) and PCC-surfaced pavements. Listed here are the preventive maintenance techniques for AC pavements that we will be discussing.

Note that many of these treatments are also rehabilitation treatments, but we will be discussing them as potential preventive maintenance treatments.

Slide 5

Techniques for PCC-Surfaced Pavements

- Joint resealing
- Crack sealing
- Diamond grinding/grooving
- Undersealing
- Joint spall (partial-depth) repair
- Full-depth repair
- Load transfer restoration
- Maintenance of drainage features

Here are the techniques for PCC-surfaced pavements. Maintenance of drainage features is one technique that is common to both pavement surface types.

Again, many of these treatments are also rehabilitation treatments, but they can be used as preventive maintenance treatments.

Slide 6

Other Treatments

Do you use treatments other than those listed?

Are there any maintenance treatments that you use in your agency that were not listed? What are they? How are they different from previously listed techniques? How well do they perform? (Have the participants discuss other treatments or other applications that are not listed. This is a good opportunity to encourage participation from the group.)

Slide 7

Techniques for AC-Surfaced Pavements

Here are the techniques for PCC-surfaced pavements. Maintenance of drainage features is one technique that is common to both pavement surface types.

Slide 8

Crack Treatments

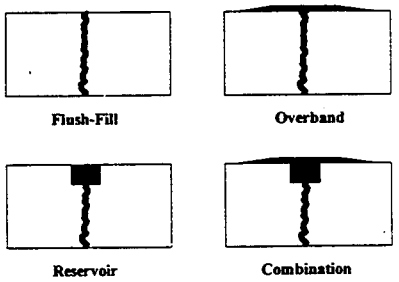
- Crack Filling
  - Lower level operation with lower quality sealant and little preparation
  - Applicable only to non-working cracks
- Crack Sealing
  - Higher level operation with higher quality sealant and more preparation
  - Working cracks

For mostly linear cracking in AC pavements, two different crack treatments are available. Crack filling is a lower level operation in which lower quality sealant materials are used and little, if any, crack preparation is performed. It is applicable for non-working cracks only, that is, those cracks that do not experience significant horizontal movements (less than 2 mm). Because crack filling is more of a "stop gap" procedure, it is not really recommended as a preventive maintenance treatment.

Crack sealing, on the other hand, is a more intensive operation in which the crack is carefully prepared (routing, cleaning, drying, backer rod insertion) and a high quality sealant material is placed. Crack sealing is geared at working cracks in the pavement.

Slide 9

Placement Configurations



Crack filling generally uses the flush-fill or overband configuration, whereas crack sealing generally uses the reservoir or combination configuration. The creation of a reservoir improves the performance but also increase the cost. Overbanding helps seals the crack but detracts from the appearance of the roadway and may be susceptible to snow plow damage.

Slide 10

Performance of Crack Filling

- Performance life
  - Not well established
  - New York reports an average of 2 years
- Timing
  - Temperature not as critical
  - Often conducted prior to surface remediation

The expected performance of crack filling is given here. Because it is a lower level operation, less benefits are expected.

The results of SHRP H-106, a 5-year performance study evaluating crack sealing and filling, is expected in mid to late 1999.

Slide 11

Performance of Crack Sealing

- Performance life
  - Average life of 3 to 5 years
  - Ontario and New York report 5 to 6 years (pavement life extension of about 2 years)
  - SPS-3 results suggest 6 to 8 years
- Timing
  - Moderate temperatures (spring or fall)
  - Most effective if performed right after cracks develop

The average life of crack sealing is generally reported to be in the range of 3 to 5 years. Ontario and New York report performance lives of 5 to 6 years, and Ontario states that pavement life extensions of about 2 years have been achieved.

Proper preparation of crack prior to sealing is essential to ensure good performance. The effectiveness is dependent upon the continued maintenance of the sealed cracks. Cracks should be sealed when near the middle of their working range to avoid excessive extension or contraction of the sealant material.

Slide 12

Cost of Crack Treatments

- Material costs, $/kg ($/lb)
  - Rubberized asphalt: 0.60 - 1.25 (0.27 - 0.57)
  - Low modulus rubberized asphalt: 1.30 - 1.60 (0.59 - 0.73)
  - Silicone: 8.50 - 11.80 (3.86 - 5.36)
- Installation costs are about $1.00 to $1.50 per meter ($0.90 to $1.40 per yard) for most rubberized asphalt materials

Typical costs for some crack treatment materials are given here. Silicone has not shown to work particularly well on asphalt pavements (based on SHRP H106 results).

The installation costs given are for high productivity, large volume operations with rubberized asphalt materials, and include the cost of routing. The use of silicone sealants will result in higher installation costs.

Slide 13

Surface Treatments

- Fog Seals
- Slurry Seals
- Microsurfacing
- Chip Seals

There are a series of surface treatments that are commonly used on asphalt pavements. We will now look at each of these briefly.

Slide 14

Fog Seals

- Light application of diluted, slow-setting asphalt emulsion without aggregate cover
- Purpose
  - Seal the pavement
  - Inhibit raveling
  - Enrich hardened/oxidized asphalt
  - Provide delineation with shoulder
- For pavements in good condition
- Not recommended on high-speed roadways

Fog seals are a light application of a diluted asphalt emulsion (typically 8:1 or 9:1 mixture) placed primarily to seal the pavement and prevent raveling. The pavement must be in relatively good condition, without cracking or major raveling. Slow-setting emulsions are most commonly used for fog seals, and these take time to break, so the pavement must be closed to traffic for about 2 hours after placement. Because fog seals have the potential for reduced surface friction if excess asphalt is inadvertently applied to the pavement, they are not recommended on high-speed roadways.

Slide 15

Performance of Fog Seals

- Most effective on pavements in good condition
  - Minor cracks
  - Some raveling or oxidation
- Performance life is typically 1 to 2 years
- Effectiveness improves with repeated applications

Again, fog seals are most effective on pavements in good condition. The performance life of a fog seal is about 1 to 2 years, and repeated applications are expected to provide improved effectiveness. However, no formal studies have been conducted to evaluate the effect of fog seals on prolonging pavement life.

Slide 16

Slurry Seals

- Mixture of materials
  - Well-graded fine aggregate
  - Mineral filler (if needed)
  - Slow-setting asphalt emulsion
- Thicknesses of 3 to 12 mm (0.12 to 0.5 in)
- Purpose
  - Stop raveling and loss of matrix
  - Reduce potential for stripping
  - Improve surface friction

Slurry seals are a mixture of well-graded aggregate and a slow setting asphalt emulsion. The are appropriate for use when the primary deterioration is related to excessive oxidation and hardening of the existing asphalt. Aggregates must be clean, angular, durable, well-graded, and uniform (prefer 100% crushed). A mix design should be performed to ensure that the desired properties and break times are achieved.

Slide 17

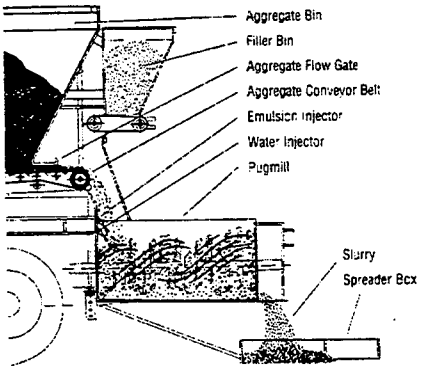
Types of Slurry Seals

Type	Max. Agg. Size, mm (in)	Purpose
I	3.2 (0.12)	Seal cracks on low volume roads
II	6.4 (0.25)	Correct raveling/oxidation on low to medium roads
III	9.5 (0.38)	Fill minor surface irregularities and restore friction

There are three types of slurry seals defined by the International Slurry Surfacing Association (ISSA), and these are differentiated based on aggregate gradation. Each also has a specific application. Type I is used to seal surface cracks on low-volumes roadways. Type II (most common) is used to correct raveling and oxidation on roadways with moderate to heavy traffic levels. Finally, Type III is used to fill minor surface irregularities and restore surface friction.

Slide 18

Slurry Seal Operation



Specially designed equipment combines ingredients into a homogenous mixture and places the material on the pavement. The mixture is in the form of a creamy-textured slurry. Common fillers are portland cement, lime, and aluminum sulfate. Curing time is generally around 2 hours, although it can be as long as 12 hours, depending on the ambient temperature.

Slide 19

Schematic of Slurry Equipment

- The slide is a schematic of the slurry seal equipment showing key materials mixing and placement components.
- The materials are combined into a homogenous mix within the truck and placed in a thin layer on the pavement.

This is a photo illustrates of the slurry seal equipment. The materials are combined into a homogenous mixture within the truck and placed on the pavement in a uniform thickness.

Slide 20

Photo of Slurry Equipment

- This photograph shows the equipment in operation.
- Note the thin material placement.
- The slurry is brown until it breaks and turns black.

Photo of the placement of a slurry seal. The emulsion is brown in color until it breaks.

Slide 21

Performance of Slurry Seals

- Typical life of 3 to 5 years
- Findings of SPS-3 study
  - Reduce development of cracking and raveling
  - Perform better in warmer climates
  - Perform best on pavements in good condition
  - Reflective cracks appear after 1 year

Slurry seals typically provide between 3 and 5 years of service on roads with moderate to heavy traffic. No information on the increase in pavement service life is available.

Under the SHRP program, various maintenance treatments are being evaluated. These SPS-3 study results are based on a 5-year evaluation.

Slide 22

Microsurfacing

- Mixture of materials
  - Polymer-modified emulsion binder
  - High-quality aggregates
- Thicknesses of 10 to 20 mm (0.4 to 0.8 in)
- Purpose
  - Improve surface friction
  - Fill ruts/minor surface irregularities
  - Seal pavement surface
- Open to traffic in 1 hour

Microsurfacing is similar to a slurry seal but it uses a polymer-modified binder and higher quality aggregates. This technique addresses oxidation and raveling on the pavement surface. However, it can also be used to fill wheel ruts up to 40 mm (1.5 in) deep in a single pass. There are two generally accepted aggregate gradations; the choice depends on the type of application. Microsurfacing has been used successfully on both low- and high-volume roadways.

The use of a CSS-1hp binder is common (the "CSS" indicates a cationic, slow setting emulsion, the "1" its relative viscosity [a "-2" is more viscous than a "-1"], the "h" meaning a harder grade of base asphalt was used in the production of the emulsion, and the "p" meaning polymer-modified).

Slide 23

Schematic of Microsurfacing Equipment

- The slide is a schematic of the microsurfacing equipment showing key materials mixing and placement components.
- This specialized equipment is similar to the slurry seal equipment.

Microsurfacing requires specialized equipment for its placement. Here is a photo of the equipment.

Slide 24

Photo of Microsurfacing Equipment

- This photo shows the microsurfacing equipment in action.

Photo of the microsurfacing operation as well as the freshly laid surfacing.

Slide 25

Performance of Microsurfacing

- Typically provides service lives of 4 to 7 years
  - Effective in rut filling applications
  - Provides high initial friction values that are maintained
  - Delays development of reflection cracking when underlying cracks are inactive
- Effective on both low and high volume roadways

Microsurfacing has been found to perform well for 4 to 7 years, depending on the condition of the existing pavement. Ruts up to 50 mm (2 in) have been successfully filled, with recurrence of rutting within 3 to 5 years. Initial friction numbers range from the mid 40s to upper 50s, where higher friction numbers represent greater friction (highway agencies typically require improved surface friction when the values dip below about 35). When underlying cracks are not working, microsurfacing delays the development of those cracks in the new surface.

Microsurfacing has been successfully used on both low and high volume roadways.

No information is available regarding the extension to pavement service life provided by microsurfacing.

Slide 26

Chip Seals

- Application of asphalt and aggregate chips rolled into pavement
- Purpose
  - Seal the pavement
  - Improve surface friction
  - Wearing course
- Some recent application on high-volume roads

Chip seals, also referred by other names including surface treatments, bituminous surface treatments, surface dressings, and seal coats, are an application of asphalt (commonly asphalt emulsion) directly on the pavement followed by an application of aggregate chips. The resulting treatment is then rolled to embed the chips in the binder.

Chip seals are effective in sealing the pavement and improving surface friction. Although they historically are used on low volume roadways, many agencies have been experimenting with them on higher volume roadways; e.g., Washington State has used chip seals on pavements with 80,000 ADT.

Slide 27

Types of Chip Seals

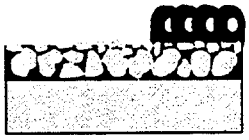
- Conventional chip seals
- Rubberized asphalt chip seals
- Sand seals
- Sandwich seals
- Cape seals

Can be placed in two or more consecutive layers

There is a complete family of treatments that falls into the "chip seal" category. Rubberized asphalt chip seals are commonly used in conjunction with overlays to retard reflection cracking. Sand seals are used to enrich a dry, oxidized surface and to prevent the intrusion of moisture and air. Sandwich seals consist of large aggregate, spray of asphalt emulsion, and application of smaller aggregate; they are used to seal surface and improve skid resistance. Cape seals are a chip seal covered with a slurry seal and are used to provide a dense waterproof surface with improved skid resistance.

Slide 28

Application of Chip Seals



Pneumatic-Tired Rolling

Application of Aggregate

Application of Asphalt or Emulsion

Existing AC Pavement

Single Chip Seal

Double Chip Seal

This figure illustrates the steps in the placement of a chip seal. Asphalt emulsion or asphalt cement may be used as the binder, with asphalt emulsions being more commonly used. The aggregate should be as close to one size as possible.

Pneumatic rollers are preferred because the adequately embed the aggregate without crushing or fracturing it.

Multiple chip seals may add up to 25 mm (1 in) of structure to the existing pavement.

Traffic may be allowed on the chip seal after rolling is completed; however, speed should be limited to 32 km/hr (20 mi/hr) for 2 hours after placement.

Slide 29

Chip Seal Operation

- Photo of chip seal operation.
- In this photo, the chips are being rolled to embed the aggregate
- Some agencies also broom after rolling and before traffic.

This is a photo of the chip seal operation.

Slide 30

Performance of Chip Seals

- Typical performance life of 4 to 7 years
- Multiple chip seals can increase life (may provide up to 10 years of service)
- SPS-3 study shows chip seals performing well after 5 years

Performance of chip seals is variable and dependent upon the proper application of the asphalt binder and aggregate chips and the subsequent compaction. Better performance can be found in non-freeze climates. Other factors include contractor experience and project selection. Any others?

Texas reports an average life of 6 to 7 years; New York reports that chips seals with an asphalt emulsion have lasted 3 to 4 years; Washington reports that chip seals with a polymer-modified sealer have lasted 5 to 7 years under heavy traffic. Multiple chip seals can provide up to 10 years of service.

Slide 31

Cost Comparison of Surface Treatments

Treatment	Life, years	Cost, $/m² ($/yd²)
Fog seal	1 - 2	0.24 - 0.30 (0.20 - 0.25)
Slurry seal	3 - 5	0.84 - 1.14 (0.70 - 0.95)
Chip seal	4 - 7	0.96 - 1.32 (0.80 - 1.10)
Microsurfacing	4 - 7	1.50 - 2.40 (1.25 - 2.00)

Here is a summary of costs for some of the surface treatments that have been discussed. Each agency must determine which treatments are the most cost effective for their particular applications.

Slide 32

Recycling Treatments

- Cold In-Place Recycling
- Hot In-Place Recycling

Descriptions of several preventive maintenance recycling treatments follow, specifically cold in-place recycling and hot in-place recycling.

What are these treatments? How do they differ? How can they be applied in the preventive maintenance setting? What experience do you have with them?

Slide 33

Cold In-Place Recycling (CIR)

- Process in which
  - Portion of existing AC pavement is milled
  - Reclaimed material is sized and mixed with new binder, additives, and sometimes virgin aggregate
  - Remixed material is placed back on the pavement
  - New wearing course placed later
- Construction options:
  - Single machine process
  - Single-pass equipment train

CIR mills off a portion of an existing AC pavement and reuses that milled material back as a layer on the existing pavement. It is performed without heat and is generally used as a base course for a new wearing surface. The reclaimed material is mixed with a new binder (usually a SS or MS emulsion) and additives to help restore its original properties, and may also be mixed with some virgin aggregate. The resulting mixture is then placed back on the pavement as a base course, with a new wearing course (AC or chip seal) placed later.

CIR may be limited to the top few inches of the existing pavement, or it may include the full depth of the asphalt layer with or without some underlying base course materials. In the preventive maintenance arena, we are looking at depths of 50 to 100 mm (2 to 4 inches).

Two construction options can be used:

--The single machine process, in which the breaking, pulverizing, and mixing is done by a single machine in a single pass.

--The single-pass equipment train, in which a series of equipment to perform the various construction activities.

Slide 34

Purpose of CIR

- Improves profile, crown, and slope
- Corrects surface distresses
- Reworks AC to depth of 50 to 100 mm (2 to 4 in)
- Mostly used on lower volume roadways (<10,000 ADT)

The primary purpose of CIR is to address distresses that are limited to the upper portion of the pavement, although it can also be used to improve the profile, crown, and cross slope of the pavement. Distresses resulting from subgrade or base failures cannot be remedied by CIR. This technique is particularly attractive on low-volume, rural roads where a central mixing plant is not located nearby.

Slide 35

Schematic of Single Recycling Machine

- This schematic shows the material handling in a single pass machine
- This equipment is highly maneuverable.

This schematic illustrates a single machine that mills existing pavement, mixes in recycling agent, and deposits the material in a windrow.

Slide 36

Schematic of Single Pass Equipment Train

- The pavement is milled, sized, remixed, and placed in a single long equipment train.

This is a schematic illustration of a single-pass equipment train. The first machine mills the existing pavement to the specified depth. The next machine crushes and sizes the reclaimed material. The material is then mixed with new binder and possibly virgin materials and windrowed. Finally, the material is picked up and laid down with a paver.

Slide 37

Photo of Cold In-Place Recycling Equipment Train

The train includes, from left to right:

Milling machine
Crusher
Mixer
Emulsion Tanker

This slide shows a photo of a cold in-place recycling operation. The train consists of the following equipment (left to right):

--Milling machine.

--Crusher.

--Mixer.

--Emulsion tanker.

The operation is moving to the left.

Slide 38

Performance of CIR

- Performance of CIR generally between 5 and 10 years
  - New Mexico reports excellent performance after 10 years
  - Maine reports no reflective cracking after 3 years
  - Indiana reports less distress and greater support than control section after 5 years
- No information on effect of treatment on pavement service life

There is general satisfaction with the use of CIR. New Mexico has used this technique extensively since 1984 and reported excellent performance from a 10-year study. Other states are also reporting good performance in the short term.

Where problems have occurred, poor or excessive binder distribution, excessive moisture in the material, or improper project selection were cited as reasons for failure.

Again, these are targeted to lower volume roadways.

Slide 39

Hot In-Place Recycling (HIR)

- Process in which the upper 25 to 50 mm (1 to 2 in) of the existing pavement is heated, mixed with a recycling agent (and perhaps virgin materials), and relaid on the pavement
- Addresses surface distresses such as:
  - Corrugations
  - Bleeding
  - Minor cracking
  - Low surface friction
  - Rutting

HIR, sometimes referred to as hot surface recycling, is a process in which the upper few inches of the existing pavement is reworked and reconditioned. This process addresses surficial distresses such as minor cracking, corrugations, bleeding, low surface friction, and rutting (if it is in the surface and not in the base).

Slide 40

Available HIR Techniques

- Heater-scarification
- Repaving
- Remixing

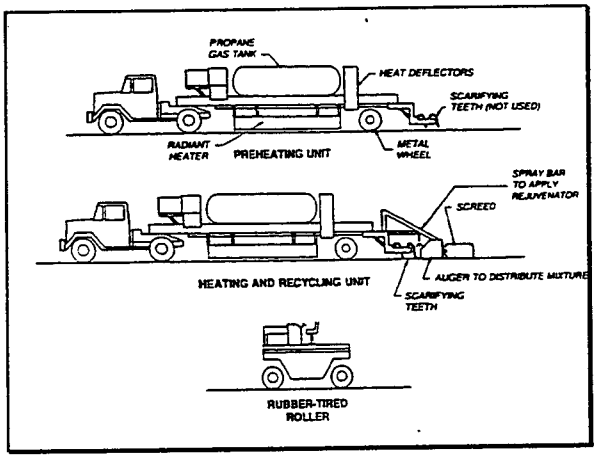
There are three available HIR techniques:

Heater-scarification is the earliest form of HIR and is a simple process in which the surface of the pavement is heated, scarified with a set of scarifying teeth, mixed with a recycling agent, and then leveled and compacted.

The repaving technique heats the existing pavement and mills or scarifies it to a depth of 19 to 25 mm, and then mixes in a recycling agent. This recycled material is then placed as a leveling course and is then followed with a hot mix wearing surface (either immediately or at some later time).

The remixing technique removes a portion of the existing pavement and then mixes it with controlled amounts of virgin mix and/or rejuvenating agents in an on-board pugmill, and the resultant mixture is then placed as the new surface course.

Slide 41



This is a schematic of the heater-scarification process. No new aggregate materials are added during this process, although a new wearing course is added later. Scarification depths typically are between 19 and 25 mm (0.75 and 1 in), although depths up to 50 mm (2 in) can be achieved.

Slide 42

Photo of Heater Scarifier

- In foreground is scarifier with spring-loaded teeth.
- Behind the scarifier can be seen the heater.

This slide shows a photo of a heater-scarifier.

Slide 43

Schematic of Repaving Process

- Steps include
  - Heating
  - Milling or scarification
  - Remixing
  - Construction of an overlay

This shows a schematic of the repaving process. The placement of an overlay is an integral part of this recycling process. The existing pavement is heated, scarified or milled. The material is mixed with a rejuvenating agent. Recycled material is placed as a leveling course, followed with a hot-mix wearing surface that forms a thermal bond between the new and recycled layer. (This photo shows a single pass operation, but, alternatively, a separate paver can be used to place the surface course immediately after the laydown of the leveling course or at some time later.)

Slide 44

Photo of Repaving Process

- Single-pass equipment train
- Placement is occurring in the lower left and the operation is moving to the right.

This photo shows a single pass repaving equipment. The operation is moving to the right.

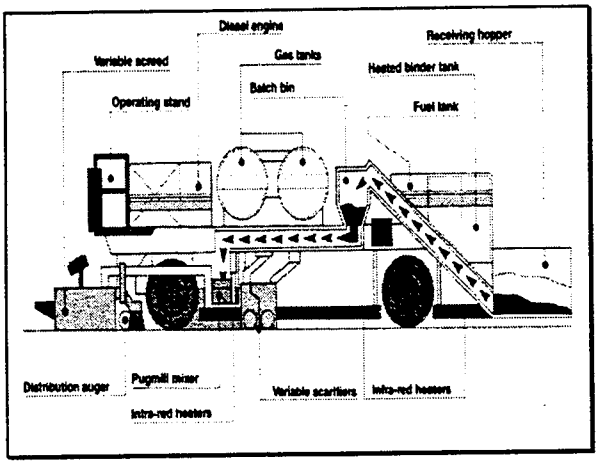
Slide 45

Schematic of Remixing Process

- Mill/scarify existing surface.
- Add virgin mix or rejuvenator.
- Replace material as a surface course.

This schematic illustrates the remixing process. In this process, enough virgin material is added so an additional overlay is not needed. The surface of the existing pavement is scarified and mixed with virgin mix and/or rejuvenator in an on-board pugmill. The resultant mixture is placed as a single, homogenous surface course.

Slide 46



This slide shows a schematic of a surface remixing equipment.

Slide 47

Surface Remixing Equipment

The photo shows surface remixing equipment in operation.

This slide shows a photo of surface remixing equipment.

Slide 48

Drum Mix Recycling

This photo shows a drum mix operation in which all of the existing materials are combined with about 4% new materials. Up to 2 inches of material may be removed.

Drum mix recycling, a hybrid of the remixing process, uses 100 percent of the existing materials and only requires approximately 4 percent of new materials. The surface is mechanically removed to about 50 mm (2 in). A rejuvenating agent and/or various additives are added and blended in a heated drum mix plant. New aggregate is added in the proper amount and type to achieve a new serviceable mix design.

Slide 49

This slide shows the condition of a road before and after a remixing operation.

Slide 50

Performance of HIR

- Some variability in service life depending on operation
  - Heater-scarification: 3 to 5 years
  - Repaving: 8 to 12 years
  - Remixing: not yet established
- Pavement must be at least 75 mm (3 in) thick and must have stable base and subgrade

The performance of HIR is somewhat variable depending on the type of operation. Heater-scarification projects generally last 3 to 5 years, but many have provided 10 years of service. Service lives of 8 to 12 years reported for projects using the repaving process. The remixing process is relatively new, but preliminary results are promising. However, because there are more steps in these HIR processes, there is also greater variability in their performance.

It is important that the existing pavement be at least 75 mm (3 in) thick and have a stable base and subgrade. Any pavement exhibiting variable conditions, such as different performance or varying levels of support, are not candidates for HIR.

Slide 51

Cost of Recycling Techniques

- Cold in-place recycling
  - 25 mm (1 in) deep: $0.96/m^2 ($0.80/yd^2)
  - 75 mm (3 in) deep: $2.00/m^2 ($1.67/yd^2)
- Hot in-place recycling (upper 25 mm [1 in])
  - Heater-scarify: $0.90-$1.61/m^2 ($0.75-$1.35/yd^2)
  - Repaving: $1.50-$2.40/m^2 ($1.25-$2.00/yd^2)
  - Remixing: $2.39-$3.90/m^2 ($2.00-$3.25/yd^2)

The cost of recycling varies significantly depending on the agency, location, contractor experience, project size, and depth.

Hot in-place recycling costs are based upon recycling of the top 25 mm (1 in) of pavement. The costs for heater-scarification and repaving include the placement of a 25-mm (1-in) AC overlay during the process. The costs for remixing include the addition of 10 to 20 percent virgin material.

Slide 52

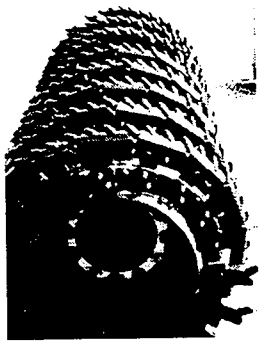
Cold Milling

- Removal of pavement surface using carbide-tipped cutting bits
- Purpose
  - Restore profiles and slopes
  - Re-establish surface friction
  - Remove layer for recycling
  - Prepare for an overlay

Cold milling is the removal of the existing pavement surface to a specified depth (generally about 50 to 100 mm). It is most commonly used prior to an overlay to restore the profile and cross slopes and to enhance the bonding between the existing pavement and the new overlay. It has also become a standard part of recycling, as it is an efficient means of removing pavement material. Cold milling has occasionally been done as a "stand-alone" treatment in which agencies want to remove a badly rutted or distorted pavement surface and will return in a few years to place a new wearing course.

Slide 53

Triple Wrap Milling Head



Drum widths vary from about 0.3 to 4.9 m (1 to 16 ft). Most machines can handle depths of up to 100 mm (4 in), although some newer equipment purports to mill up to 300 mm (12 in) in a single pass.

New drum heads have become available with more teeth and closer spaced teeth. This provides a smoother surface texture and is considered more acceptable as a riding surface if the milled pavement is to be left open to traffic.

Slide 54

Photo of cold milling operation. Teeth mounted on rotating drum chip away material and feed it onto a conveyor belt for deposit into truck. The milled material is often reused (30 percent is common) in the rehabilitation of that or another pavement.

Slide 55

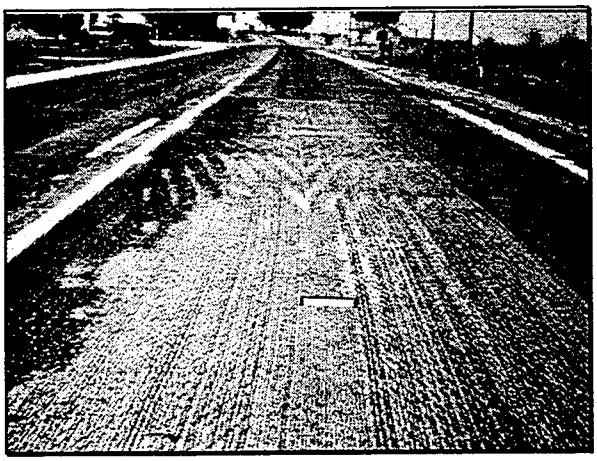


Photo of pavement surface after cold milling.

Slide 56

Performance and Costs of Cold Milling

- Integral part of many overlay projects and most recycling projects
- Cold-milled surface can last 3 to 7 years
- Typical costs range from $0.60 to $3.60 per m^2 ($0.50 to $3.00 per yd^2)

Cold milling is an integral part of many overlay projects and most recycling projects. As such, it is difficult to factor out the performance and effectiveness of the cold milling operation on the life of the treatment, although cold milling's widespread use and popularity speaks volumes.

Cold milling is not suitable for pavements with significant deterioration. A cold milled surface occasionally has been used to carry traffic, and when this has been done a service life of 3 to 7 years may be expected. However, the newer equipment with more cutting bits are needed to produce a smoother texture.

The costs of the cold milling operation can vary significantly depending on the depth of removal, type of coarse aggregate, and the size of the project.

Slide 57

Thin HMA Overlays

- Thin (19 to 38 mm) plant mixtures of asphalt cement and aggregate
  - Dense Graded
  - Open Graded (OGFC)
  - Stone Matrix Asphalt
- Purpose
  - Restore rideability
  - Improve surface friction
  - Reduce hydroplaning and tire splash (OGFC)

Thin HMA overlays are plant-mixed combinations of asphalt cement and aggregate. The thickness typically varies from 19 to 38 mm (0.75 and 1.50 in).

Three different types are available:

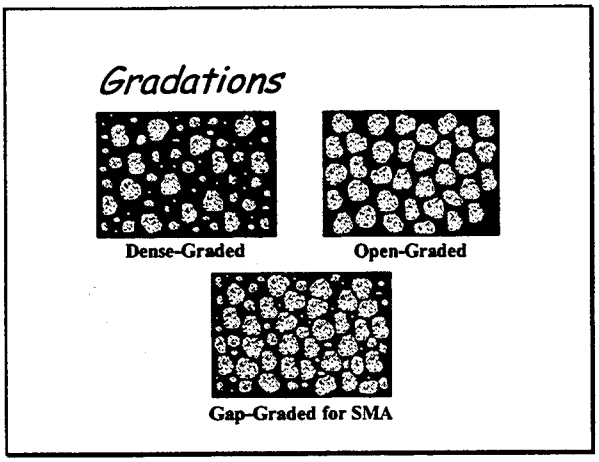
--Conventional dense-graded

--Open graded friction course

--Stone matrix asphalt (SMA)

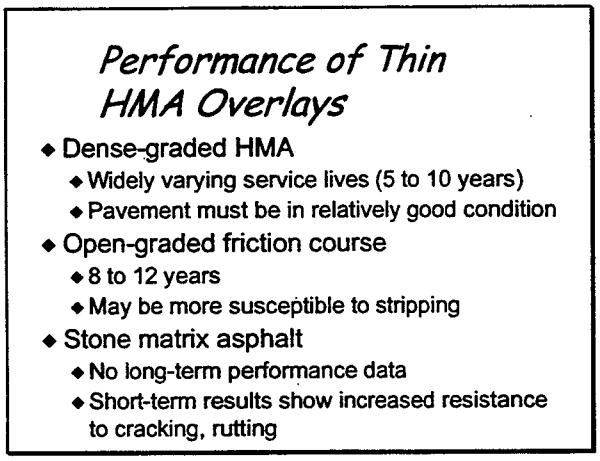
Generally, the purpose of these thin overlays is to restore ride and improve surface friction. Little additional structure is added to the pavement, so it must be in relatively good condition. Additional benefits provided by OGFC are reductions in hydroplaning and tire splash/spray.

Slide 58



These are schematic representations of the gradation used in each thin HMA overlay type. Dense-graded or well-graded aggregate is uniformly distributed throughout the full range of sieve sizes. Aggregate particles in open-graded friction courses are uniformly graded (i.e., of predominantly a single size). Aggregates in stone matrix asphalt (SMA) overlays are gap-graded, meaning that they contain coarse fractions and fine aggregate sizes, but no medium aggregate sizes. SMA also uses a high percentage of mineral filler (8 to 10 percent), and stabilizing additives such as fibers and polymers are added to control segregation and draindown.

Slide 59



The performance of these thin HMA overlays depends on the condition of existing pavement, adequacy of mix design, quality of overlay construction, and traffic levels. Perhaps the most variable in performance is dense-graded HMA overlays, which show service lives of 5 to 10 years. Where failures have occurred, it is often because of its placement on an excessively deteriorated pavement.

OGFC overlays have performed well, with service lives of 8 to 12 years. Because of their open nature, they may be more susceptible to stripping and steps may need to be taken to reduce the potential for stripping (heavier film of asphalt on the aggregate).

No long-term performance data for Stone matrix asphalt overlays are available, but the short term results are promising. The results of an NCAT field evaluation study showed, after up to 5 years of service:

--No appreciable rutting

--No evidence of raveling

--Greater resistance to cracking than adjacent dense-graded mixtures

Slide 60

Costs of Thin HMA Overlays

- Dense-graded HMA
  - $28 - $34 per Mg ($31 to $38 per ton)
  - $2.03 - $2.63 per m^2 ($1.70 - $2.20 per yd^2)
- Open-graded friction course
  - $39 - $40 per Mg ($43 - $44 per ton)
  - $1.50 - $1.70 per m^2 ($1.25 - $1.42 per yd^2)
- Stone matrix asphalt
  - 20 to 40 % greater than dense-graded HMA

Here are some typical costs for the thin HMA overlay types. These assume overlay thicknesses of about 25 mm (1 in). No cost information is available for SMA, but it is estimated to be about 20 to 40 percent more than dense-graded HMA.

Slide 61

Maintenance of Drainage Features

- Applicable to both AC and PCC
- Any activity that will improve drainability of pavement section
  - Install and maintain reference markers
  - Clear debris from outlets and culverts
  - Inspect edge drain pipes
  - Flush and rod edge drain system
  - Clean ditches and re-establish grades
  - Restore cross slopes

This technique is applicable to both AC and PCC pavements. Pavements with drainage systems, particularly those with permeable bases, require regular maintenance to be effective. Recent studies using video inspection equipment have found numerous problems, such as clogged pipes from debris, vegetation, rodent nests, as well as crushed pipes from construction.

However, even pavements without drainage systems can benefit from maintenance activities such as cleaning and regrading ditches, restoring cross slopes, and clearing debris from culverts and outlets.

Slide 62

This photo shows an example of a failure caused by lack of drainage. Poor drainage can lead to numerous problems on both AC and PCC pavements.

What factors might be contributing to the drainage problem in this photo?

(no ditches, shoulders appear to be higher than the pavement elevation, might be a longitudinal "low spot")

Slide 63

Drainage Recommendations

◆ Pavement cross slope	≥ 2 %
◆ Shoulder cross slope	≥ 3 %
◆ Slope of ditches	4:1 max
◆ Width of ditches	0.9 - 1.2 m
◆ Depth of ditches	≥ 1.2 m
◆ Grade of ditchline	≥ 1 %

Here are some drainage recommendations for the pavement and ditches. These are targeted more to interstate-type pavements, but still indicate major factors to consider to help ensure good drainage.

Slide 64

Performance of Drainage Maintenance

- Depending on activity and exposure conditions, drainage enhancement may last from several months to several years.
- Periodic inspections are required throughout the life of the pavement
- Costs also dependent on activity being performed
- Impact of positive drainage on pavement performance currently being studied

Drainage enhancements or corrections (cleaning of outlets, cleaning of culverts, ditch reshaping) may last anywhere from a few months to several years depending on conditions. The costs of inspection and maintenance vary depending on the type and extent of activity. Shaping and grading of ditches is reported to be about $1,000 per 100 linear meter ($300 per 100 linear feet).

Slide 65

Other Emerging Maintenance Treatments

- Scrub seals
- Ultrathin friction courses

There are several other maintenance treatments that are gaining some acceptance by state highway agencies. These include scrub seals and ultrathin friction courses. Each will be discussed briefly.

Slide 66

Scrub Seals

- Surface restoration that rejuvenates asphalt and fills voids and cracks
- Application process
  - Apply polymer-modified asphalt agent
  - Broom asphalt into voids and cracks
  - Apply sand or small aggregate
  - Broom aggregate and asphalt mixture
  - Roll with pneumatic tire roller

Scrub seals have actually been in use since the 1950s, with California and Arizona being some of the pioneers in its use. Only recently have other states started to look at scrub seals as a viable maintenance treatment.

Scrub seals are intended to rejuvenate the asphalt surface and to fill voids and surface cracks. They consist of a layer of polymer-modified asphalt that is broomed into the voids and cracks of the pavement, followed by the application of sand or small-sized aggregate. This mixture is then broomed again and then rolled with a pneumatic-tired roller.

Slide 67

Performance of Scrub Seals

- Good performance on low volume roads
- Advantages:
  - Seals small cracks
  - Address raveling
  - Easy to apply
  - Inexpensive
- Disadvantages
  - Possible low friction numbers
  - Requires special equipment

Scrub seals are showing good performance on lower volume roads (less than 7,500 ADT). They have been used extensively in California and Arizona, and recently are seeing more use in Missouri.

There are some concerns regarding low friction levels on some roadways.

Slide 68

Ultrathin Friction Course

- Gap-graded, polymer-modified HMA placed on a heavy, polymer-modified emulsified asphalt tack coat
- Thicknesses of 10 to 20 mm (0.4 to 0.8 in)
- Benefits:
  - Addresses surface distress
  - Reduces noise
  - Increases surface friction

Ultrathin friction courses, also called paver placed surface seals, consist of a gap-graded, polymer-modified HMA placed on a polymer-modified tack coat in thicknesses of 10 to 20 mm (0.4 to 0.8 in). This technique is widely used in France and was recently introduced to the United States. It is an alternative to chip seals, microsurfacing, or thin HMA overlays as it effectively addresses surface distresses and increases surface friction.

In the U.S., this product is marketed under the NOVACHIP ® name.

Slide 69

Performance of Ultrathin Friction Courses

- No long-term performance data
- Short-term performance promising
  - Texas and Pennsylvania report pavements in excellent condition after 3 years
  - Noticeable increase in surface friction
  - No raveling or stripping
- Installation costs: $3.00/m^2 ($2.50/yd^2)

Although no long-term performance data are available, the short-term performance of ultrathin friction course projects has been promising. Texas and Pennsylvania are two states monitoring the performance of these installations, and they report excellent performance after 3 years.

The installation cost for ultrathin friction courses is about $3 per square meter ($2.50 per square yard), about 50 percent more than a thin dense-graded HMA overlay.

Slide 70

Techniques for PCC-Surfaced Pavements

Now we are going to look at a few preventive maintenance techniques for PCC-surfaced pavements...

Slide 71

Joint/Crack Resealing

- Application of a sealant material in concrete pavement joints and cracks
- Purpose
  - Minimize moisture infiltration
  - Prevent intrusion of incompressibles
- Sealant Materials
  - Rubberized asphalt
  - Silicone

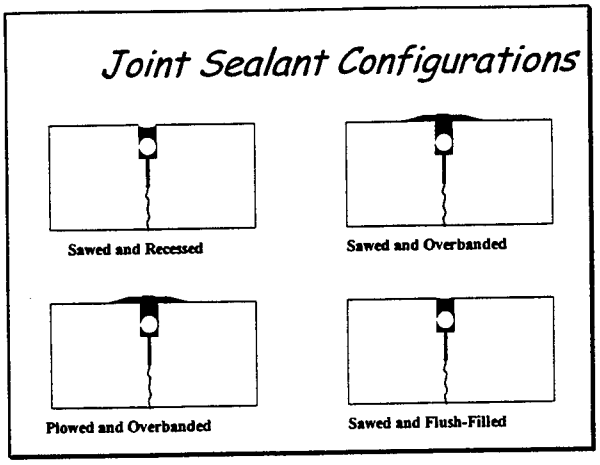
The first and perhaps most common maintenance technique performed on concrete pavements is joint/crack sealing. The purpose of sealing joints and cracks in concrete pavements is to minimize the amount of water that gets into the pavement structure and also to prevent the intrusion of incompressibles.

What distresses can develop if excessive water gets into the pavement? (pumping/faulting)

If incompressibles get into the joint? (spalling/blowups)

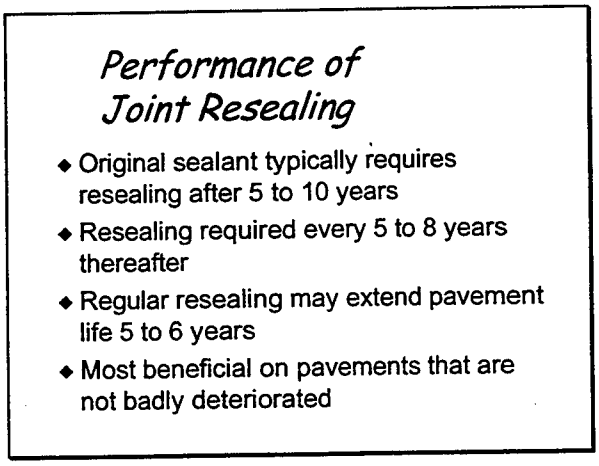
For concrete pavements, the most common sealant materials are rubberized asphalt and silicone.

Slide 72



A variety of sealant placement configurations can be used. Sawed and recessed is the most commonly used configuration. Using this configuration, the existing joint is sawed to the desired width, the joint sidewalls are cleaned, a backer rod is installed, and the sealant material is placed with a slight recess below the surface.

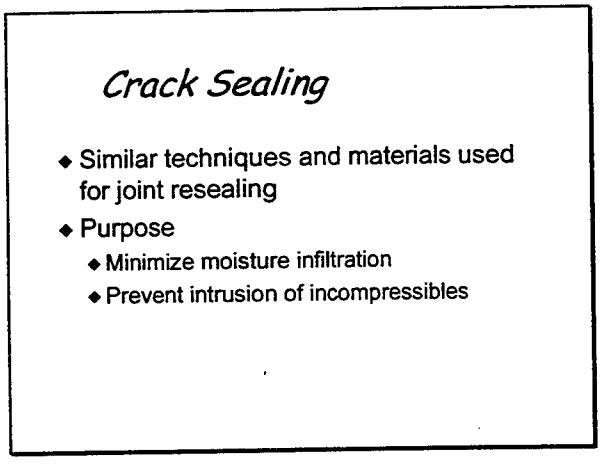
Slide 73



Joint sealants show a wide variation in service life depending on material, climate, and so on. Silicone sealants are expected to provide a longer service life before resealing, and the SHRP H-106 study, after 7 years of evaluations, indicate that silicone sealants have provided the best performance.

Results compiled by Geoffroy suggest that regular resealing may extend pavement life by 5 to 6 years. Resealing is most effective on pavements that are in relatively good condition.

Slide 74



Crack sealing on concrete pavements uses techniques and materials similar to those used for joint sealing. One major difference, however, is that cracks are irregularly shaped and may require routing or sawing to establish the sealant reservoir.

Slide 75

Performance of Crack Sealing

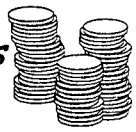
- Resealing of cracks required about every 5 years
- No data regarding extension to pavement life
- Most effective on cracks between 3 and 19 mm (1/8 and 3/4 in) wide with limited spalling

The life of crack sealing installations is similar to joint sealing--about 5 years. Hot-poured, rubberized materials are more commonly used.

Crack sealing is most effective on cracks between 3 and 19 mm (0.12 to 0.75 in) wide. Cracks less than 3 mm (0.25 in) do not need to be sealed. Cracks greater than 19 mm (0.75 in) are best addressed by other methods.

Slide 76

Joint Sealing Costs



- Material costs, $/kg ($/lb)
  - Rubberized asphalt: 0.60 - 1.25 (0.27 - 0.57)
  - Low modulus rubberized asphalt: 1.30 - 1.60 (0.59 - 0.73)
  - Silicone: 8.50 - 11.80 (3.86 - 5.36)
- Installation costs range from about $2.50 to $6.50 per meter ($2.30 to $5.95 per yard)

Essentially the same materials are used for joint/crack sealing in PCC as in crack sealing in AC. However, the installation costs are generally higher because of increased preparation.

Slide 77

Surface Texturing

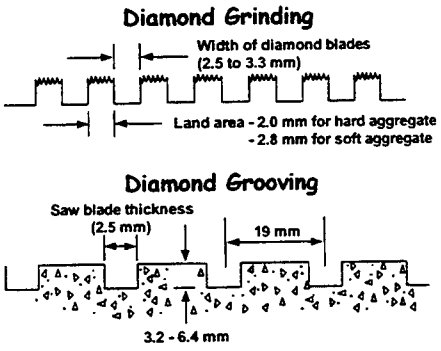
- Diamond Grinding
  - Removes thin layer of PCC surface
    - Removes faulting
    - Restores smoothness
    - Increases friction
- Diamond Grooving
  - Creates discrete grooves in PCC surface
  - Reduce hydroplaning and wet weather accidents

Two surface texturing techniques are available for use on concrete pavements, and each has a specific purpose

Diamond grinding removes a thin layer of concrete (typically about 6.4 mm [0.25 in]) such that faulting is removed and smoothness and high friction levels are restored. Diamond grinding is most often performed over an entire project; most diamond heads are about 0.9 m (3 ft) wide. The pavement should be in relatively good condition without durability distress.

Diamond grooving creates narrow, discrete grooves in the concrete surface that is intended to reduce hydroplaning and wet weather accidents. Unlike diamond grinding, diamond grooving is often performed at localized areas where wet-weather accidents have historically been a problem (curves, intersections, etc.). Grooving is most commonly performed longitudinally due to ease of construction.

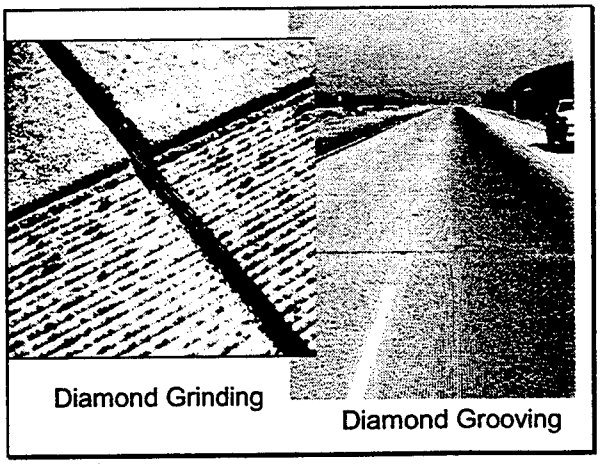
Slide 78



This figure illustrates the typical dimensions associated with each activity. For diamond grinding, the land area depends on the hardness of the aggregate; the idea is that the land area will break off under traffic.

Diamond grooving produces grooves that are more widely spaced.

Slide 79



These photos illustrate the difference between a diamond-ground surface and a diamond-grooved surface.

Slide 80

Performance

- Diamond grinding
  - Provides about 10 years of service
  - May be reground 3 to 4 times
  - Faulting can return to significant levels in a few years if cause(s) not concurrently addressed
- Diamond grooving
  - 60 to 75 % reductions in wet-weather accidents
  - Benefits achieved throughout service life

A recently completed study showed that diamond grinding produces a surface that is as smooth or smoother than newly constructed pavements, and lasts about 10 years. Factors affecting the service life of diamond grinding include traffic loadings, existing pavement condition, climate, and concurrent repair/restoration work such as patching and undersealing. The pavement may be reground 3 to 4 times without significantly compromising the structural integrity of the pavement. However, if the cause of the faulting is not addressed (load transfer, pumping), faulting can return to significant levels in a few years.

Diamond grooving has shown marked decreases in wet-weather accidents, and these benefits are realized throughout the life of the pavement (the grooves are permanent and do not need to be re-established).

Slide 81

Surface Texturing Costs

- Diamond grinding
  - Soft Aggregate:
    - $2.40 - $3.60/m² ($2.00 - $3.00/yd²)
  - Med. Aggregate:
    - $3.60 - $6.00/m² ($3.00 - $5.00/yd²)
  - Hard Aggregate:
    - $6.00 - $9.60/m² ($5.00 - $8.00/yd²)
- Diamond grooving
  - $1.80 - $3.00/m² ($1.50 - $2.50/yd²)

Here are some typical costs for diamond grinding and diamond grooving. The costs can vary substantially, depending upon the hardness of the aggregate in the pavement being ground.

Slide 82

Undersealing

- Pressure insertion of flowable material (grout) beneath the PCC slab
- Purpose
  - Fill underlying voids (not to raise slab)
  - Reduce pavement deflections
  - Minimize pumping and faulting

Another preventive maintenance activity for concrete pavements is undersealing, sometimes called subsealing, pressure grouting, or slab stabilization. It is the pressure insertion of a flowable material beneath the concrete slab at areas where pumping and loss of support occur (such as beneath transverse joints and deteriorated cracks). The purpose is to fill the underlying voids and reduce pavement deflections and minimize pumping and faulting. Note, however, that the slab is not to be lifted in this process.

Slide 83

Undersealing Operation

Usual material is cement-flyash grout

Design issues include number and location of holes, amount of material

This photo shows the process of undersealing. The material, usually a cement-flyash grout, is inserted under pressure through a hole drilled in the concrete slab, as shown.

Slide 84

Performance of Undersealing

- Short- and long-term reductions in pavement deflections
- Most effective on pavements with little structural damage
- Should be conducted only where voids are known to exist

Undersealing should only be performed at joints and cracks where voids are know to exist. The following methods can be used to detect voids:

--Visual distress survey (looking for signs of pumping).

--Deflection testing.

--NDT methods (ground penetrating radar, infrared thermography).

--Epoxy/core method.

Undersealing of slabs prior to AC overlay may reduce reflective cracking.

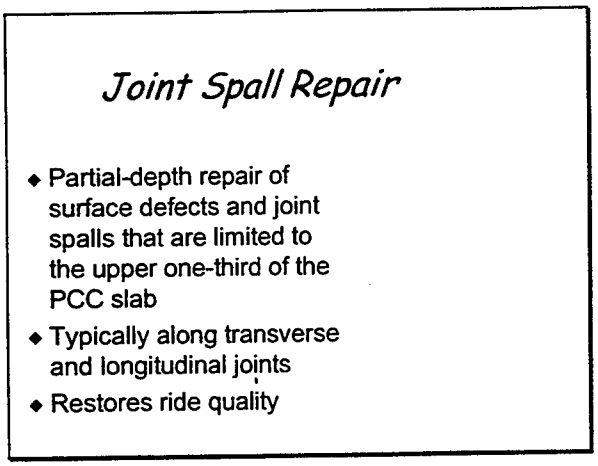
Slide 85

Undersealing Costs

- Cement-grout undersealing
  - $1.08 - $1.20/m^2 ($0.90 - $1.00/yd^2)
- Asphalt undersealing
  - $0.54 - $0.60/m^2 ($0.45 - $0.50/yd^2)

Typical costs for undersealing are shown here. These will vary depending on the size of the project, the hole pattern, and the typical size of the voids being filled.

Slide 86



Joint spall repairs, also known as partial-depth repairs, can be used to address joint spalling and other surface defects so that overall pavement rideability can be restored. This technique is most commonly used along transverse joints but can be used at longitudinal joints also. It provides a uniform joint sealant reservoir at repaired areas along joints that will be resealed. A variety of materials may be used:

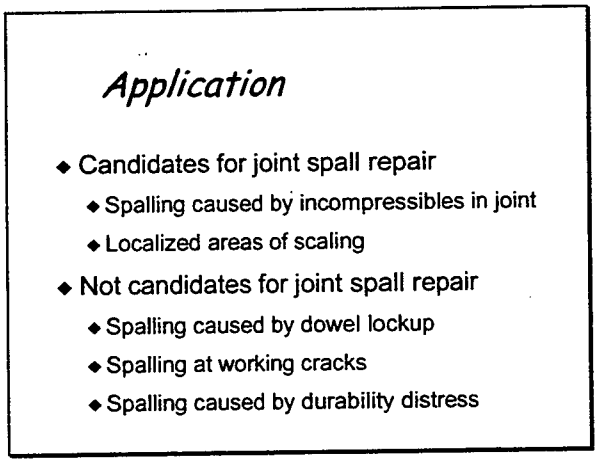
--Cementitious (PCC or other).

--Polymer-based concrete.

--Bituminous materials.

Only distresses limited to the upper one-third of the slab can be addressed with partial-depth repairs. Distresses that are deeper are more effectively repaired through full-depth repairs.

Slide 87



Only certain types of distresses can effectively be addressed though joint spall repairs. The distress should be limited to the upper one-third of the slab. Full-depth repairs are required for distresses not suitable to joint spall repair

Slide 88

Performance of Joint Spall Repairs

- Proper installation is critical
  - Service life of 8 to 10 years with appropriate use and installation
  - Can fail within 2 years when used inappropriately
- Cementitious and polymer-based materials are best suited for long-term repairs

Joint spall repairs exhibit variable performance due to use on inappropriate distresses or because of poor installation practices.

Slide 89

Joint Spall Repair Material Costs

- Type III PCC
  - $375/m³ ($10.62/ft³)
- Proprietary magnesium phosphate cement
  - $1,300/m³ ($36.82/ft³)
- Epoxy patching mixture
  - $8,500/m³ ($240.69/ft³)
- Bituminous patching mixture
  - $185/m³ ($5.25/ft³)

Typical costs for joint spall repair materials are shown here.

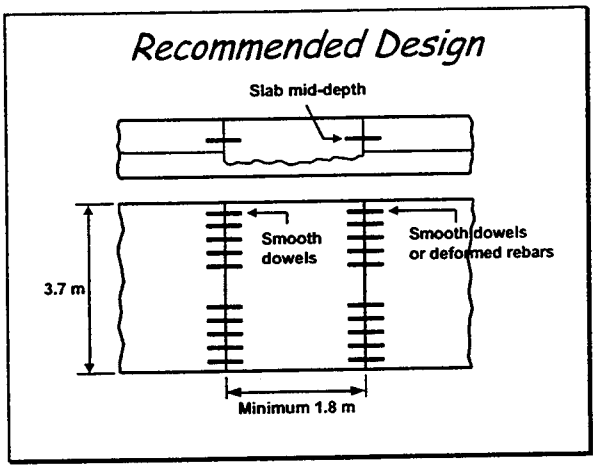
Slide 90

Full-Depth Repair

- Removal and replacement of concrete through entire depth
- Typically performed at joints and cracks
- Purpose
  - Restore rideability
  - Prevent further deterioration

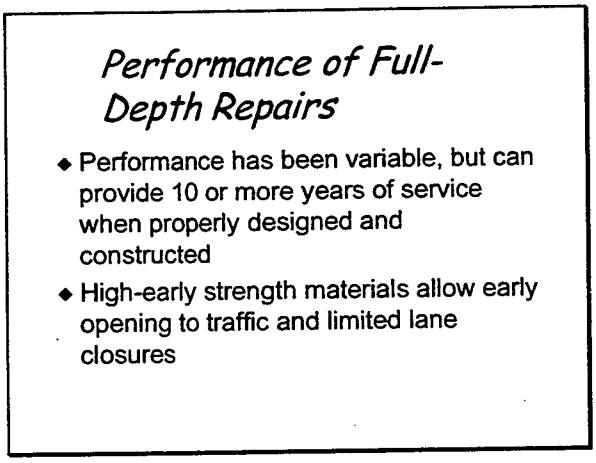
Full-depth repairs differ from spall repairs in that the entire depth of the concrete slab is removed in the distressed area and replaced with new concrete. Distresses that can be addressed with full-depth repairs include transverse and longitudinal cracks, blowups, joint spalling, faulting, and punchouts. In the preventive maintenance arena, FDR may be appropriate for localized areas of pavement that are known or suspected to be deteriorated.

Slide 91



Full-depth repairs should be at least 1.8 m (6 ft) to ensure the extent of deterioration is addressed and to provide a more stable repair that exhibits more slab-like behavior. Smooth dowels should be placed at one or both ends; deformed tiebars can be placed at one end only. The dowels should be placed at mid-depth within the slab.

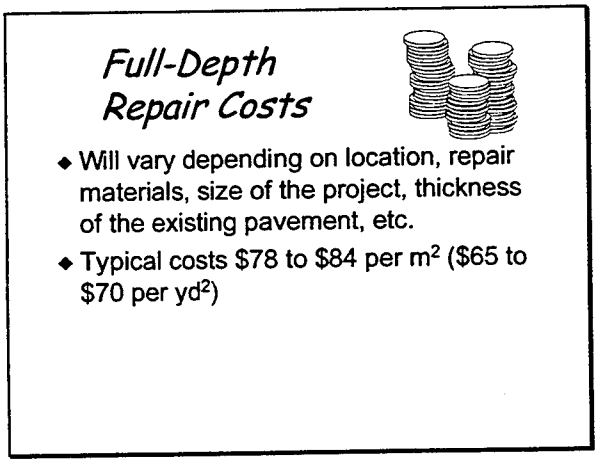
Slide 92



Full-depth repairs can provide long-term performance when properly designed and constructed. Several FDR projects resulted in poor performance, and most of these early failures were attributed to inadequate design (most notably poor load transfer) or poor construction quality.

For preventive maintenance, the use of high-early strength materials is recommended to allow the pavement to be opened to traffic quickly. The use of a Type III cement, high cement contents, and chemical accelerators (such as calcium chloride) allow opening within 4 to 6 hours.

Slide 93



Typical costs for full-depth repairs are shown here. These costs will vary substantially from location to location and from project to project.

Slide 94

Load Transfer Restoration

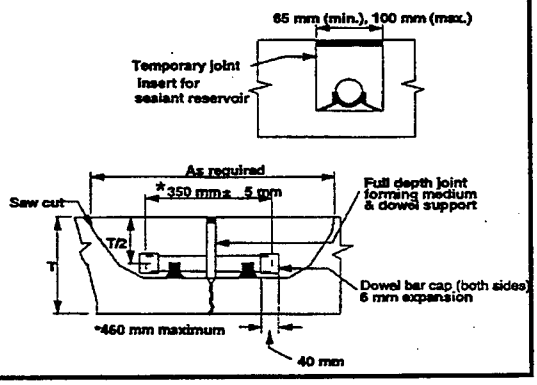
- Placement of load transfer devices across joints or cracks of existing pavements
- Candidate projects
  - Poor load transfer (< 70 %)
  - Pumping
  - Faulting
  - Corner breaks

Also known as retrofitted load transfer, load transfer restoration is a technique used on existing jointed PCC pavements that were constructed without dowel bars at the transverse joints. The purpose is to provide reliable load transfer across the joints (and/or cracks) so that pumping and faulting is reduced or eliminated. It is most appropriate for pavements in relatively good condition that do not exhibit significant levels of distress.

Smooth round dowel bars are the recommended retrofitted load transfer device. Others devices have been tried but have not provided reliable performance.

Slide 95

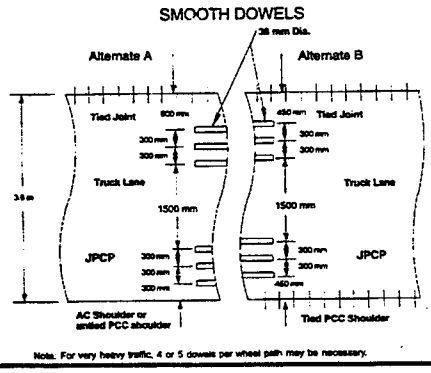
Retrofitted Dowel Bar Assembly



In the load transfer restoration process, slots are saw cut into the pavement. Dowels are placed on supports at mid-depth and backfilled with cementitious material and finished flush with existing pavement.

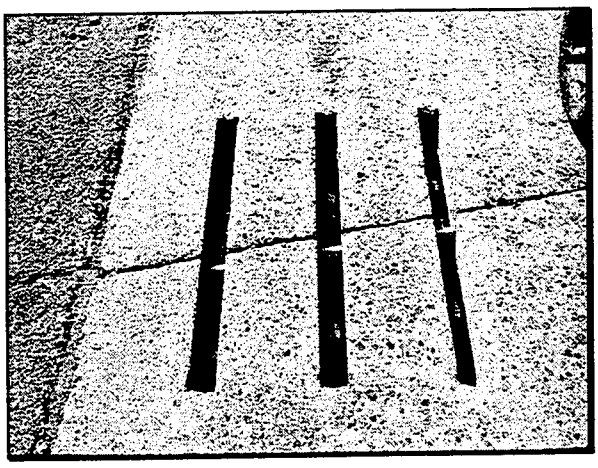
Slide 96

Retrofitted Dowel Bar Layout



Dowels are generally clustered in groups of three dowels in each wheelpath. Groups of 4 or 5 dowels in each wheelpath may be required for very heavily-trafficked pavements.

Slide 97



This photo illustrates the placement of the dowel bars in the slots. The dowels are placed on chairs to keep them horizontal and at the right depth.

Slide 98

Performance of Load Transfer Restoration

- FHWA - 9 years of service
- Puerto Rico - 0.5 % failures after 8 years (7,000 dowels installed)
- Washington - excellent performance with service lives of 10 to 15 years

The performance of retrofitted dowel bars has generally been good. Washington State has been one of the leaders in the use of this technology, although many other states (Kansas for example) are now using this technique.

Slide 99

Load Transfer Restoration Costs

- Installed costs: $25 to $35 per dowel on production jobs

Typical costs for load transfer restoration varies, but on production jobs costs between $25 to $35 per dowel are common.

Slide 100

Treatment Selection Process

1. Establish existing pavement condition
2. Obtain project information
3. Determine causes of distress
4. Develop feasible alternatives
5. Perform life cycle cost analysis
6. Select preferred alternative
7. Construct and monitor performance

Because there are many different treatment methods, as well as variations within a treatment method, a methodical approach to the selection of preventive maintenance treatments is recommended. This approach is outlined in this figure and includes a life cycle cost analysis, which will be described in the next module. It should be noted that the expected performance life of each treatment is needed for the LCCA, and this is not always well established for the treatments, particularly under a variety of conditions (traffic, environment).

Slide 101

Project Timing

- Applying the right treatment to the right pavement *at the right time*
- No universal method available
- Most agencies rely on policy or experience of field personnel

Timing is a critical factor on the effectiveness of a giving treatment. If performed too early, there is not enough performance benefit to offset the cost of applying the treatment. If performed too late, the pavement is too deteriorated to benefit from the treatment. Unfortunately, at the present time there is little guidance on identifying the right time for applying preventive maintenance treatments, and most agencies rely on policy or on the engineering judgment of experienced field personnel.

Slide 102

Summary

- Many available treatments for AC and PCC pavements
- Each has advantages and limitations
- Performance and cost vary with given conditions

This module has presented a broad overview of the available preventive maintenance treatments for both AC and PCC pavements. It is not intended to provide detailed design and construction information for each technique, but rather to present the different techniques and provide some general information as to what they address and when they might be used.

A summary table of the various techniques is provided in the reference manual at the end of module 3.

MODULE 4

COST ANALYSES

NOTES

MODULE 4
COST ANALYSES

Instructional Time: 75 minutes
Presentation File: Mod 4 Cost Analyses.ppt
Reference Manual: Module 4, "Cost Analyses," p. 87-122

Overview

This module introduces some of the techniques available for demonstrating the cost-effectiveness of preventive maintenance programs and the importance of early maintenance in reducing the life cycle costs of pavement preservation. The analyses support a shift in emphasizing the importance of preventive maintenance from a program that receives the funds remaining after all other needs have been addressed to a recognized program that receives cyclic funding for scheduled activities. The results of the cost analyses discussed in this module provide the information needed for preventive maintenance programs to more effectively compete for funding with other road needs such as rehabilitation, reconstruction, or reactive maintenance activities.

Learning Objectives

The learning objectives for this module are as follows:

1. Become familiar with cost analysis approaches and the role of PMS in cost analyses.
2. Understand the basic principles of engineering economics.
3. Describe the common methods used to compare alternatives.
4. Discuss ways that cost analysis results can be used in decision making.

Participant Review Questions And Answers

1. What role does cost analysis play in the development and implementation of pavement preventive maintenance programs?

   Cost analysis tools are essential in demonstrating that a preventive maintenance policy is able to contribute to lower overall system preservation costs. As such, these tools can be used both to demonstrate the need for a program as well as document the benefits that an existing program are providing to an agency. Cost analysis allows an agency to calculate

the long-term financial implications of preventive maintenance, or any other pavement preservation strategy.

2. How does a pavement management system provide information for engineering economic analyses?

   A PMS can be used to determine the life of a treatment and the performance of that treatment. A PMS is especially useful for analyzing the network performance implications of different funding scenarios and different preservation policies. This information can then be used to calculate the funding needed to maintain the pavement network at a desired level, or to see the effects of different levels of funding support on pavement condition.

3. List some benefits that could be considered in a cost analysis.

   Benefits can be measured in many different ways. In addition to cost savings, some of the common benefit measures are: safety, reduced travel time, reduced tort liability claims, reduced vehicle operating costs, reduced disruption to users, reduced discomfort, increased service life, and improved overall pavement condition.

4. What are some of the approaches to cost analyses? Which are most commonly used?

   Some of the approached to cost analyses are first cost comparisons, life cycle cost analysis (LCCA), benefit/cost (B/C) analysis, and longevity cost index. Probably the most commonly used approaches are LCCA and B/C analyses.

5. Differentiate between an interest rate, an inflation rate, and a discount rate.

   The interest rate can be thought of the time value of money, or the amount by which an investment will increase over time. The inflation rate is the general increase in price levels over time, caused by an increase in the volume of money and credit relative to the availability of goods. It reflects the rate of decline in the general purchasing power of a currency, so that over time money may earn interest, but lose value. The discount rate takes into consideration both the interest rate and the inflation rate, and is meant to provide an indication of the net effect on an investment of these two competing forces. However, real discount rates do not incorporate an inflation rate.

6. Why are user costs controversial in the computation of life-cycle costs?

   User costs, which may include vehicle operating costs, accident costs, delay costs, discomfort costs, social costs, and other direct and indirect costs associated with the use of a pavement facility, are extremely difficult to calculate. Once calculated, they can dominate the results of a cost analysis, so that the treatment costs are almost negligible in comparison.

7. What advantages does the Benefit/Cost approach have? What disadvantages does it have?

   A B/C analysis includes a representation of the performance of a treatment (in terms of its benefits) and as such provides an indication of the cost-effectiveness of one treatment or strategy over another. However, for it to be used, an agency must be able to calculate or estimate the effect that the treatments under analysis have on pavement life. To date, modeling maintenance treatment effects has not been widely accomplished.

8. Why are sensitivity analyses often conducted on cost analysis results? How does this lend credence to a probabilistic (i.e., risk analysis) approach?

   A sensitivity analysis examines the effect of one input to the process on the output. Sensitivity analyses on cost analysis studies help an agency to determine the variables that have the greatest impact on the LCCA results. These results can be used to determine the economic conditions under which one results is preferred over another.

Pitfalls

Don't get bogged down on a lot of the details of the various cost analyses. The important point here is that the tools are available and should be used. Neither the cost nor the performance alone should be used to drive decision-making.

Discussion Points

There are several points that someone in the course should be able to provide information on. These include the agency's policy on user costs, what interest rates or discount rates are commonly used for analyses, and what sort of analyses are currently being performed with the agency's pavement management system.

Are the analytical tools available to evaluate preventive maintenance effectiveness? If not, what sort of capabilities need to be added?

Areas To Reduce If Time Constraints Exist

Many of the cost analysis procedures can be gone over very quickly to conserve time.

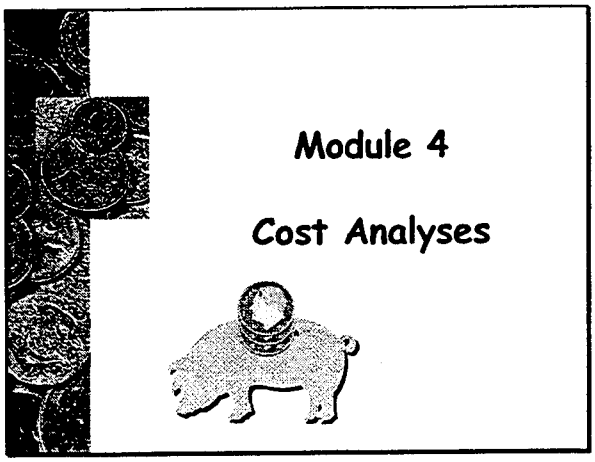
Associated Workshop

Workshop 3, *Demonstrating the Importance of Your Preventive Maintenance Program to Management.*

NOTES

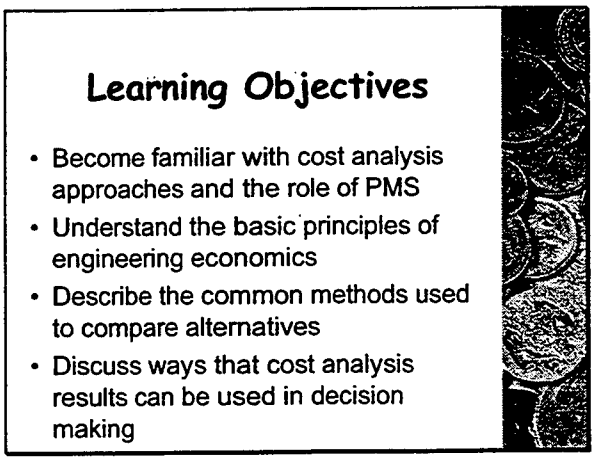
Presentation Graphics and Instructor Notes

Slide 1



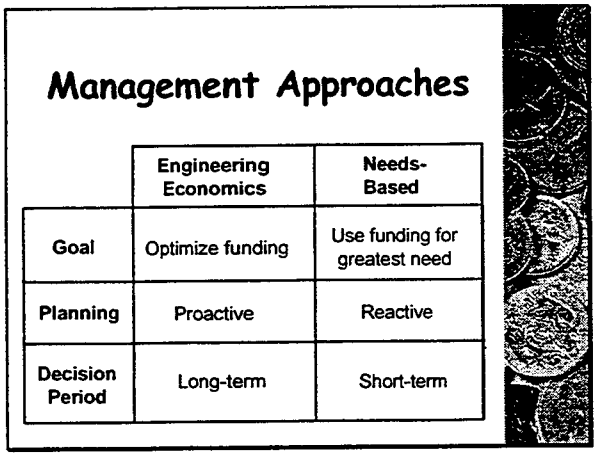
This module describes methods for performing cost analyses. These methods are useful in quantifying the benefits of a preventive pavement maintenance program. By quantifying the benefits, the merits of a preventive maintenance program can be demonstrated to both management and the public.

Slide 2



These are the learning objectives of this module. Each will be discussed in this presentation.

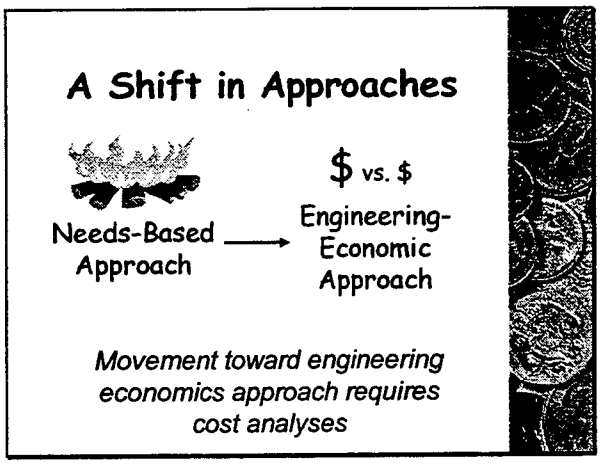
Slide 3



Two approaches used in managing pavements are an engineering economics approach and a needs-based approach. This table highlights some of the important differences between the two, with the primary differences being the extensive planning and analysis that goes into the engineering economics approach.

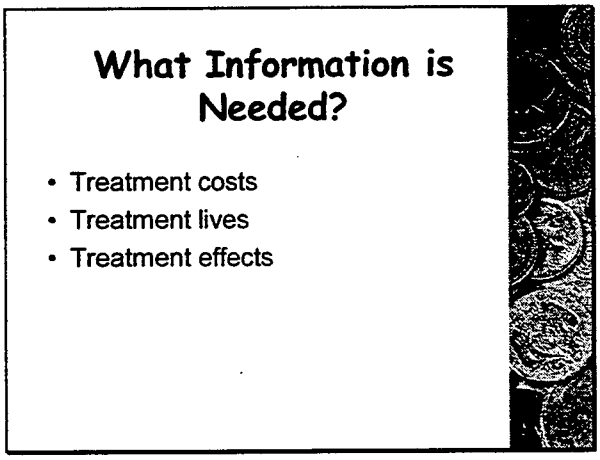
This module focuses on the engineering-economic approach, which focuses on economic decisions that are linked to our design decisions. An agency with a large backlog will not spend less money using this approach, but it can make better use of the money that they have.

Slide 4



In order to make the change from a needs-based approach to an engineering-economic approach, we need to be able to conduct cost analyses, which provide a means of evaluating the costs and benefits associated with various treatment options.

Slide 5



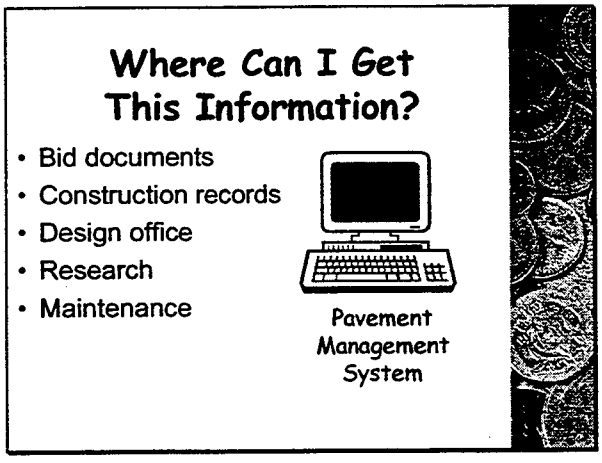
In order to conduct cost analyses, what information is needed? Address this question to the class to get their input.

--Treatment costs refer to the costs of the treatment, including material costs and installation/construction costs.

--Treatment lives refer the treatment itself (i.e., How long will it last before reapplication or rehabilitation is needed?).

--Treatment effects refer to the effect of the treatment on the existing pavement (i.e., How much will it improve the existing pavement condition? Will the treatment extend the life of the pavement?).

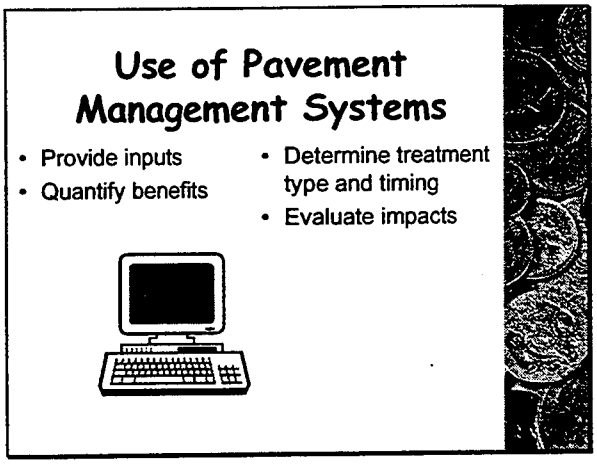
Slide 6



Where can we get the information needed to conduct the cost analyses? Again, address this question to the class. Is this information available?

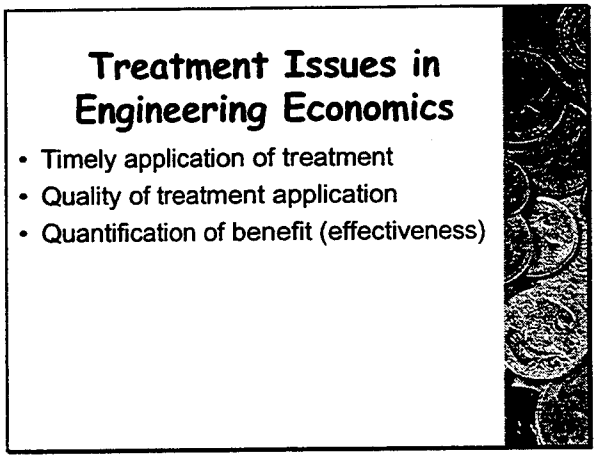
Much of this information may be available in an existing pavement management system. If the pavement management system is set up correctly, much of the information should already be available there.

Slide 7



The use of pavement management systems can simplify many analyses. It is an important source of objective data that can be used to justify budgets and quantify the benefits of maintenance, rehabilitation, and capital improvement programs. All the information is stored in one database and can be accessed to evaluate specific strategies and treatments.

Slide 8

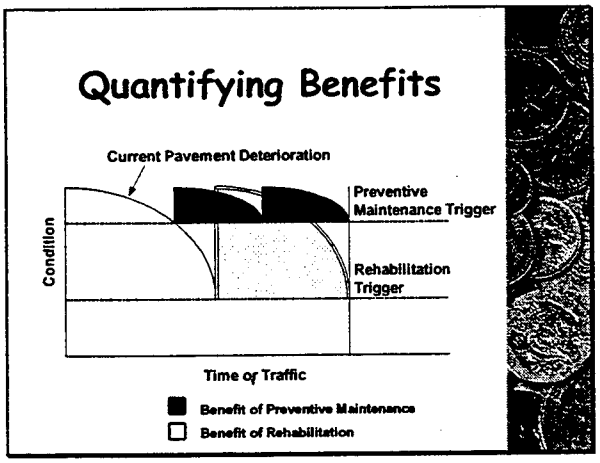


Several important issues come into play during a cost analysis. The first issue is the timing of the application of the treatment. In order to be successful, preventive maintenance must be applied at a time when the pavement is in good condition with little evidence of structural deterioration (there is a window of opportunity). Deferred maintenance will result in benefits that are not realized or are less than expected.

The second issue is the quality of the treatment application. The analyses assumes good quality materials and application techniques; deviations will have a negative impact on results.

The third issue is the quantification of the benefits achieved through the treatments. When conducting a cost analysis, one must evaluate the benefits associated with preventive maintenance, whether they are project-level or network-level, and attempt to quantify these benefits. Benefits include reduced life cycle costs, extended service life, safety, travel time savings, reduced tort liability claims, reduced vehicle operating costs, reduced discomfort, and preservation of the investment. Benefits can be difficult to quantify, but several techniques are available for demonstrating the benefits of a treatment.

Slide 9



Here is an example of a benefit computation. This method has been used in PMS. The shaded area illustrates the benefit in terms of pavement performance. Some agencies use a weighting (such as ADT) to assess the impact of the benefit. The decision then accounts for user impacts in an indirect manner. This factor is especially important when considering alternatives on a network rather than a project level

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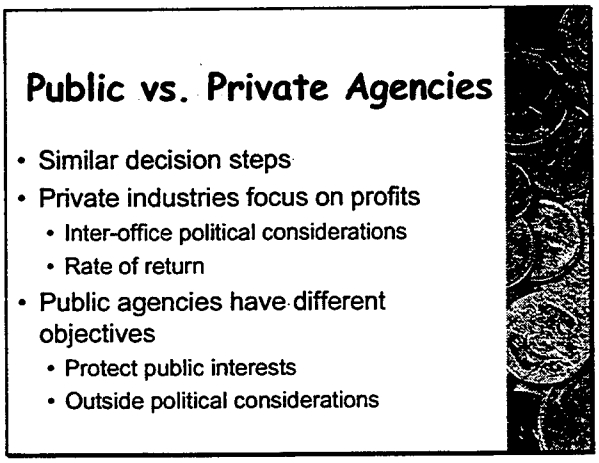
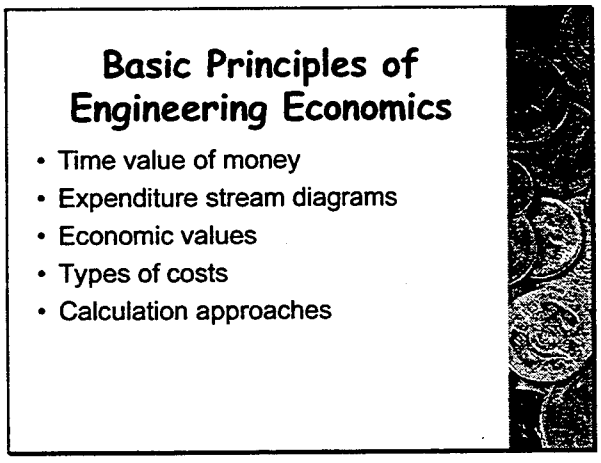
Slide 10



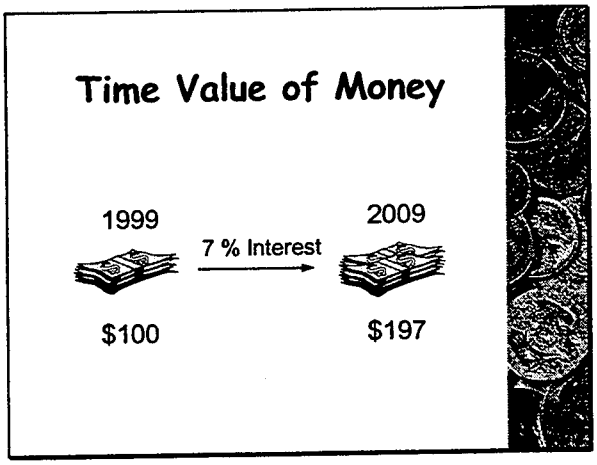
Although the decision steps for evaluating alternatives are often similar, there are many differences between public and private agencies. For example, politics has a larger interest in public agencies than in private industry. Therefore, decisions are not always made on the basis of pure engineering or economic sense. Also, private industry focuses on generating a profit for its shareholders, whereas public agencies do not have such an objective because any excess funds are distributed to other public needs.

Slide 11



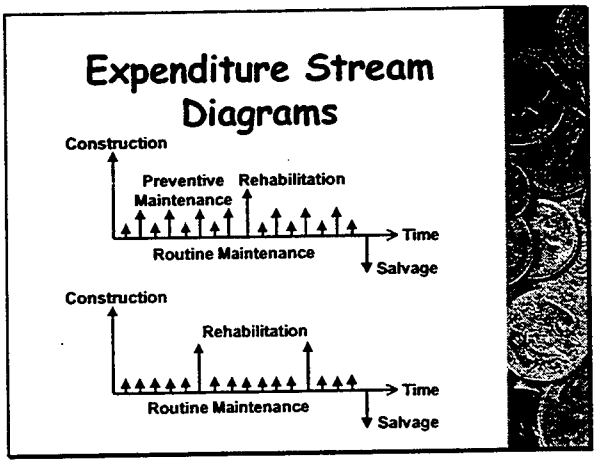
With that background on the use of engineering economics in the preventive maintenance setting, we are now ready to delve into more of the details of conducting various cost analyses. First, however, we will begin with some basic principles of engineering economics.

Slide 12



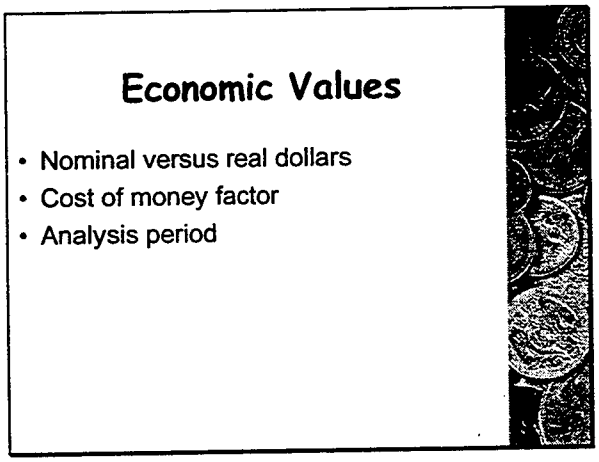
The most basic principle in engineering economics is understanding the time value of money. The concept is that money earned today does not have the same value at a later date because it can be invested rather than spent. For example, $100 invested today at 7 percent interest would be worth $197 in 10 years. We will get into the actual mathematical calculation later.

Slide 13



Expenditure stream diagrams are a useful tool to help visualize the expenditures and income over an analysis period. Two different strategies are outlined here. The top diagram considers preventive maintenance activities, whereas the bottom diagram does not. This is the first step to comparing these strategies using a life cycle cost approach. Discounted values of activities far in the future have little impact on the present worth.

Slide 14



There are several economic values used in a life cycle cost analysis that need to be defined. Each will be discussed.

Slide 15

Nominal vs. Real Dollars

- Real (constant) dollars
  - Purchasing power stays the same over time
- Nominal (inflated) dollars
  - Purchasing power fluctuates over time

Do not mix nominal and real dollars.

Use the same approach for discount rate.

Real dollars reflect dollars that have a constant level of purchasing power over time. Thus, the cost of conducting some type of activity in the future would be no different than if the activity were performed today. Nominal dollars, on the other hand, reflect dollars whose purchasing power fluctuates over time. They typically account for increased costs associated with inflation.

Normally, the use of real dollars is recommended.

Stress that you can not mix real and nominal dollars in the same analysis. Also, the discount rate must be based on the same approach. FHWA recommends the use of real dollars and real discount rates.

Slide 16

Cost of Money Factor

- Interest rate
- Inflation rate
- Discount rate

Using real dollars:
Discount Rate = (Int - Infl) / (1+ Infl)
~ Int - Infl

Using nominal dollars:
Discount Rate = Interest Rate

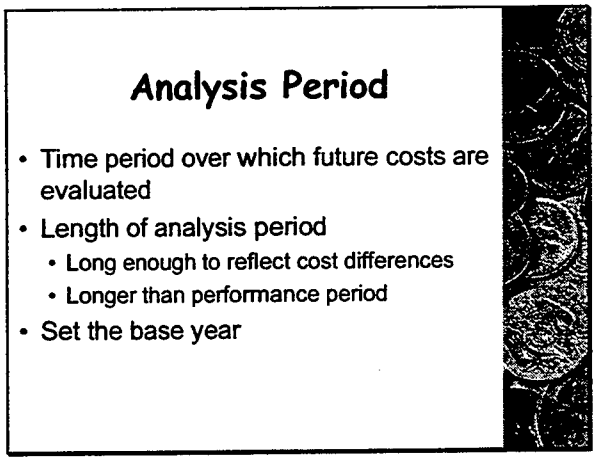
The factor that accounts for the change in the cost of money is sometimes called the interest rate, but more accurately it is called the discount rate. The discount rate accounts for the effects of inflation.

Using real (constant) dollars, the discount rate may be computed using the equation shown, or may be approximated as the numerical difference between the interest rate and the inflation rate.

Using nominal dollars, costs have already been inflated so they are discounted using the interest rate only.

Ask the class what an appropriate discount rate might be. Does it stay constant over time? Also ask what should be the basis for an interest rate and the inflation rate. Many experts believe that the interest rate can be represented by the rate on Treasury Notes and that the inflation rate can be represented by the Consumer Price Index. The FHWA suggests values between 3 and 5 percent for the discount rate (when using real dollars).

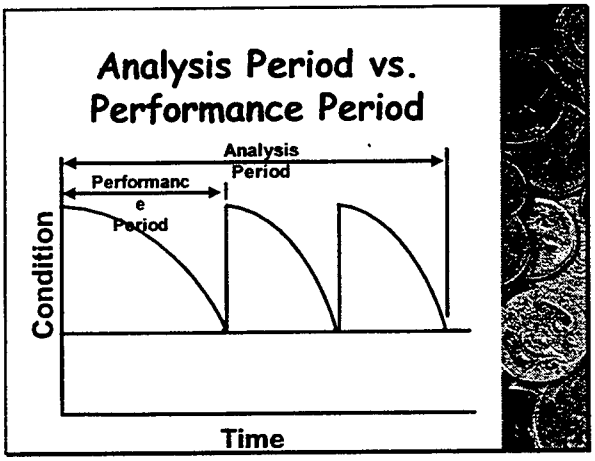
Slide 17



The analysis period is the length of time over which all costs will be evaluated. The analysis period should be longer than the performance period (design life) of a particular pavement design. FHWA recommends an analysis period of at least 35 years for all pavement projects, and should include at least one major rehabilitation activity.

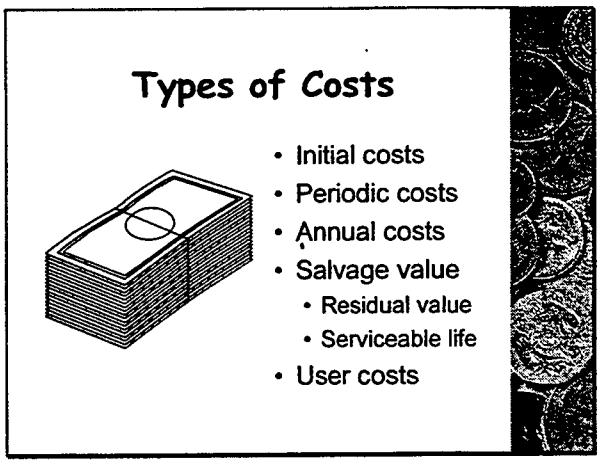
The base year represents the time to which all costs are discounted. This point can be sometime during the design phase, during construction, or after construction is complete and the road is opened to traffic.

Slide 18



This figure illustrates the difference between the analysis period and the performance period.

Slide 19

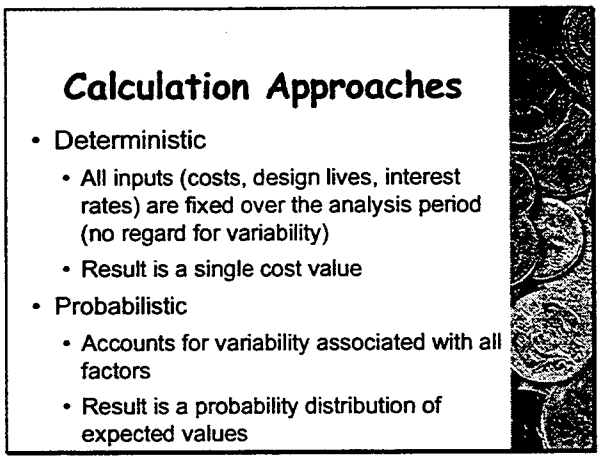


A variety of costs must be included in a detailed cost analysis. These include initial construction costs, future periodic costs (e.g., an overlay at year 10), annual costs (e.g., annual crack sealing costs), salvage value, and user costs.

Preventive maintenance costs fall under periodic costs. Routine maintenance costs are considered annual costs. The use of user costs is a subject of much debate; some say they are not legitimate agency costs and should not be included, whereas others claim that they are a legitimate cost to the traveling public and should be considered. User costs are difficult to quantify and can often dominate the analysis. We will discuss user costs in a little more detail at the end of the module.

It should be noted that generally only differential costs need to be considered. Costs that are common to all alternatives (such as planning and mowing) do not need to be considered.

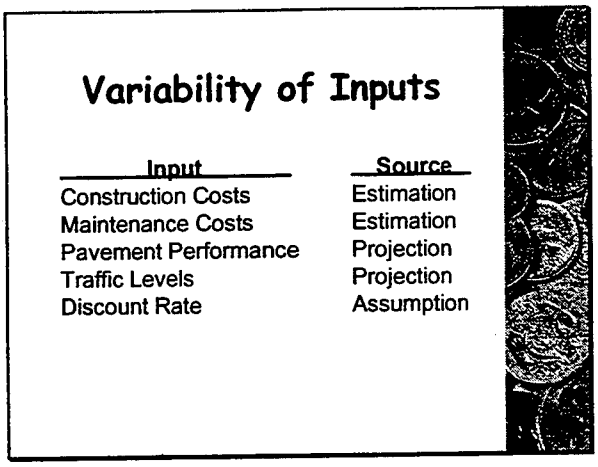
Slide 20



There are two calculation approaches when conducting cost analyses. The first is a deterministic approach, in which it is assumed that all factors (costs, design lives, interest rates, etc.) are fixed and do not vary over the analysis period. The result is a single cost value for the strategy.

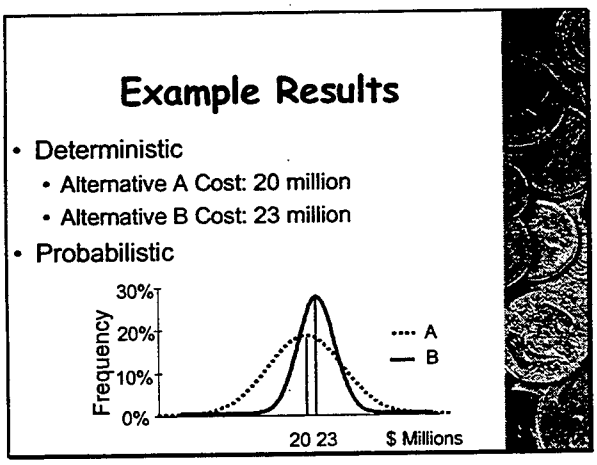
The second approach is probabilistic approach in which it is recognized that there is variability associated with each of the inputs (the life of the pavement and treatments, costs of the treatments, the discount rate, etc.). By assigning probability distributions to each of these variables, a probability distribution of expected cost values is obtained. This approach exposes areas of uncertainty and clearly illustrates the risk involved with making certain decision. By knowing the risk, an opportunity is provided to take mitigating action to reduce or minimize the amount of risk.

Slide 21



To illustrate why the probabilistic approach is so attractive, consider a few of the input values in a cost analysis and where they come from. It is clear that there is variability associated with nearly every input in an LCCA. Yet using a deterministic approach, this variability is not considered; a single value is assigned.

Slide 22



This example shows the difference between the two calculation procedures. Assume that two alternatives are being evaluated. A deterministic calculation shows that alternative A costs 20 million while alternative B costs 23 million, suggesting that alternative A is better. However, a probabilistic calculation reveals the probability distributions shown in the figure. Although the mean cost of alternative A is indeed less than alternative B, the variability of alternative B is far less, meaning that it is more likely to be around the 23 million dollar figure.

The FHWA recently published a Technical Bulletin detailing the approach to probabilistic cost modeling. Although not currently in common use, many agencies are exploring the use of probabilistic modeling in their cost analyses.

Slide 23

Methods to Compare Alternatives

- Life cycle cost analysis (LCCA)
- Benefit/cost analyses
- Longevity cost index
- First cost comparison

We now want to look at some of the different methods used to compare alternatives. Most of the discussion will focus on life cycle cost analysis, although some of the other methods will be briefly discussed.

There are several other methods (payback period, internal rate of return) that will not be discussed in this presentation.

Slide 24

Life Cycle Cost Analysis

- Most common approach for comparing alternative strategies
- Evaluates all costs over analysis period
- Uses equivalent dollars to compare projects at different times and cost distributions
- Does not account for varying levels of service

Life cycle cost analysis (LCCA) is the most common approach for conducting an economic analysis. This method considers factors such as projected performance, future maintenance and restoration, length of analysis period, and economic conditions over the analysis period to try and express costs in terms of equivalent dollars so that projects with varying performance lives and costs can be compared. However, this approach does not account for the varying levels of service that different alternatives might provide (that is, the fact that, say, alternative A provides a higher level of smoothness over the analysis period than alternative B is not directly considered).

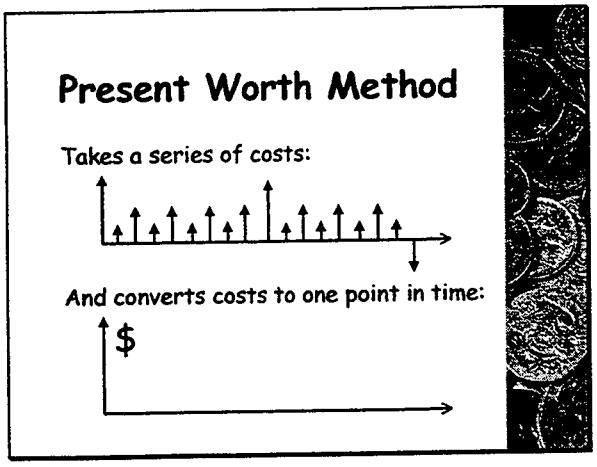
Slide 25

Approaches to Life Cycle Cost Analysis

- Present worth (PW)
- Equivalent uniform annual cost (EUAC)

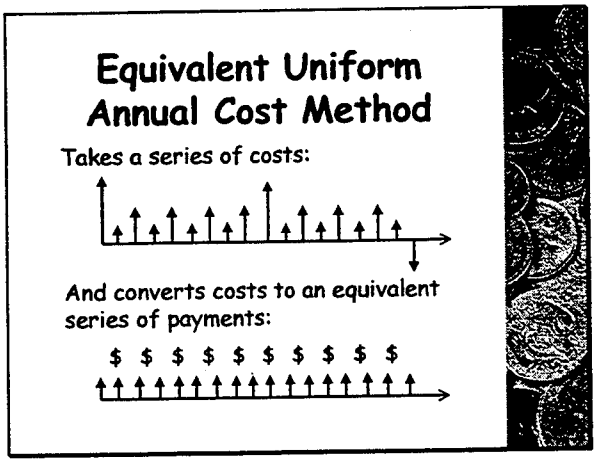
There are two methods to analyze the life cycle costs: the present worth approach and the equivalent uniform annual cost approach. Each will be described briefly in the following slides.

Slide 26



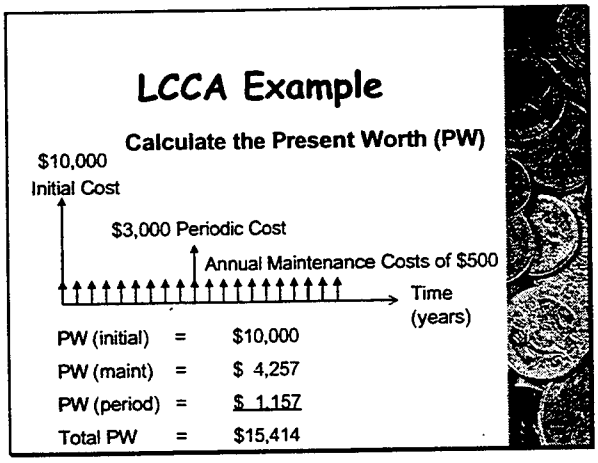
The present worth approach is the most common method. The present worth method uses a discount rate to convert all costs (including one-time costs and a series of costs) to a single point in time. The result is a single value that represents the present worth of all costs and income associated with a strategy. Multiple alternatives can be evaluated and compared using an equivalent value.

Slide 27



The equivalent uniform annual cost method uses the same concepts as the present worth method but all costs are converted to an equivalent uniform annual cost. This cost represents the amount that would have to be invested each year of the analysis period to match the total present worth of the project.

Slide 28



This example is in the reference book on page 101. Quickly walk the participants through it and point out the equations used to convert the future costs to a present worth cost. Indicate that the EUAC calculation is similar.

Slide 29

Life Cycle Cost Analysis

- Advantages
- Disadvantages

Ask the group to list some of the major advantages and disadvantages of the LCCA approach.

Among the advantages: The approach has been widely used for many years and is familiar to most people. It is an objective method of comparing alternatives and the inputs are fairly easy to quantify. Variations in the inputs can be evaluated using either a sensitivity analysis or a probabilistic approach.

The main disadvantage is that pavement condition is not considered in the analysis. It assumes that all alternatives provide the same level of service.

Slide 30

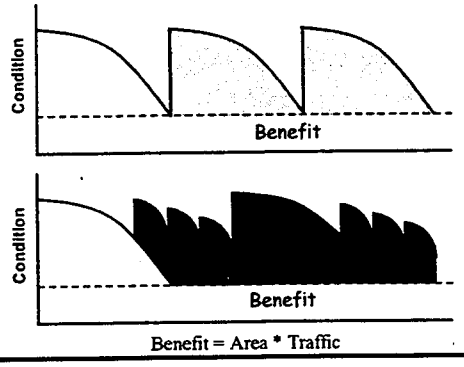
Benefit/Cost Analysis

- Considers both the cost and effectiveness of a treatment
- Costs determined using LCCA
- Benefit accounts for performance and users impacted
- Approach is used in many PMS

An approach that is being widely used in the PMS area is the benefit/cost analysis. This approach provides better results in terms of performance and user impact than life cycle or equivalent annual cost approaches. It is a more sophisticated approach in that it considers both costs and the benefits or effectiveness of each alternative. The benefit is measured in terms of the effectiveness of the treatment.

Slide 31

What is Benefit?



One way of quantifying the benefits is using the area under the pavement performance curve multiplied by a traffic factor such as average daily traffic.

One difficulty with the benefit/cost approach is quantifying multiple benefits using a common basis.

Slide 32

Benefit/Cost Comparison

Strategy	Benefit	ADT	Cost
Preventive Maint.	250	7000	$500,000
Rehabilitation	1000	7000	$3,500,000

PM Strategy: $B/C = \frac{250 * 7000}{500{,}000} = 3.5$

Rehab Strategy: $B/C = \frac{1000 * 7000}{3{,}500{,}000} = 2.0$

Here is an example of a simple benefit/cost calculation. In this case, the rehabilitation strategy provides more benefit but at a much greater cost than the preventive maintenance strategy. The result is that the preventive maintenance strategy has a greater benefit-cost ratio and is the most cost-effective alternative.

Slide 33

Benefit/Cost Strategy On A Network Level

Σ Highest Benefit/Cost Ratios

The most cost-effective strategies are selected

The previous examples involve an evaluation at the project level. On a network level, the most cost-effective strategies, in terms of the benefit to the network, are selected. Said another way, not all strategies can be performed due to funding constraints, so this process selects the best projects.

Slide 34

Benefit/Cost Analysis

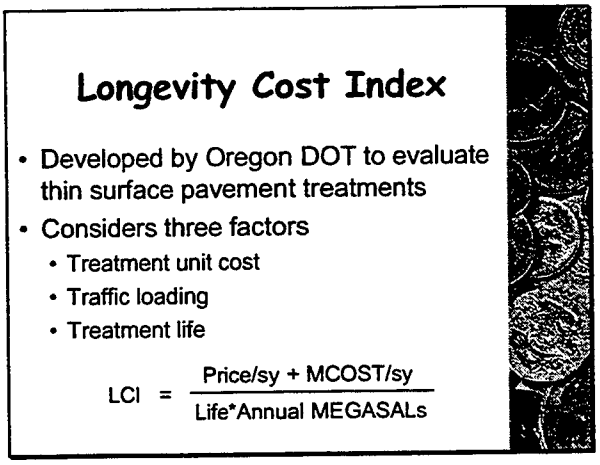
- Advantages
- Disadvantages

Ask the class to name some of the advantages and disadvantages of the benefit/cost analysis approach.

Advantages: This method considers both the cost and benefits associated with each alternative. Some pavement management systems are set up to handle this type of analysis.

Disadvantages: This method is more complex than other methods. Also, it is often difficult to quantify the benefits. This method can be difficult without a pavement management system.

Slide 35



The longevity cost index method is not widely known. It provides a relatively straightforward method of determining cost-effectiveness of treatments. It requires performance data from a PMS.

LCI = (Price/sy + MCOST/sy) / (Life x Annual MEGASALs)

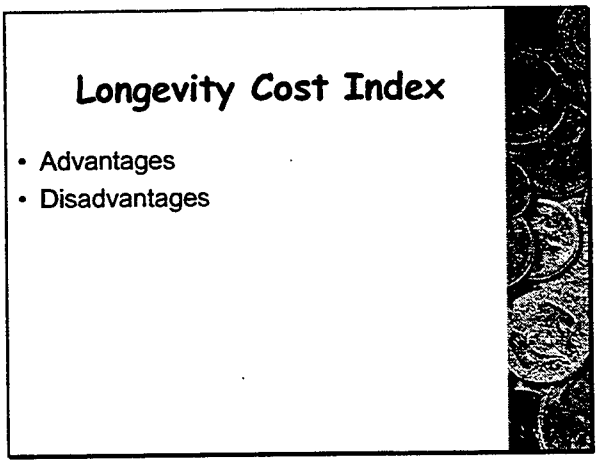
Price/sy = initial unit price of treatment.

MCOST/sy = present value of the unit maintenance cost during treatment life.

Life =average or median life of the treatment.

MEGASALs = one million equivalent single axle loads.

Slide 36

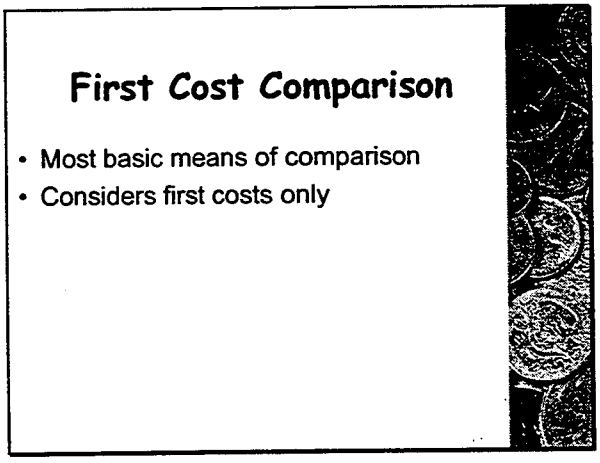


Ask the class if they can name any advantages and disadvantages to the LCI

Advantages: Although not as common, this method does provide a straightforward means of determining the cost effectiveness of a particular treatment under different applications.

Disadvantages: It requires inputs that may not be easy to determine (such as ESALs). The use of a PMS can simplify the use of this method.

Slide 37



This is the most basic method of comparison. This technique compares the unit cost of options on a unit of production basis. In other words, the unit cost is the total cost divided by the amount of production.

Slide 38

First Cost Calculation

- Sealant costs = $6,000
- Labor costs = $4,000
- Equipment costs = $2,000
- 4000 feet of cracks to seal

What is the unit cost?

$$\frac{\$12,000}{4000\ ft} = \$3.00/ft\ (\$9.84/m)$$

Here is an example of the first cost calculation.

Note that this method can only be used to compare alternatives with equal, short-term performance periods. In addition, it should not be used as the sole method of comparison because it ignores many important variables, such as annual costs, time value of money, and effectiveness.

Slide 39

First Cost Comparison Analysis

- Strategy 1: Crack Sealing
  - Unit cost = $0.91/m (3.00/ft)
- Strategy 2: Chip seal
  - Unit cost = $1.67/m^2 (1.40/yd^2)

How do you compare these strategies?

This example points out some of the shortcomings of this method. What are the problems with comparing these two strategies? What is the performance life of each? What is the benefit provided by each? The first cost comparison approach can not readily address those issues. Again, this type of analysis can only be used to compare alternatives with equal, short-term performance periods.

Slide 40

First Cost Comparison Analysis

- Advantages
- Disadvantages

Ask the class to list some of the advantages and disadvantages of the first cost comparison approach.

The main advantage of this method is its simplicity. However, it does not consider some important factors such as annual costs, time value of money, life cycle costs, and effectiveness. It is not recommended as the sole method of analysis.

Slide 41

Use of Results for Decision Making

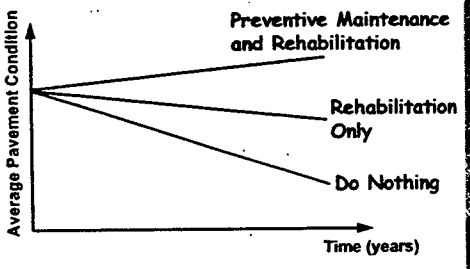
- Determine cost-effective strategies
- Lower overall life cycle cost of pavement preservation
- Improve overall network conditions

We now want to spend a little time highlighting how the cost analysis results can be used to improve and enhance the decision-making process within a transportation agency, and also how it can be used to determine optimal funding levels needed for preventive maintenance.

The following slides present ways of evaluating the information in order to make informed decisions.

Slide 42

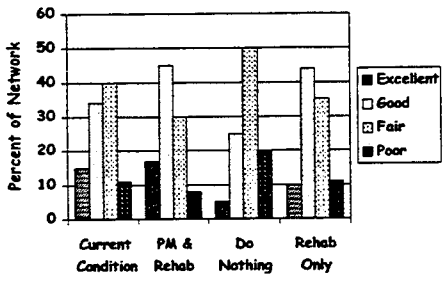
Illustration of Strategy Impacts



This is one format for evaluating the impacts of different strategies. This figure plots the average condition of the pavement over time for three alternatives. Instead of pavement condition, other factors that can be evaluated are percentage of pavements in various categories or remaining service life.

Slide 43

Network Distribution Under Different Strategies



Another way to present the data is to look at the percentage of pavements in various categories. This example figure looks at the percentage of pavements in excellent, good, fair, and poor condition after 5 years for different strategies and compares it to the current condition. The preventive maintenance strategy results in the highest percentage of pavements in the excellent and good categories. The benefits could become more apparent over time until the pavement condition stabilizes.

Slide 44

Cost Comparison (New York)

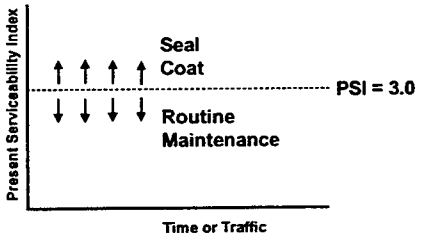
Description	Preventive Maintenance Yes	No
Life Cycle Cost	$144,036	$382,590
Life Cycle Cost Ratio	0.376	1.0
Effectiveness (Cond. Years)	176	128
Cost-Effectiveness Factor	1.22	0.335
Cost-Effectiveness Ratio	3.65	1.0

Here is an example of a cost comparison that was conducted by the New York State Department of Transportation in determining the cost effectiveness of preventive maintenance. The preventive maintenance strategy includes a thin AC overlay at year 12 and crack sealing at years 4, 8, 16, and 20. The second alternative includes no preventive maintenance but complete reconstruction at year 24. The comparison indicates that the preventive maintenance strategy is about one-third the cost and 3.65 times more cost effective than the second alternative.

Slide 45

Indiana Preventive Maintenance Study

Goal: Minimize User Costs

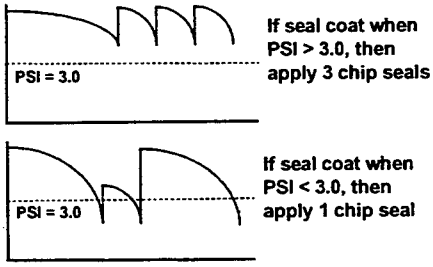


Another example of a cost comparison was conducted using information in the Indiana Department of Transportation database. The study found that to achieve the maximum user cost savings, the seal coat activities could not be postponed beyond a PSI value of 3.0. If deferred, the study found that the best strategy is to conduct annual routine maintenance rather than a seal coat.

Slide 46

Indiana Preventive Maintenance Study

Goal: Minimize Agency and User Costs



Combining agency and user costs, however, revealed that the most cost-effective strategy is the application of three consecutive chip seals with routine maintenance, if they are performed before the PSI drops below 3.0,. If deferred, the most cost-effective strategy included basic routine maintenance with one chip seal.

Slide 47

Michigan DOT Example

$315 million Rehabilitation and Reconstruction = $190 million Rehabilitation and Reconstruction + $10 million Preventive Maintenance

Achieved same results for $115 million less

Here is an example from Michigan DOT. Michigan used a remaining life analysis within its PMS to demonstrate the long-term effects of several different funding scenarios. One such analysis evaluated the effect of supplementing their traditional rehabilitation and reconstruction program with a small preventive maintenance program. The results indicated that $315 million is needed for a rehabilitation and reconstruction program to match the same performance of a $200 million program that included $10 million for preventive maintenance. That is, $10 million spent on preventive maintenance saved $115 million annually.

Slide 48

Wisconsin Transportation Center Example

Strategy	Expenditure	Backlog	Condition Rating
Do Nothing	$0	$5.1	4.0
PM Only	$0.5	$3.6	5.6
PM First	$2.7	$0	7.2
Unconstrained	$2.7	$0	7.1
Worst-First	$3.5	$0	7.0
No PM	$3.5	$0.3	6.5

This example was developed by the Wisconsin Transportation Information Center. They evaluated six scenarios over a 109-km (68-mi) network. The annual budget was limited to $800,000. The condition rating represents the average condition on a 1-to-10 scale at the end of the 5-year analysis period.

Based on their analysis, the most cost-effective strategy is to apply preventive maintenance where appropriate and then address reconstruction and rehabilitation needs where preventive maintenance is no longer effective. The most costly option is the one in which preventive maintenance is not conducted.

Slide 49

Sample Problem

- 1,000 lane-kilometers of AC pavements
- No preventive maintenance strategy
- Currently fix when pavements reach poor condition
- Annual budget of $5 million
- Growing backlog

Now let's work through a sample problem. This problem is presented in the Reference Manual beginning on page 116. Here are the current conditions.

Slide 50

Challenge

- Requested an additional $2.5 million annually to rehabilitate 20 more lane-kilometers per year
- Legislature says to consider some alternative policies

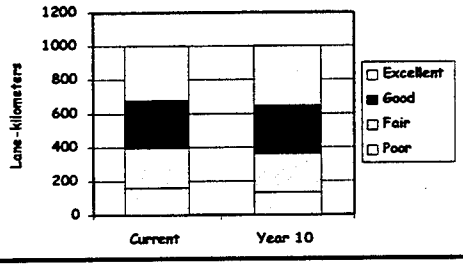
The agency has requested additional funding to address the growing backlog. However, the legislature asks for a consideration of various alternatives and documentation of the results.

How would you handle this situation? Work through this example with the class. Try not to get bogged down in the details of the problem, but rather focus on the points that the example is trying to make.

Slide 51

Step 1

- Project network condition if continue using present practice with extra funding



The first step is to analyze the condition after 10 years if they continue to follow their current practice. After 10 years, they see a slight increase in the number of lane-kilometers in excellent condition and a slight decrease in the number of lane-kilometers in poor condition.

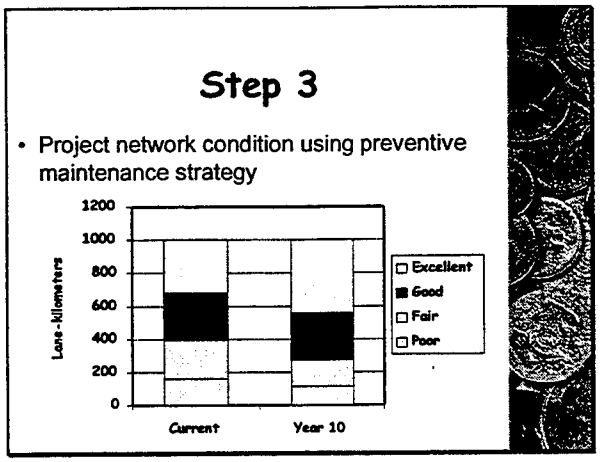
Slide 52

Step 2

- Develop preventive maintenance policy
- Determine impacts
  - 6 more years to reach poor condition
  - 4 more years of excellent condition
  - 2 more years of good condition
- Estimate costs

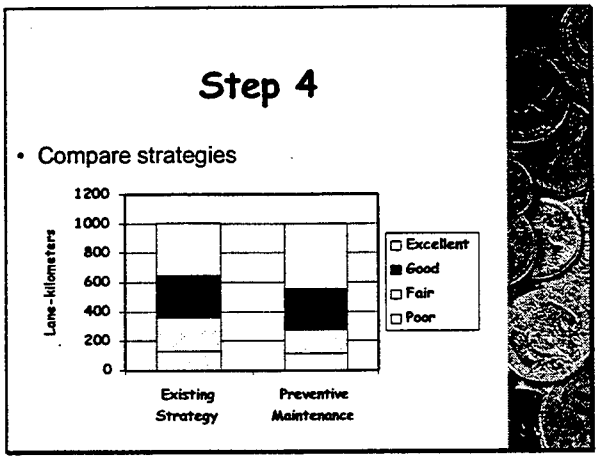
The next step is to develop a preventive maintenance policy. The strategy selected is to crack seal the pavements in excellent and good condition every 2 years and apply a thin AC overlay at year 8. This strategy slows deterioration to lower condition levels as shown.

Slide 53



After 10 years, the number of lane-kilometers in excellent condition has risen dramatically, whereas the number of lane-kilometers in poor and fair condition has decreased.

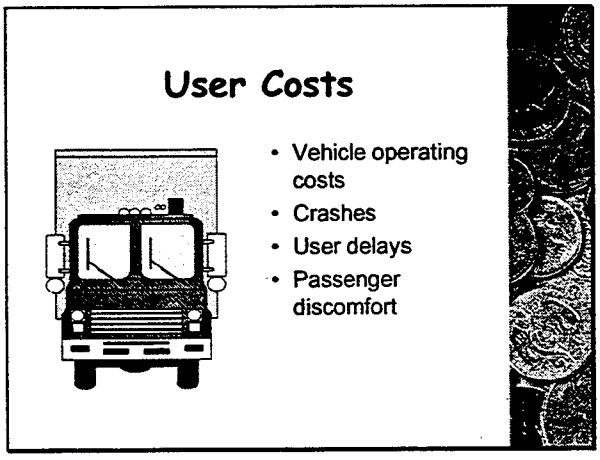
Slide 54



A comparison of the two strategies illustrates the improved pavement condition after 10 years by implementing a preventive maintenance program.

This example not only demonstrates the benefits of the preventive maintenance strategy over the current policy, but also illustrates that it can take several years before the full benefits of preventive maintenance strategies are realized.

Slide 55



One final item that we mentioned earlier was user costs. User costs are defined as costs that are incurred by the traveling public. In a comparison of strategies, only the differential costs need to be considered. The difficulty is that user costs are not easily quantified. For example, what is the extra expense for a vehicle as the pavement deteriorates?

The highest user costs occur during traffic jams when users experience long delays. What is the cost associated with this delay? Again, it is difficult to quantify, but there are models available to estimate these costs.

Slide 56

How to Address User Costs in a Cost Analysis

- Cost components
  - Normal operating costs
  - Work zone operating costs
- Comparison of user delay times
- Comparison of cost effectiveness (try to quantify benefits)
- User costs can dominate LCCA so some agencies ignore

Many agencies have used the area under the performance curve multiplied by traffic levels to represent user benefits. Other agencies choose to quantify the user benefits as a reduction in user costs.

If looking strictly at cost, user delay costs can dominate the analysis to the point where construction and maintenance costs become insignificant. Demonstration Project 115 has more information on this topic.

Slide 57

Summary

- Basics of engineering economics presented
- Various cost analysis methods available for comparing alternatives
- Cost analyses is an integral part of implementing a preventive maintenance program by demonstrating the benefits and cost effectiveness of the approach

In summary, we have presented some basic concepts on engineering economics, and illustrated how they can be used in promoting a preventive maintenance program. Agencies need to be able to prove a preventive maintenance program will be cost effective. The best techniques are those that look at both the costs and the benefits associated with each strategy.

NOTES

MODULE 5

CASE STUDIES

NOTES

MODULE 5
CASE STUDIES

Instructional Time: 90 minutes
Presentation File: Mod 5 Case Studies.ppt
Reference Manual: Module 5, "Case Studies," p. 123-154

Overview

This module summarizes the findings obtained from a series of visits with highway agencies regarding their pavement preventive maintenance programs. The case studies presented here include information about the events that led to the development and implementation of the preventive maintenance program as well as key information about some important elements of implementation. These elements include the following: funding sources, levels and allocations; treatments used; project and treatment selection procedures and guidelines; performance; barriers to implementation; maturing of the plans; and lessons learned during the implementation and maturation process. The five DOTs visited were California, Georgia, Michigan, New York, and Texas.

Learning Objectives

The learning objectives for this module are as follows:

1. Become familiar with pavement preventive maintenance programs in other states.

2. Recognize the similarities adopted by the various agencies in the implementation and execution of the their respective pavement preventive maintenance programs.

3. List the barriers faced by many of the agencies and describe how these were overcome.

Participant Review Questions And Answers

1. How does studying other agencies' pavement preventive maintenance help in getting a program established?

   The experiences that these agencies have already gone through serve as a knowledge resource for others trying to follow the same path. Since the treatments are roughly similar, most pavements are subjected to the same external and internal forces, and economic analyses do not vary, all that's left are differing organizational structures and constraints. How the different agencies face these differences helps others to identify approaches that can be used within their own organizations.

2. What are some ways that agencies select suitable projects?

   The most common methods include worst-first programming, ride or roughness triggers, and various condition indices.

3. What types of barriers to implementation were encountered by the various agencies? How were these overcome?

   Barriers include changes in funding levels, decentralization and lack of organization-wide buy-in, lack of training, lack of management support, lack of public support, determining the right treatment and timing for a given pavement, poor treatment performance, and lack of experienced personnel.

   Some of the methods to overcome these barriers have included developing training programs, performing research on treatment performance, the development of more polished promotional tools, and industry-agency partnerships.

4. Why is selling a pavement preventive maintenance program a continuing effort?

   Funding to public agencies is legislated by elected officials. Funding within those agencies is usually distributed by appointed officials. These people face numerous conflicting demands in their decision making, and then soon are out of office and are replaced by a new group. Preventive maintenance is a shift away from worst-first programming, which most officials understand. In order to obtain support for a long-term goal, it is usually necessary to start anew with the education process about its benefits every time there is a change in leadership.

Pitfalls

In the presentations, try not to repeat the same basic information for each state. Instead, focus on the unique approaches or lessons learned from each highway agency.

Discussion Points

Where do the barriers lie within your organization? Should the push for preventive maintenance be a top-down or bottom-up activity? What did you see in the different states' experience that would be useful to you?

Areas To Reduce If Time Constraints Exist

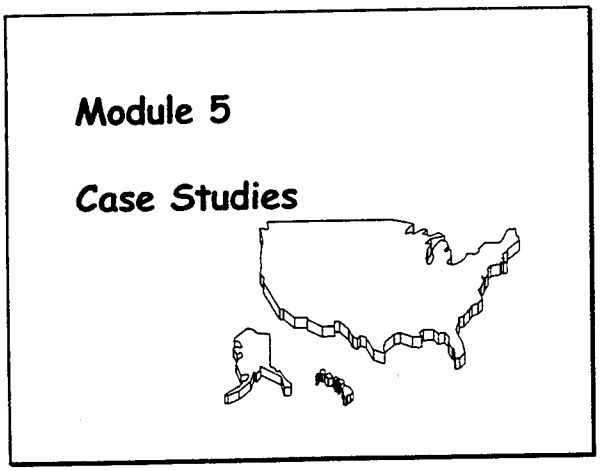
None.

Associated Workshop

None.

Presentation Graphics and Instructor Notes

Slide 1



Five state highway agencies that have successfully implemented preventive maintenance programs were identified and visited. These five agencies were interviewed to determine some important elements of implementation:

--Funding sources, levels, and allocations.

--Treatments used.

--Project and treatment selection procedures and guidelines.

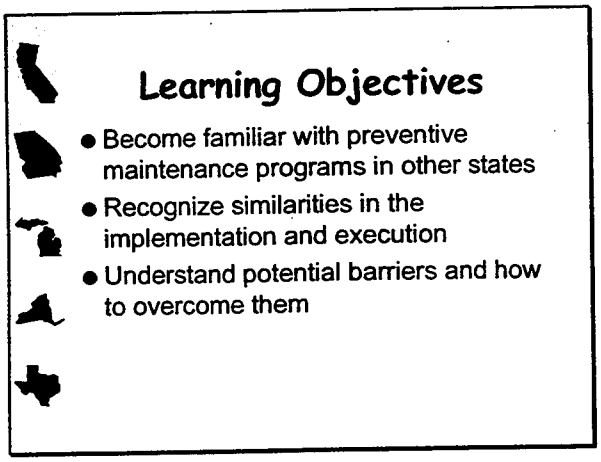
--Performance.

--Barriers to implementation.

--Maturing of the plans.

--Lessons learned.

Slide 2



These are the learning objectives of this module.

Slide 3

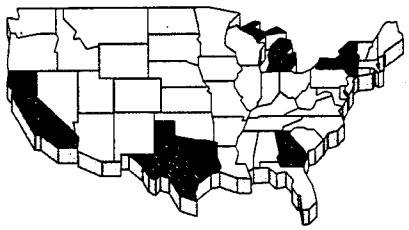
Reasons for Case Studies

- Provide success stories
- Illustrate the benefits of implementation
- Learn means of overcoming challenges
- Avoid repeating same problems as other States

Why were case studies conducted? There are success stories that we can build on to avoid repeating the same problems.

Slide 4

Case Study States



The five DOTs visited were California, Georgia, Michigan, New York, and Texas. Each of these organizations is unique in its structure, geography, and approach to implementation. Each have been practicing preventive maintenance for different lengths of time as well.

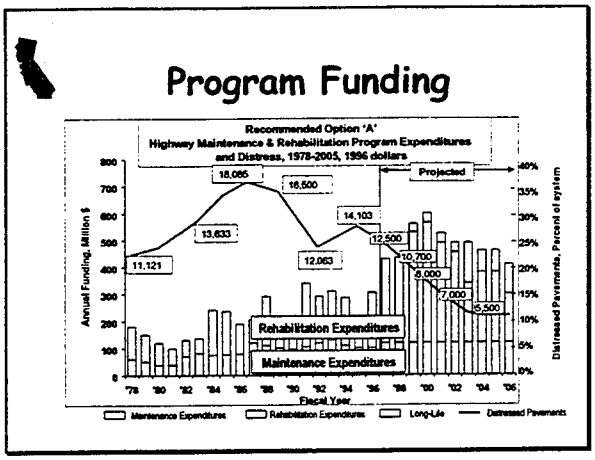
Slide 5

California

- Decision to reduce the number of lane miles that need rehabilitation
- A preventive maintenance strategy was analyzed
- Presented to CTC in July 1996
- 10-year program (SHOPP) submitted in 1998

Caltrans budget process requires that any request for additional funds go to the California Transportation Commission (CTC). It was a member of the CTC that first suggested a preventive maintenance strategy. Expenditures for State Highway Operation and Protection Program (SHOPP) are for major capital improvements needed to preserve and protect the state highway system.

Slide 6



Increased funding for projects through 2007-08 will reduce the inventory of deteriorated pavements to the desired level. The red line represents the amount of distressed pavements; blue portion at the bottom of each bar represents maintenance expenditures; green portion represents rehabilitation expenditures; light blue portion at the top of each bar represents expenditures on longer-life rehabilitation strategies. Much of the funding was allocated to bridges after the 1989 earthquake.

Slide 7

Goals of the Program

- Reduce deteriorated pavement needs from 14,100 to 5,500 miles (29 to 11 %)
- Switch from a "worst-first" to "preventive treatment" management strategy
- Use longer-life rehabilitation on roadways
  - ADT > 150,000
  - ADTT > 15,000

California State Highway System consists of about 50,000 lane miles. Changing from worst-first to preventive treatment management will reduce rehabilitation costs by up to 10 percent. Longer-life pavements provide high user benefit and are very cost-effective.

Slide 8

Funding

Category	Current Funding	Projected Increase	Steady State
Routine Maint.	$70		$50
Preventive Maint.	$50	$53	$75
CAPM	$75		$50
Rehabilitation	$300		$100

Routine maintenance projects are less than $25,000 and are performed by state maintenance forces. Preventive maintenance projects are completed by contract and include base repairs, crack filling and sealing, seal coats, chip seals, and thin overlays. Capital Preventive Maintenance (CAPM, pronounced "Cap M") projects include thicker overlays (although only up to 64 mm [2.5 in]), PCC slab replacement, and grinding. Rehabilitation projects are typically the 3R projects.

Slide 9

AC Pavement Strategies and Expected Life

● Crack seal	1-3 years
● Patching	1-3 years
● Slurry seal	2-4 years
● Chip seal	2-5 years
● Thin overlay	2-5 years
● Thick overlay	4-7 years
● AC overlay (rehab)	7-15 years

Caltrans uses several preventive maintenance treatments. There are also different types of each treatment for different applications; for instance, there are four types of thin hot mix overlays. What they refer to as thick overlays are not very thick; they are limited to 64 mm (2.5 in).

The estimated service lives are believed to be on the conservative side. The Districts have better experience with these service lives than Headquarters.

Slide 10

PCC Pavement Strategies and Expected Life

● Crack seal	2 years
● Shoulder grind/fill	2-5 years
● Undersealing	3-10 years
● Diamond grinding	5-10 years
● Slab replacement	3-7 years
● Crack/seat/overlay	10-15 years
● Lane replacement	15-20 years

There are also many types of treatments used on PCC pavements. Again, the estimated service lives are conservative.

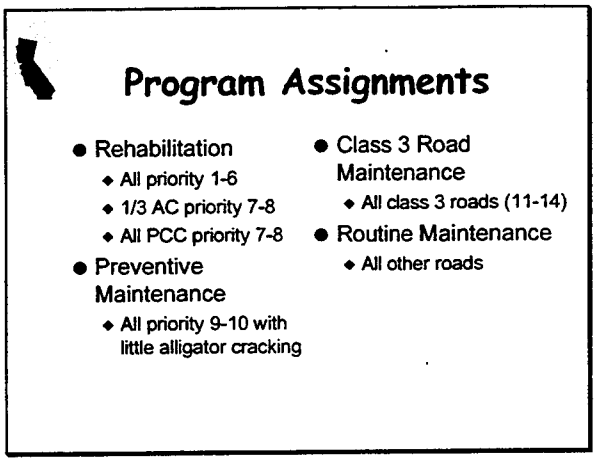
Slide 11

Treatment Categorization Matrix

Ride Quality	Structural Problem	Highway Class 1	2	3
Poor	Major	1	2	11
	Minor	3	4	12
	None	5	6	13
Acceptable	Major	7	8	14
	Minor	9	10	15

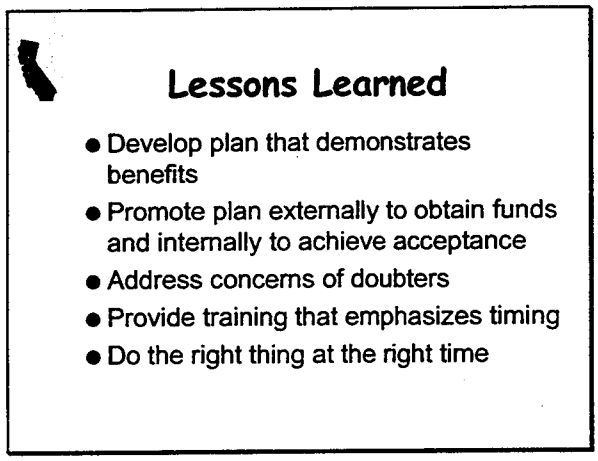
This priority system provides a means of categorizing pavement conditions and selecting treatments. Class 1 roadways have ADT greater than 5000. Class 2 roadways have ADT between 1000 and 5000. Class 3 roadways have ADT less than 1000. Highest priority would be a Class 1 roadway with poor ride parameters and major structural problems. Priority 15 indicates a "do nothing" approach. The emphasis for pavements in good condition is preventive maintenance.

Slide 12



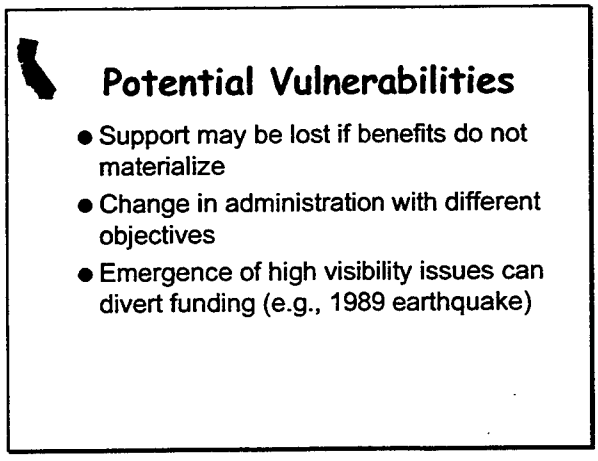
Depending on its priority, a section of roadway is a candidate for inclusion in one of the funding programs described previously. The Preventive Maintenance program includes Capital Preventive Maintenance (CAPM). Candidate projects are reviewed by district personnel and the maintenance program advisor from headquarters.

Slide 13



Need to be able to demonstrate the benefits to get people to buy into it. Safety benefits realized may help to convince those who have reservations.

Slide 14



Continued support is necessary for objectives to be met. Must demonstrate the benefits or support could be lost.

California recently encountered a change in administration. They are not sure of the impact on the program.

The 1989 earthquake is a good example of high visibility issues that can divert funding. Funding was diverted to bridge system after the earthquake.

Slide 15

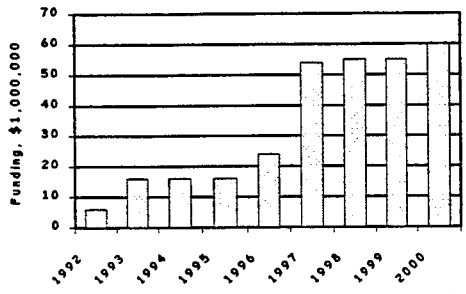
Michigan

- Implemented a Preventive Maintenance Program in 1992 with passage of ISTEA
  - Pavements
  - Bridges
- Preventive maintenance extends the remaining service life of pavements and bridges

Michigan used their pavement management system to evaluate several alternatives ranging from preventive maintenance to major reconstruction. Analysis demonstrated that the only way they could maintain their system was with a Preventive Maintenance Program.

Slide 16

Highway Funding



This chart highlights the funding for highway preventive maintenance projects (does not include bridges). Funding has increased from 6 million in 1992 to 60 million in 2000. All funds are Federal-aid; funds for Preventive Maintenance Program were transferred from Capital Program.

Slide 17

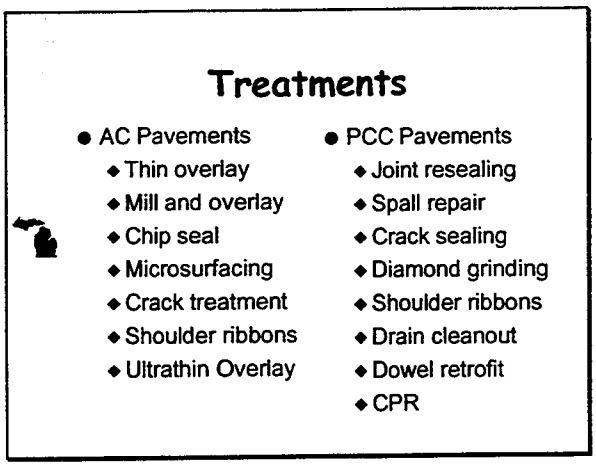
Funding Allocation

- Funds distributed to 7 Regions based on need
- Regions can distribute funds as needed
- 1998 distribution
  - Joint/crack sealing $10 million
  - Surface seals $19 million
  - Enhancements $25 million

Regions receive funds for three strategies: rehabilitation, reconstruction, and preventive maintenance. Regions have the option to use rehabilitation and reconstruction funds for preventive maintenance.

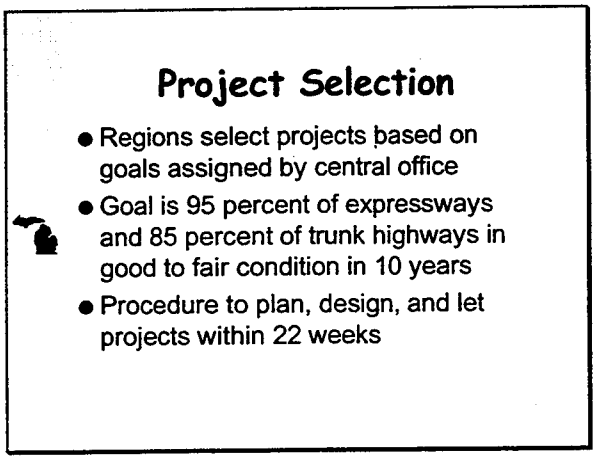
Fundamental Pavement Enhancements include functional improvements such as 38-mm (1.5-in) overlays and inlays.

Slide 18



Thin overlays are generally 38 mm (1.5 in). Bituminous shoulder ribbons, which range from 0.9 to 2.7 m (3 to 9 ft), provide transition from the driving lane to the gravel shoulder. Michigan plans to add NOVACHIP for flexible pavement treatments. All preventive maintenance work is done by competitively let contracts. Michigan has developed a warranty bond requirement for chip seals in which the contractor must warranty the work for 2 years.

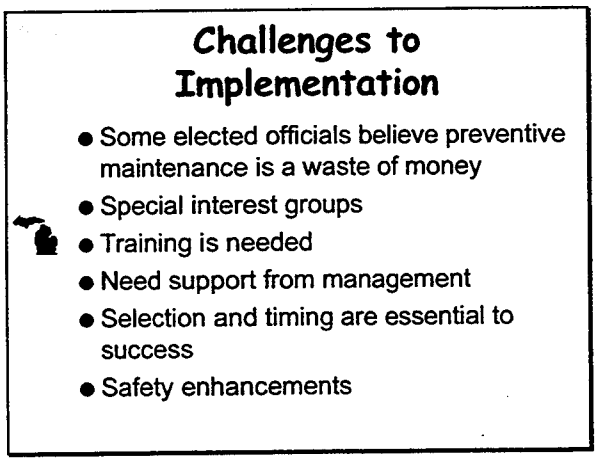
Slide 19



The output from the pavement management system is used as a start in project selection. They also consider accident history and their goals.

Michigan has developed a new procedure to plan, design, and let projects within 20 to 22 weeks from the time a Statewide Strategy is developed and the funds are distributed to the Regions. The process starts in early fall (October) so that the contracts and the contractors can begin work the following spring (March). They let their preventive maintenance in equal lettings. All preventive maintenance activities are performed by the private sector.

Slide 20



Even Michigan, considered one of the nation's leaders in this field, faces problems. However, they work continually to meet these challenges.

Special interest groups are continually pushing for treatments that may not be in the best interests of the state. Contractor prefer the bigger rehabilitation contracts over smaller maintenance projects.

The requirement to also address safety features in order to receive Federal funding increases needed funding and can mean that the project will not get done.

Slide 21

Maturing of the Plan

- All projects are delivered in first 6 months of fiscal year
- PMS used as network planning tool and to assist in treatment selection
- Structural design does not consider preventive maintenance even though extended life is expected

Michigan's fiscal year runs from October to September; the goal is to have all projects let by March so construction can begin in summer.

The pavement management system is now being used to assist in treatment selection. Almost all treatments are warranted.

Slide 22

Lessons Learned

- Keep the projects simple
- Seal cracks (overband) before applying single surface treatment
- Need management support and backing
- Allow the program to build up
- Work with industry to develop specs
- Keep workload balanced

Don't flood the industry with work; allow the program to build up gradually and mature. Industry needs to be brought up to speed on the techniques. Also need to keep the workload balanced to support industry.

Slide 23

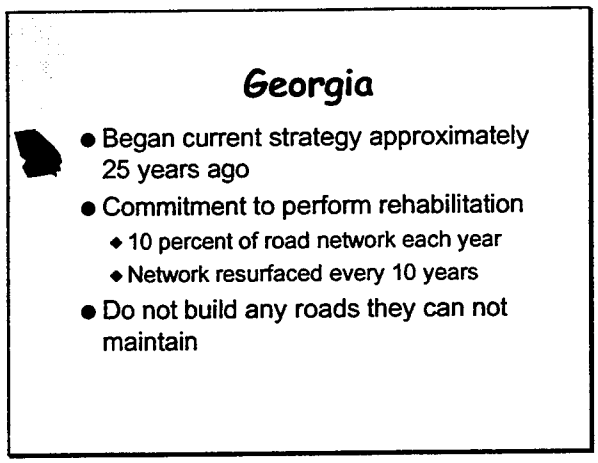
More Lessons Learned

- Requires long-term commitment
- Don't oversell the treatments
- Update costs
- PMS and preventive maintenance support each other

The industry and contractors need assurances that it will be an on-going program before they build up their capabilities. Don't oversell the treatments; one treatment does not do everything. A PMS is not required to do preventive maintenance but it will help support the program.

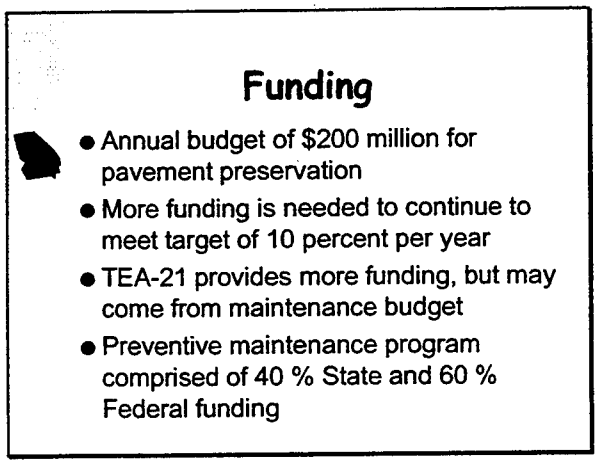
The process is being refined as MDOT goes through its second cycle of treatments and beyond.

Slide 24



Maintenance of the existing highway network became the Department's top priority and still is today. Georgia has now reached a steady-state condition in which the pavement condition remains stable year after year. Georgia now has one of the best overall network conditions in the United States.

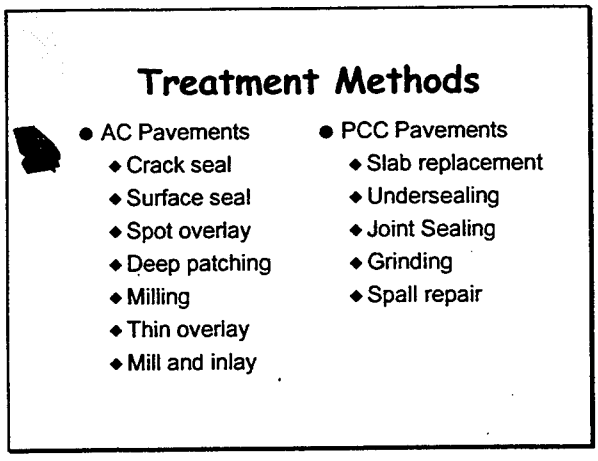
Slide 25



Annual budget figure includes all roadway improvements, including interstate rehabilitation and interchange improvements. Budget for maintenance and rehabilitation of non-interstate pavements has been set at $72.5 million for many years, which includes 75,600 lane kilometers (47,000 lane miles).

Georgia is anticipating an increase in funding due to the new TEA-21 legislation, but they are not sure if the state matching funds will be available. The Maintenance Division fears that the funds could be taken out of the maintenance budget, further reducing the amount of funding for maintenance activities.

Slide 26



Because of a long-term commitment to preventive maintenance, reconstruction and thick overlays have not been included in the program for at least 10 years.

Slide 27

Project Selection

- Project selection made at central office
- Condition survey conducted each year by Area Asst. Maintenance Engineers
- Identify and re-inspect all sections with rating less than 70
- Submit final list to Maintenance Division in Central Office
- Add sections to reach target of 10 %

Area Assistant Maintenance Engineers conduct condition surveys of their network each year and submit results to the central office. Sections below 70 are then re-inspected by the central office. Sections are selected from the final list on a worst-first basis If funds are available, pavements above a 70 may be included in the program.

Slide 28

Maintenance and Rehabilitation Treatment Selection

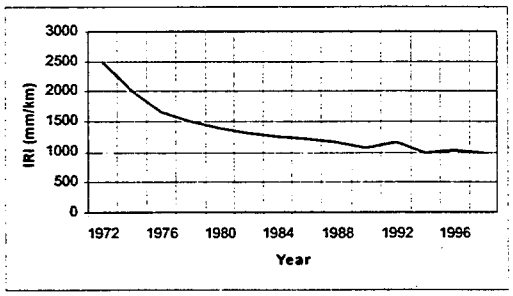
Treatment	Rating	Forces
Crack/Joint Sealing	75-80	In-house
Surface Seal	70-77	Both
Spot Overlay	70-80	In-house
Deep patching	Localized	In-house
Mill/Thin Overlay	< 70	Contract
PCC Restoration	< 70 (also ride and faulting)	Both

Condition ratings and individual distresses are evaluated to determine the recommended treatment. Additional testing may be performed in some instances. Pavements with high traffic levels are more likely to receive an overlay.

Within surface seals, microsurfacing is done under contract whereas other surface treatments are performed by in-house maintenance forces. Deep patching may be better characterized as reactive maintenance.

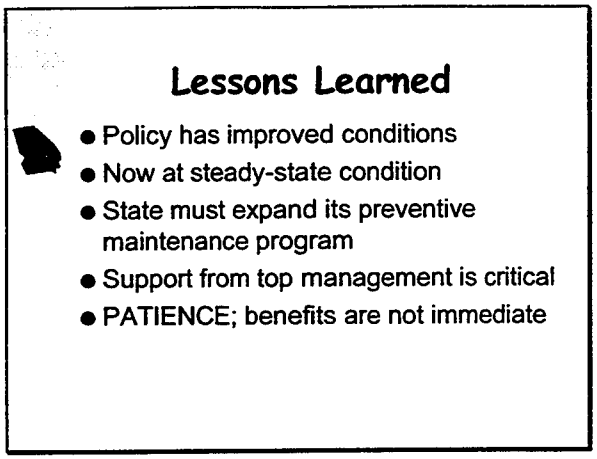
Slide 29

IRI at Treatment



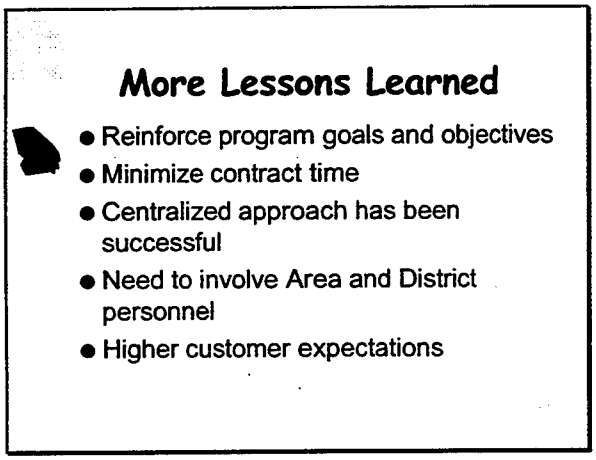
Money from the Dedicated Fund is used to fund pavement preventive maintenance. Funds from Capital Program are used to fund additional contracts for preventive maintenance. No federal funds are used in the preventive maintenance program. Federal funds are used on 3R projects.

Slide 30



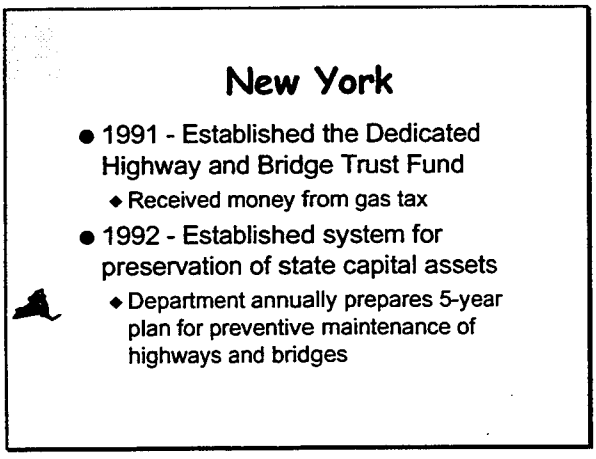
The policy has worked very well in Georgia, resulting in improving the overall network conditions. Due to its commitment to the program, Georgia has now reached a steady-state condition that allows approximately 10 percent of the road network to be addressed each year for the same level of funding. Georgia has found that not many major projects have to be delayed in order to address a large number of lower-cost strategies. Top management support is critical to ensure funding.

Slide 31



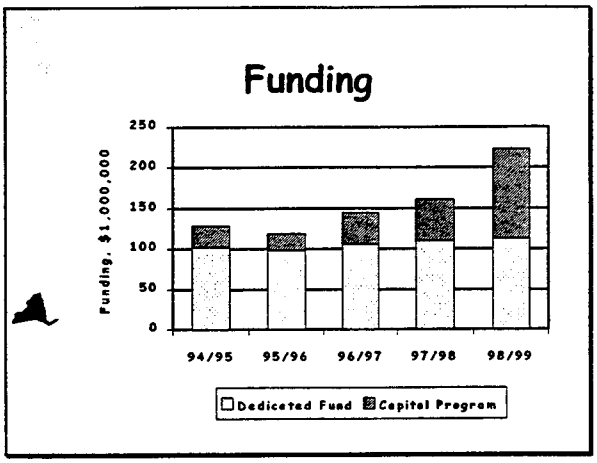
Need to make annual presentations to the Board (or other political entity). Quick turnover of contracts is important so that pavements do not deteriorate further. A centralized approach to decision-making has had a tremendous impact on the success of the program due to the ease of communication. However, special efforts must be made to involve other office personnel. As road conditions improve, expectations of the traveling public and the DOT increase. On the other hand, the public has responded well to funding for good pavements.

Slide 32



Until early 1990s, New York did not dedicate a portion of gas tax revenues to highways; it depended upon bond issues to finance infrastructure.

Slide 33



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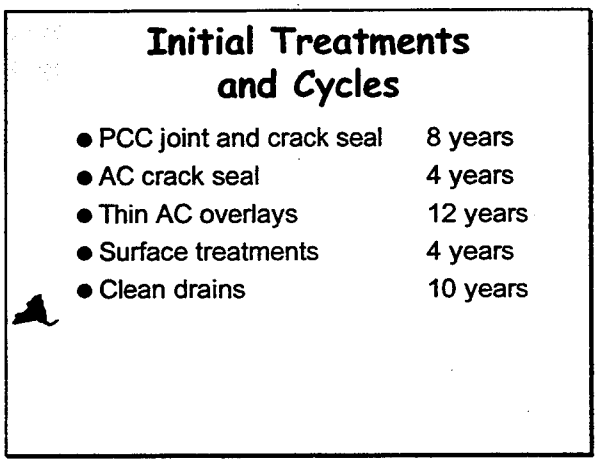
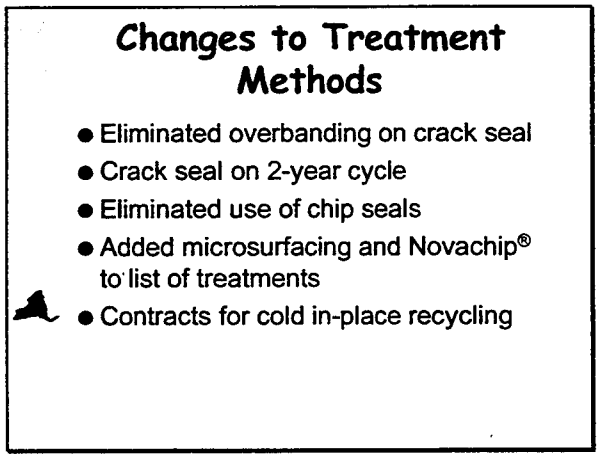
Slide 34



When they started their program, NYSDOT simply made an estimate of how long treatments would last and when they would need to be repeated.

Slide 35



Cracks are now routed and sealed. Sealing done every 2 years to seal the cracks that have developed since the last sealing. Chip seals are being reintroduced on a limited basis. Cold in-place recycling is considered to be a corrective maintenance treatment.

Slide 36

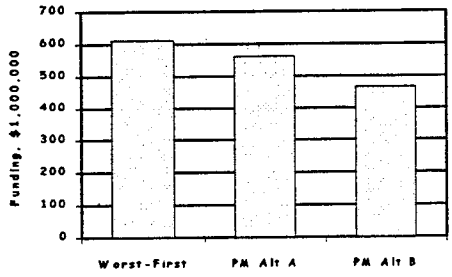
Project Selection

- Regions select, based on guidelines
- Resident Engineer develops candidate list of projects
- By 1997, 70% of paving mileage was PM projects

Cracks are now routed and sealed. Sealing done every 2 years to seal the cracks that have developed since the last sealing. Chip seals are being reintroduced on a limited basis. Cold in-place recycling is considered to be a corrective maintenance treatment.

Slide 37

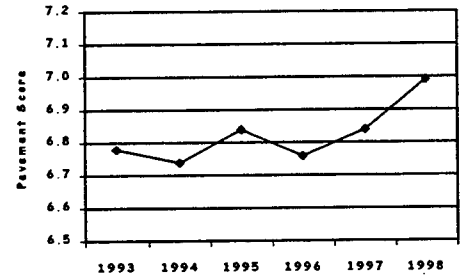
Alternative Strategies



To evaluate the need for preventive maintenance, an analysis was run on their network database to compare three different strategies. Preventive maintenance strategy A was to achieve the same percent poor pavements in 1999 as the worst-first strategy. Preventive maintenance strategy B was to achieve the same percent of poor plus fair pavements in 1999 as the worst-first strategy.

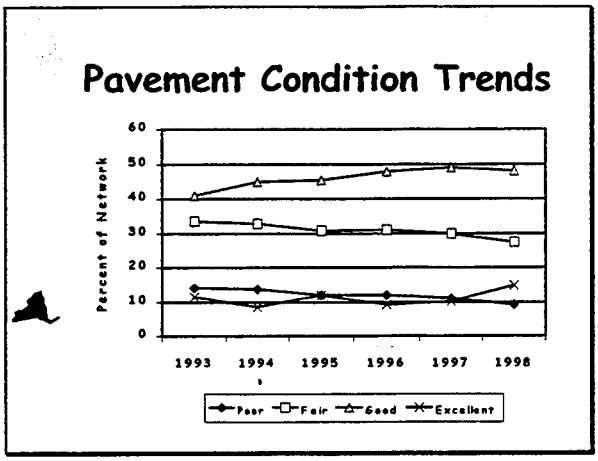
Slide 38

Effect of Preventive Maintenance Program



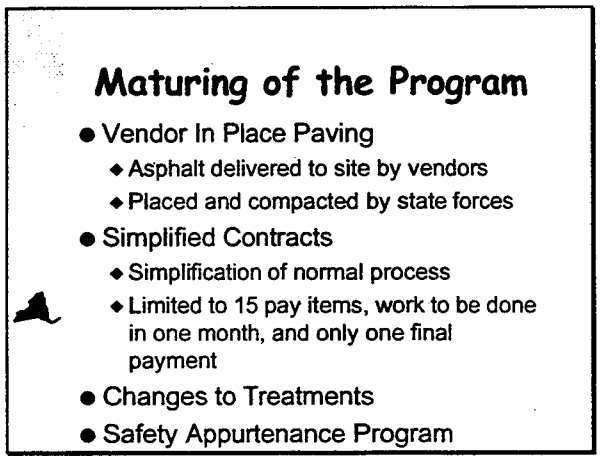
Average pavement scores are increasing once the preventive maintenance program was initiated.

Slide 39



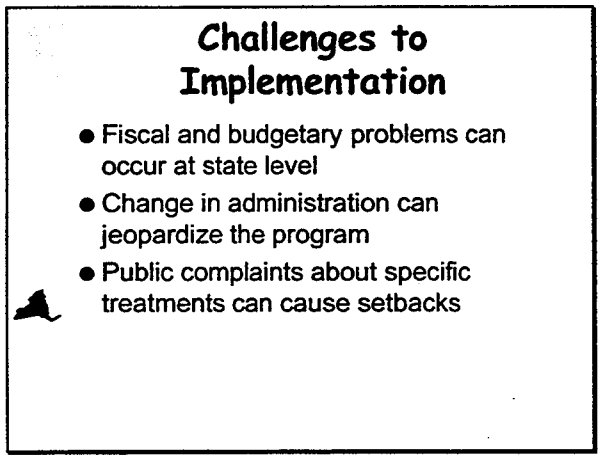
Percentage of good and excellent pavements is increasing. Percentage of poor and fair pavements is decreasing.

Slide 40



New project delivery mechanisms were developed to advance preventive maintenance projects. Program has survived and grown, even with changes at the Department and Gubernatorial levels.

Slide 41



The year when the program received less funding (FY 1995-1996) occurred when the state had funding problems and all agencies had to take a cut.

As mentioned previously, administrative changes have not jeopardized New York's program.

Public complaints must be addressed. Motorcyclists had concerns over the initial crack sealing procedures.

Slide 42

Lessons Learned

- Need dedicated funding
- Need support of management
- Program needs champions
- Selling the program is a continuing effort
- Monitor the program and solve problems quickly

Resident engineers in charge of maintenance operations have seen the results of the program and are believers; they continually defend the program to Executive Management.

Slide 43

Texas

- Has applied preventive maintenance treatments for over 20 years
- Developed a formal "Preventive Maintenance Program" in 1987

Originally funded at $145 million annually and has been annually renewed. The purpose is to prevent major deterioration to roadways and bridges through a planned cycle of repairs.

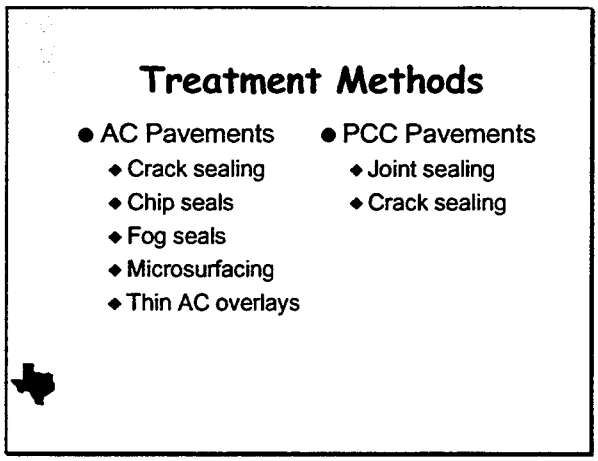
Slide 44

Funding

- Current funding is $175 million per year
- Increase of $75 million in 2000
- Generally supported by state funds
- Funds are allocated to Districts

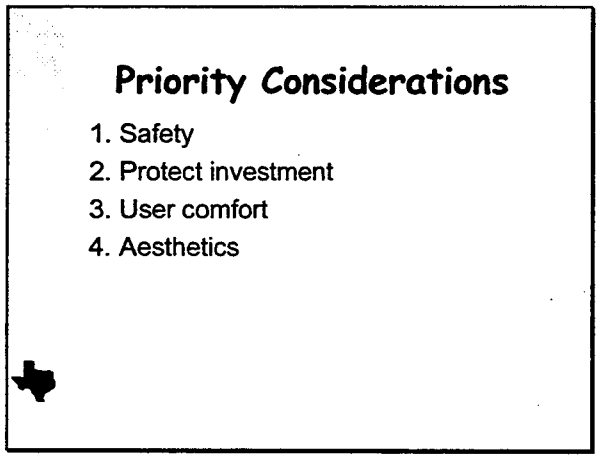
Federal-aid funds are used for microsurfacing projects on the Interstate.

Slide 45



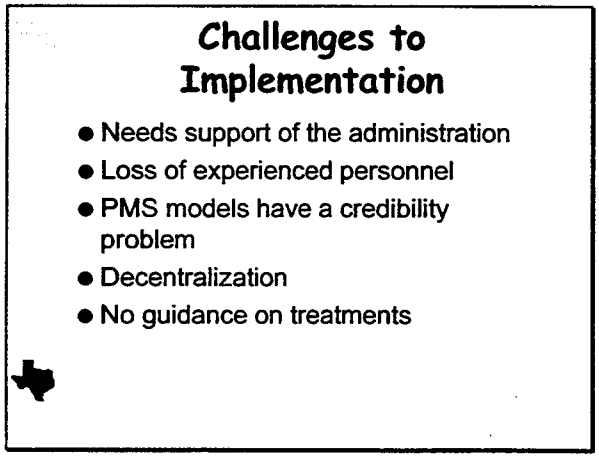
Crack sealing is generally done before placing an overlay.

Slide 46



Districts select the projects. The DOT offers these priority considerations in the project selection process. Emphasize the order of the considerations; safety is the #1 priority.

Slide 47



TXDOT is losing 100 to 150 professional engineers every year.

Funding allocation to the Districts is based on lane miles and then the Districts can do what they want.

Texas is integrating a statewide program to provide more guidance on the treatment methods.

Slide 48

Maturing of the Plan

- Obtain dedicated funding for preventive maintenance at time of construction
- Ability to transfer funds
- Develop consistent ride specification
- Statewide specifications for treatments

Some ongoing efforts will help to improve the acceptability of the plan.

Slide 49

Case Study Summary

- Preventive maintenance programs have improved pavement condition

- Preventive maintenance is most cost-effective approach to achieve goals
- Need training to obtain support and approval of executive management

- Need to be patient; benefits are not immediate

- Selling the program is a continuous effort

Any questions?

NOTES

MODULE 6

IMPLEMENTING PREVENTIVE MAINTENANCE AS PART OF A PAVEMENT PRESERVATION PROGRAM.

NOTES

MODULE 6
IMPLEMENTING PREVENTIVE MAINTENANCE AS PART OF A PAVEMENT PRESERVATION PROGRAM

Instructional Time: 60 minutes
Presentation File: Mod 6 Implementation.ppt
Reference Manual: Module 6, "Implementing Preventive Maintenance as Part of a Pavement Preservation Program," p. 155-180

Overview

In this module, an approach to developing a preventive maintenance program is outlined. The suggested approach draws on the experiences of the agencies that have made preventive maintenance a keystone of their pavement preservation practices, as described in module 5. It also draws upon the economic analysis tools presented in module 4. This module is intended to help agencies assemble these and other components of preventive maintenance into a working preventive maintenance program. In the process, it also addresses how the obstacles to these programs can be addressed.

Learning Objectives

The learning objectives for this module are as follows:

1. Identify the benefits associated with the implementation of a pavement preventive maintenance program.

2. Describe some of the key factors for a successful pavement preventive maintenance program.

3. Describe some of the innovative approaches used to assist in the promotion of pavement preventive maintenance programs.

Participant Review Questions And Answers

1. What are the major benefits that can be obtained through the implementation of a pavement preventive maintenance program?

   The major benefits which have been promoted throughout this course include the following: safer roads, improvement in overall pavement condition, lower costs, greater customer satisfaction, and better pavement preservation strategies.

2. List some of the keys to successful pavement preventive maintenance programs. Why are each of these important?

   The keys components of pavement preventive maintenance programs include the following: goals that serve as a guide to the agency's policies and that can be used to monitor progress; documented benefits, needed to continually promote and sell the benefits of the program; dedicated funding, which is essential to the long-term success of the program (the true benefits of preventive maintenance are realized over time); improved treatments and timings, because preventive maintenance requires better tools than more conventional preservation strategies.

3. What are some of the primary data items to be collected as part of a pavement preventive maintenance monitoring program? Why is ongoing monitoring important?

   Primary data items to be collected and saved include: pavement condition prior to treatment application, conditions at the time of treatment, design and construction details, milepost limits of the treatment, cost of construction, and performance of the treatment over time (by any of the measures that are important to the agency). Ongoing monitoring is important because it helps to determine whether the treatment performed as desired and whether it is an effective application or needs to be modified or discarded from the list of agency treatments.

4. Why is securing dedicated funding for pavement preventive maintenance programs important?

   Dedicated funding is critically important for preventive maintenance programs. Most projections of the need for these programs are based on applying a certain magnitude of financial resources to problems over time. If the level of funding or the agency support shifts, it is highly unlikely that the benefits of the program can ever be realized by the agency.

5. Describe some of the innovative practices of promoting pavement preventive maintenance programs.

   The greatest innovations have been along the lines of simplified contracts and warranties. These have helped agencies to reduce treatment costs and improve performance at the same time. Agencies have also targeted training initiatives to address specific areas where additional skills are needed, such as familiarity with treatments, contracting procedures, or simply the overall programs.

Pitfalls

None.

Discussion Points

What do the participants hope to get out of a program? Is this realistic? Is there currently integration between PMS and preventive maintenance? If not, how difficult would this be to add? What barriers exist to dedicated funding?

Areas To Reduce If Time Constraints Exist

None.

Associated Workshop

Workshop 4, *Integrating the Preventive Maintenance Program Into the Agency.*

NOTES

Presentation Graphics and Instructor Notes

Slide 1

Module 6

Implementing Preventive Maintenance As Part of A Pavement Preservation Program

Each module has presented a different aspect of a preventive maintenance program, from the application of the treatment methods to the analysis of the cost effectiveness. This module brings together all the pieces to the puzzle to solve the most critical issue: implementation.

Slide 2

Major Benefits

- Improved pavement condition
- Safer roads
- Lower life cycle costs
- Reduced congestion
- Customer satisfaction
- More cost effective use of funds

These are the three main benefits to implementing a pavement preventive maintenance program. These benefits are those that have a great enough impact that they should influence an agency's maintenance decisions. The first two benefits are critical to the users of the roads. These benefits translate to fewer repairs, less delay, more efficient roadway operations, and better long-term performance. The final benefit—lower overall costs for pavement preservation—is the most likely reason for agencies to implement a program

Slide 3

Challenges

- Dedicated funding challenges
- Management resistance
- Management's perception of public reaction
- Poor data tracking
- Lack of applicable research
- Absence of relevant training

The benefits of preventive maintenance are desirable and success stories within states have been documented. So why aren't more agencies applying preventive maintenance activities? There are many obstacles in the way, as listed here. Overcoming these obstacles requires a formidable effort. Some obstacles are easier to overcome than others. A previous obstacle was the lack of Federal legislation supporting funding for maintenance activities. Several events have helped remove this obstacle:

1991 — Passage of ISTEA.

1995 — Clarification of treatments eligible for NHS Appropriations Act.

1998 — Passage of TEA-21.

Slide 4

Keys to Successful Programs

- Establish goals
- Document the benefits
- Promote the benefits
- Obtain dedicated funding
- Develop guidelines
- Identify champion
- Obtain top management support

These are several keys to implementing a successful program. Each will be discussed in detail in subsequent slides. Just mention them briefly here and move on.

Slide 5

Establish Goals

It is essential that a road agency select a long-term objective and structure its maintenance selection policy to achieve its objective.

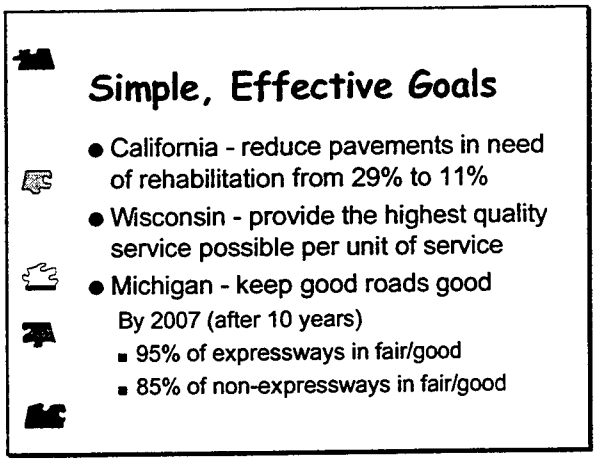
- Rohde et al. 1997

Advocating a philosophy of preventive maintenance is the most important factor in developing a successful program.

- Galehouse 1998

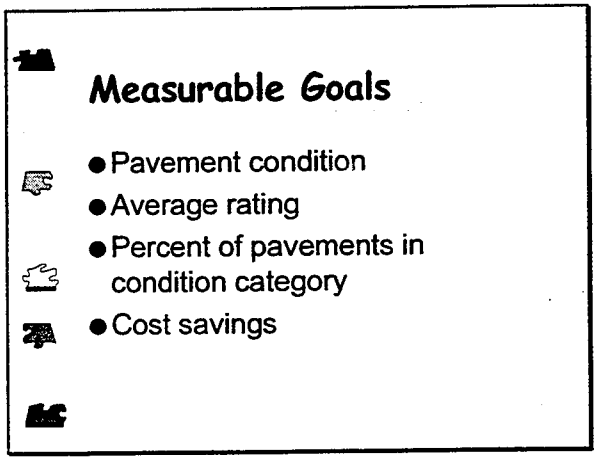
How can an agency expect to reap the benefits of preventive maintenance if they do not know the goals? An objective provides the agency with a justification for its policy decisions as well as a measurable means of tracking progress. Everyone involved can work together to achieve a common goal.

Slide 6



What are some examples of a simple goal for a preventive maintenance program? The goals do not need to be complicated. The most successful programs have simple goals that developed out of necessity. California's program initiated when a Commissioner questioned whether the agency's practices were leading to a growing backlog of their pavement system. Wisconsin evaluates each maintenance or rehabilitation action by determining the effect on the customers' comfort, convenience, safety, and costs. Georgia began its program because a Commissioner believed that Georgia's roads were the worst in the southeast.

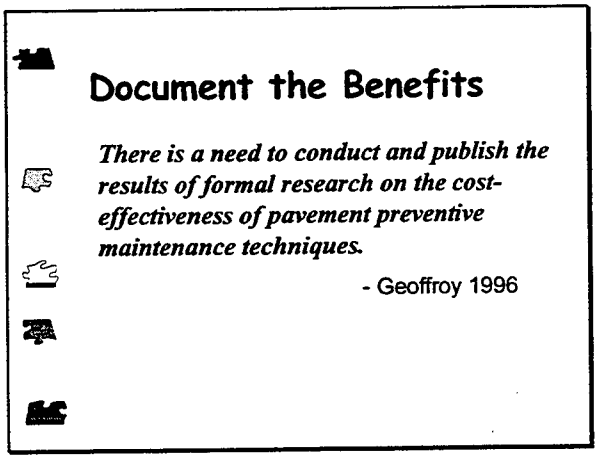
Slide 7



It is not enough to establish goals; there must also be a means of measuring the benefits. This list provides a few examples of benefits that can be measured. Monitoring one or more these indicators is one means of quantifying the benefits of the program.

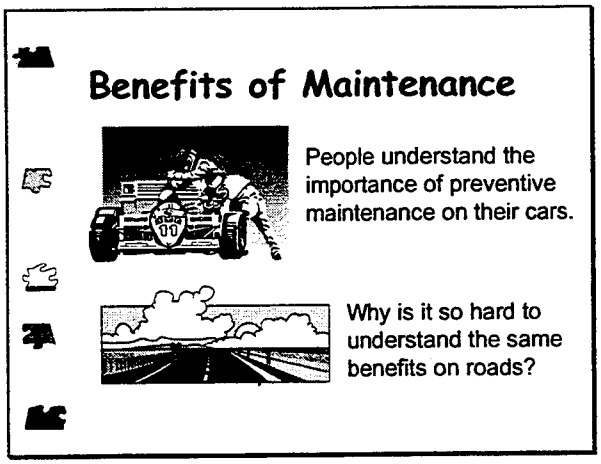
Agencies that currently have a PMS will not have to develop a new system of monitoring. A PMS can track the pavement condition and other information that is required for monitoring purposes.

Slide 8



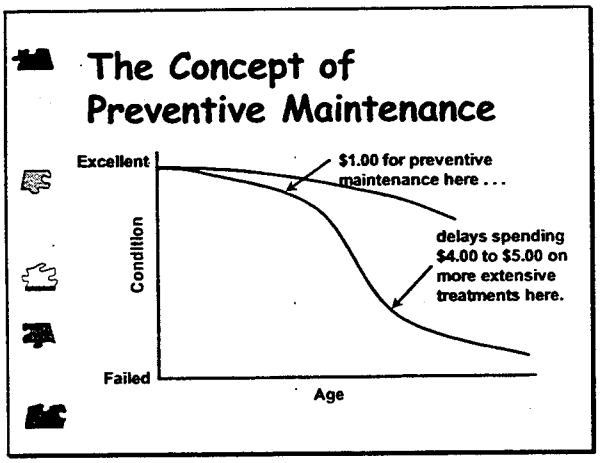
Once a preventive maintenance program is implemented, the effort must continue. If those who establish policy can not see the benefits, funding will most likely be discontinued.

Slide 9



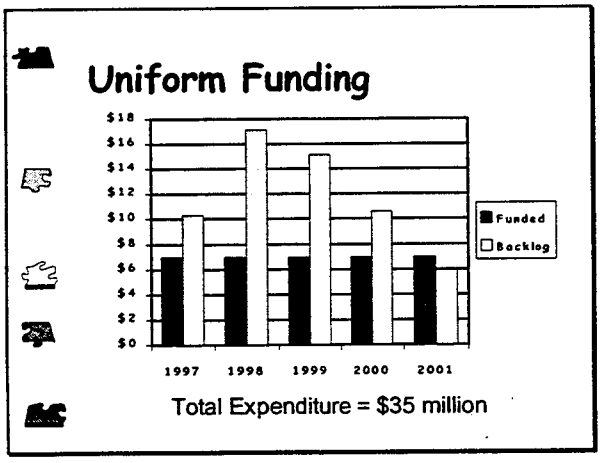
The importance of preventive maintenance on your vehicle is obvious. You can either perform preventive maintenance such as oil changes and tune-ups, or you can wait until the vehicle dies and spend a lot more to overhaul the engine.

Slide 10



Spending money to apply preventive maintenance treatments to pavements in good condition is much cheaper than waiting until the pavement is in poor condition. The concept is that by conducting preventive maintenance activities, we can slow the deterioration process and end up with a flatter curve. However, this figure is rarely presented with any supporting information to suggest that it is anything other than an idealized representation of the costs of different strategies.

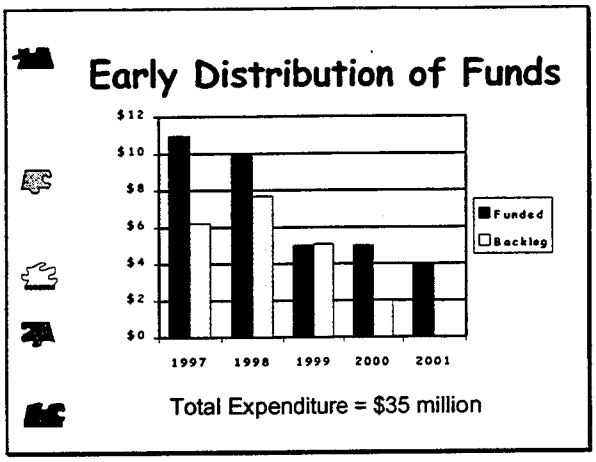
Slide 11



The first example comes from the Public Services Department in Bedford, Texas. The engineering staff were seeking to secure a greater investment in a preventive maintenance program.

This figure illustrates a funding scenario in which the funds are distributed equally ($7 million per year) over the next 5 years. The total expenditure under this scenario is $35 million. This scenario reduced the backlog to about $6 million over the next 5 years.

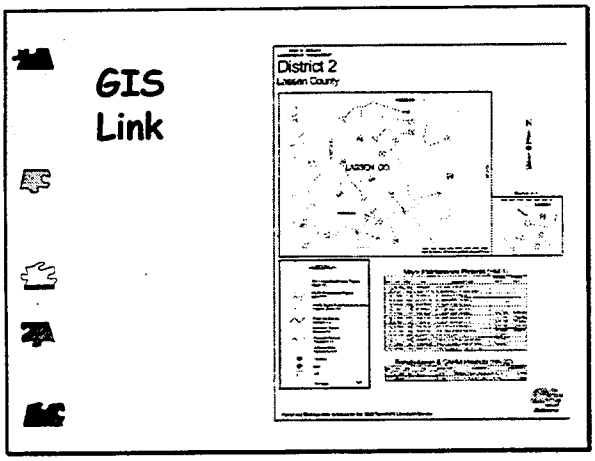
Slide 12



The second scenario shifted more funding to the first 2 years, although the total expenditure remained the same at $35 million. However, this scenario completely eliminated the backlog of projects.

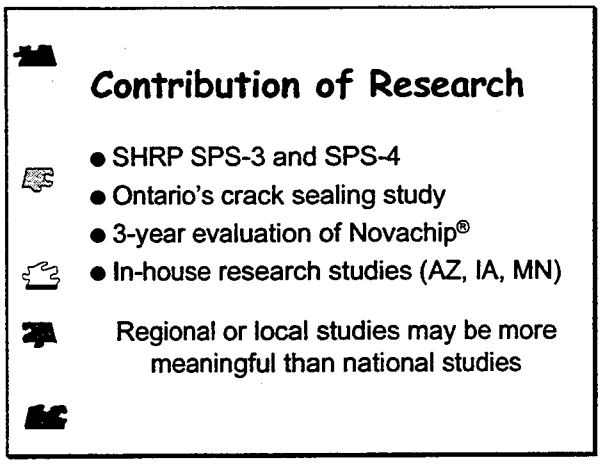
This illustration was persuasive enough that the City came up with an additional sales tax to both provide sufficient funding to improve the network condition to acceptable levels and to fund ongoing maintenance activities.

Slide 13



The use of a GIS link, available through a PMS, is another useful means of presenting information. This particular link documents the maintenance plans of the California Transportation Commission.

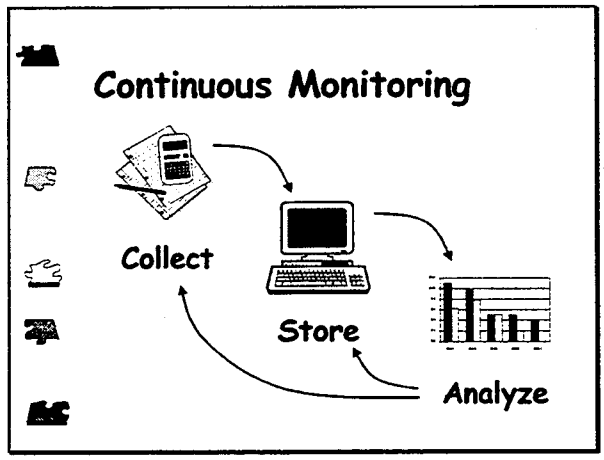
Slide 14



Research studies are another means of evaluating the performance and cost effectiveness of preventive maintenance treatments. Some early research was conducted in the 1970s. We are now starting to get back to conducting research. A national study on maintenance effectiveness was conducted under SHRP. Unfortunately, the study did not resolve many of the critical issues regarding maintenance effectiveness. This study exposes the problem with conducting maintenance studies on a national level. National studies introduce too many variables, as preventive maintenance activities on more dependent on local variables such as climate, materials, and techniques.

Other local studies have been more successful. For example, Ontario recently conducted a study of the effectiveness of crack sealing on AC pavements. The following conclusions were made: (1) the consequences of not sealing cracks are increased rehabilitation costs and shortened service life, (2) routing and sealing cracks can minimize secondary crack growth and increase service life by at least 2 years, and (3) life cycle cost analysis indicates that rout and seal treatments are a cost effective procedure.

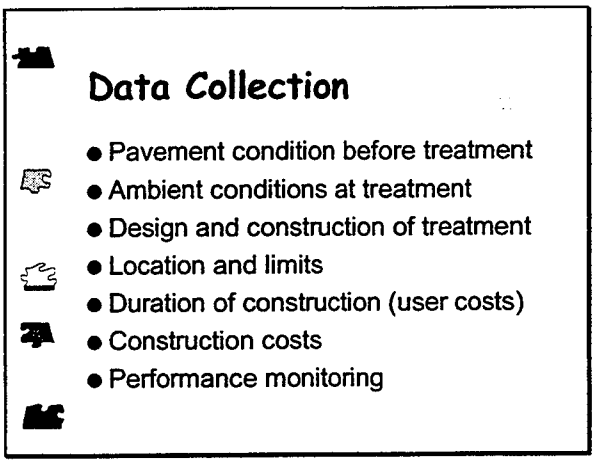
Slide 15



Monitoring the long-term performance of maintenance treatments is essential for sustaining a preventive maintenance program for the long haul. This step should not be ignored once the program has been implemented.

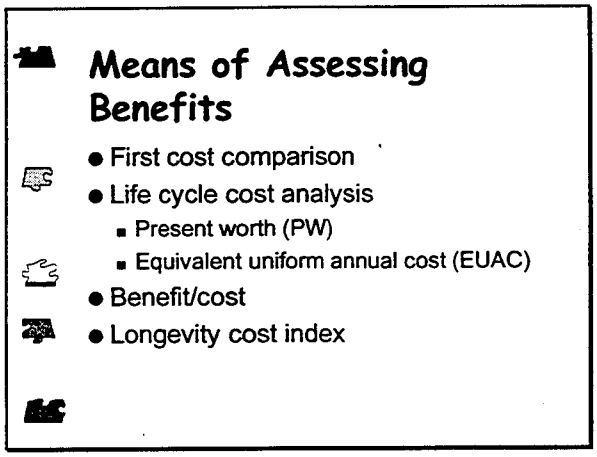
Early analysis is important; an agency could continue bad practice for years if there is no proof that the treatment is not performing as expected. Due to the relatively short service lives with respect to new pavement design and rehabilitation, early analysis will also be more meaningful.

Slide 16



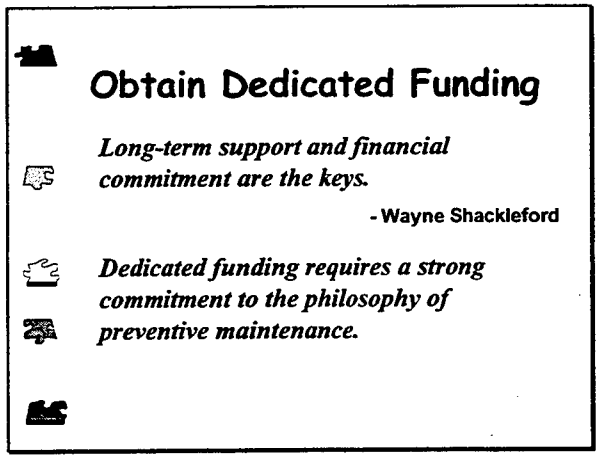
The condition is important in order to ensure the treatment was in fact preventive in nature, to evaluate the most effective time to apply the treatment, and to measure the initial benefit. Design and construction information allow the agency to track performance by treatment type and to differentiate between successful and unsuccessful treatments. Was the quality controlled through a QC/QA program? All costs (agency costs, contract costs, and any implied costs) need to be documented so that the benefits or cost effectiveness can be analyzed in the future.

Slide 17



These approaches to assess the benefits were discussed in module 4. The benefit/cost analysis is preferred because it simultaneously considers both the costs and the benefits, whereas others look at one or the other.

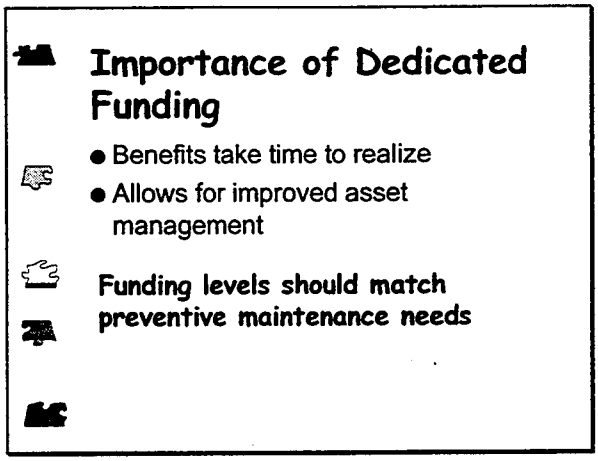
Slide 18



Since a preventive maintenance program requires a continuous level of effort for a period of time before the program's success can be realized, the most successful agencies have established dedicated funds for preventive maintenance.

The two quotes emphasize the importance of dedicated funding to the overall success of the program. The case study states in module 5 also point out the importance of dedicated funding.

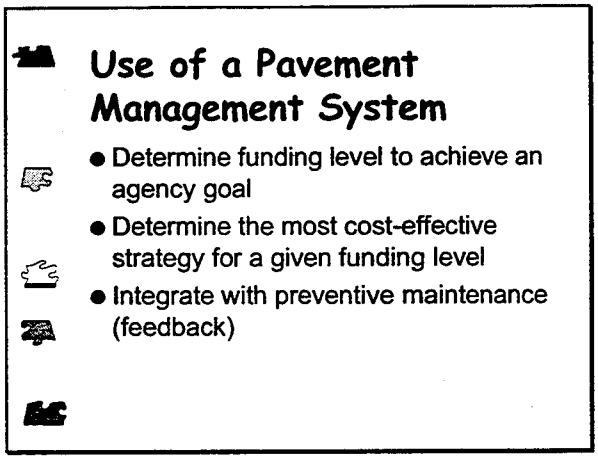
Slide 19



Agencies that have succeeded in implementing preventive maintenance programs recognize the importance of obtaining an adequate and secure source of funding. The need for financial support over a long enough period of time to see program results requires support from top management and a commitment to the long-term goals of the program.

The case studies noted that patience is a key; these program take time before the benefits are realized. Dedicated funding ensures the program will not be eliminated before the benefits are realized. The funding can not be static either. Other costs are continuously rising and the funding must keep pace.

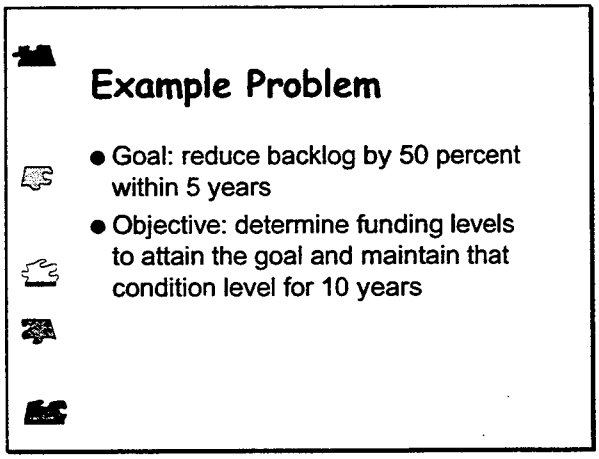
Slide 20



The first example typically requires an iterative process in which multiple strategies and funding levels are programmed to determine the condition at the end of the analysis period. The current strategy will be used as the base case. Other strategies, such as worst-first and preventive maintenance, can also be analyzed. Preventive maintenance will usually prevail as the most cost effective strategy.

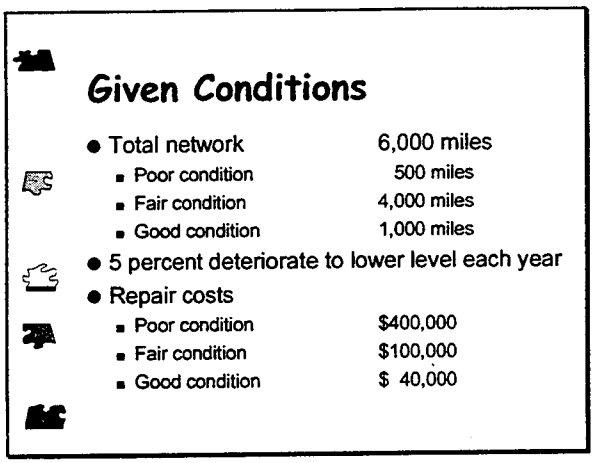
The second example is the more traditional approach, because funding levels are typically fixed. Again, multiple strategies can be analyzed to determine the strategy that provide the best condition at the end of the analysis period.

Slide 21



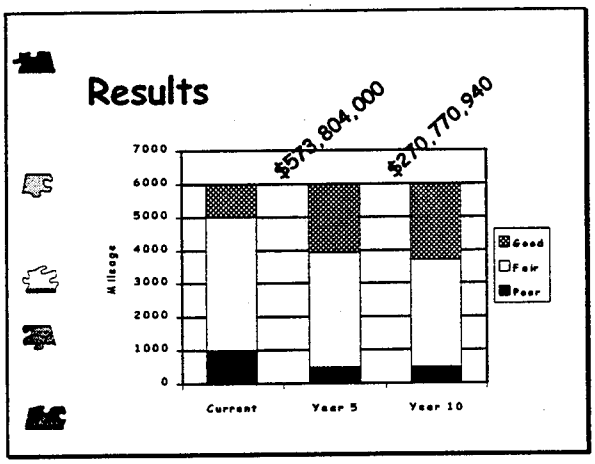
Work through this example problem with the class. Have the participants open the Reference Manual to the problem so they can follow along.

Slide 22



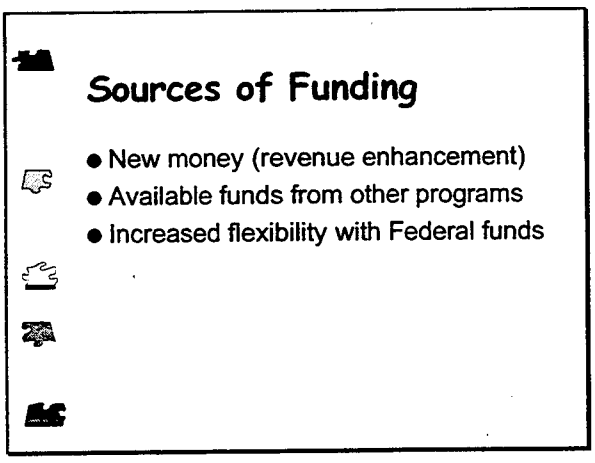
Go over the problem statement with the participants. Then work through the example with the participants following along in the Reference Manual.

Slide 23



During the first 5 years, 100 miles of backlog must be addressed each year to cut the overall backlog in half. This results in a cost of over $100 million per year, which totals $573,804,000 by the end of Year 5. At Year 6, a preventive maintenance program is put into place. The resulting condition at Year 10 is slightly better but the cost is less than half, totaling $270,770,940 over the 5 years.

Slide 24



This list shows three available sources for funds. Federal participation on maintenance projects is now at an 80 percent reimbursement rate with fewer restrictions than ever. The other methods require support from top management to obtain funding.

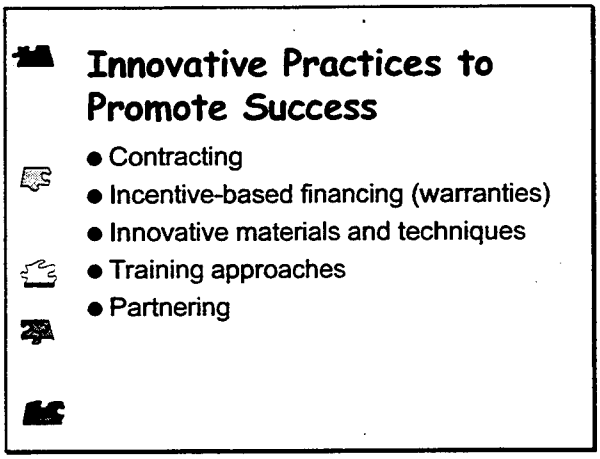
New York recognized the "need for long-term financing that was stable, predictable, and adequate." Support from management helped established a Dedicated Fund. The fund included provisions for annual increases and an additional $88 million to give the program an aggressive start.

Slide 25

The program can only be as successful as the treatments themselves. Even with adequate funding and support, the program will not be successful if the treatments do not work. Continuous research and monitoring are required to assess the effectiveness of the treatments. PMS can be used to effectively track the performance of the treatments. Where treatments are not performing up to standards, they can either be dropped from the program or modified.

Some states have developed their own Manuals of Practice for maintenance treatments. For example, Montana developed a *Maintenance Chip Seal Manual* to provide guidance on the proper design and construction of chip seals. Michigan has outlined all of their preventive maintenance treatments in a document entitled *Capital Preventive Maintenance Program.*

Slide 26



Preventive maintenance projects are quite different than typical projects that an agency is used to handling. Differences include the following:

--Reduced treatment costs.

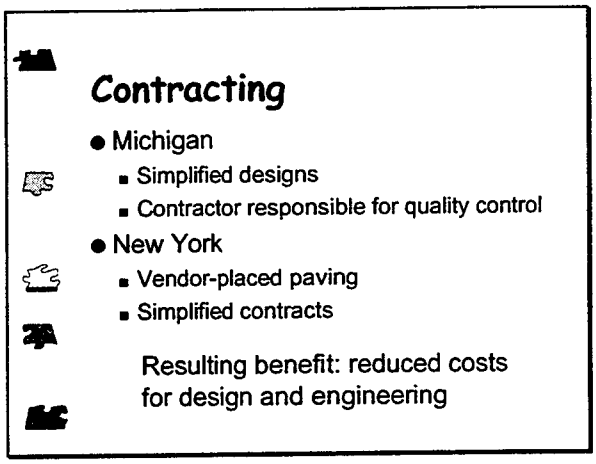
--More timely application.

--Reduced manpower needs.

--Less construction time.

Agencies have developed innovative ways of dealing with preventive maintenance projects that result in lower overall costs.

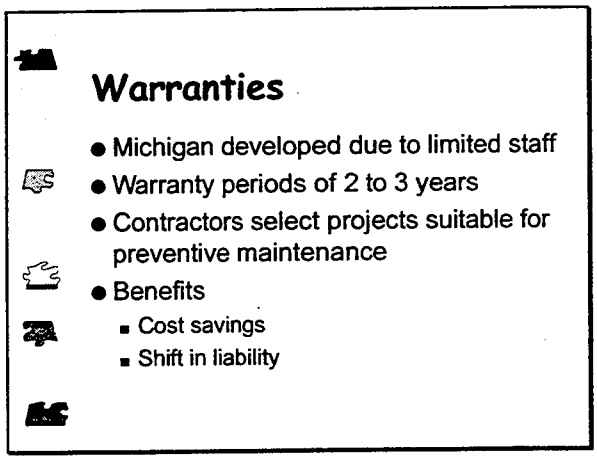
Slide 27



Michigan reduced its design costs from 5 to 2 percent of the project due to the simplicity of most preventive maintenance projects. In addition, by making the contractor responsible for quality control, they reduced their construction engineering costs from 15 to 5 percent of the project.

New York also implemented some innovative practices. Vendor-placed paving uses a combination of state and contractor forces to apply lower cost treatments. For example, the vendor hauls material to the site and state forces use their equipment and manpower to place the material. Simplified contracts have a simpler and quicker scoping process, limited number of pay items, restricted to less than 1 month of construction, and allow more flexible (longer) construction seasons.

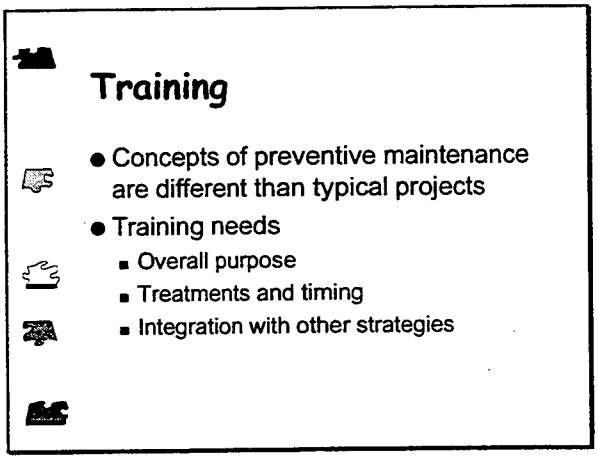
Slide 28



Michigan initiated warranties out of necessity due to loss of manpower, especially of field inspection personnel. The warranty periods are designed to last long enough to ensure that premature failures related to construction were covered. Chip seals, microsurfacing, slurry seals, crack sealing, and joint resealing have 2-year warranty periods. Thin overlays, cold milling and overlays, and PCC repairs have 3-year warranty periods.

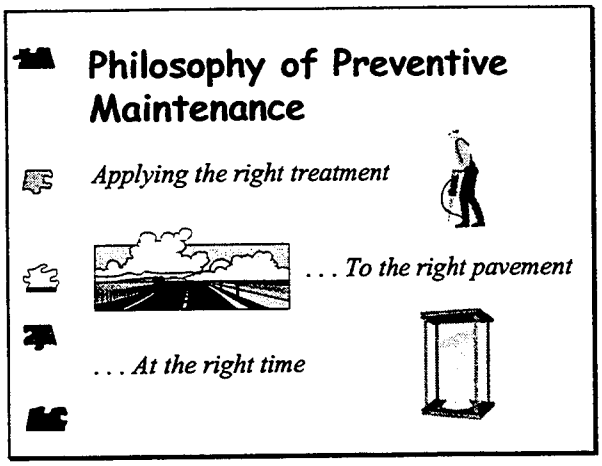
Better contractors bid on projects with warranties. Also, contractors are allowed to determine which projects are suitable candidates for preventive maintenance so treatments are not applied to pavements in poor condition.

Slide 29



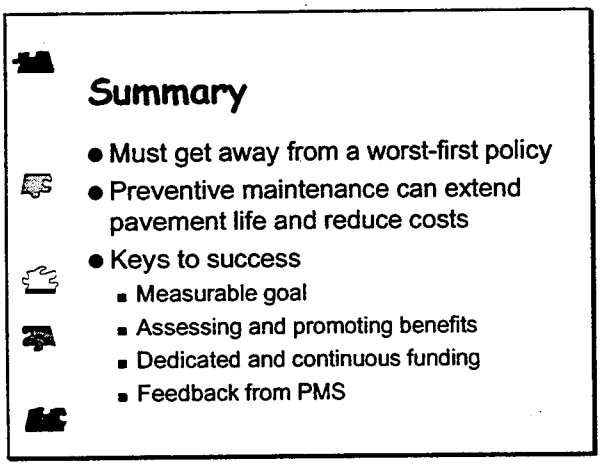
The concepts promoted in preventive maintenance are often radically different from the usual way of doing business. Thus, training is essential.

Slide 30



This is the basic philosophy behind pavement preventive maintenance.

Slide 31



Agencies must get away from a worst-first policy that is reactive rather than preventive in nature. Preventive maintenance programs have been successful in extending pavement life and reducing overall costs. They also promote flexibility with transportation budgets.

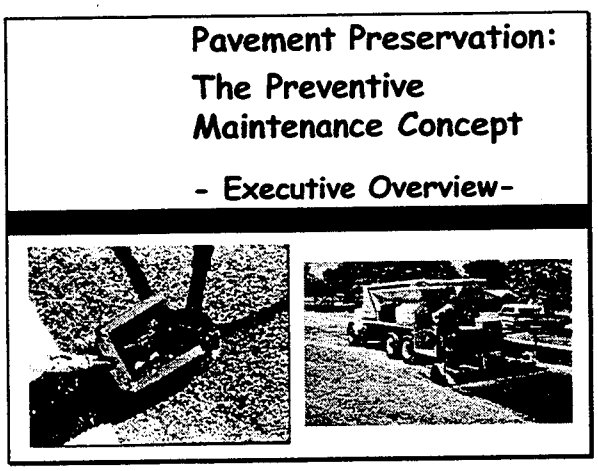
There are continuous barriers to the implementation and execution of preventive maintenance program. However, the barriers are not insurmountable. Studies have shown that the public is ready to embrace the philosophy of preventive maintenance.

EXECUTIVE OVERVIEW

NOTES

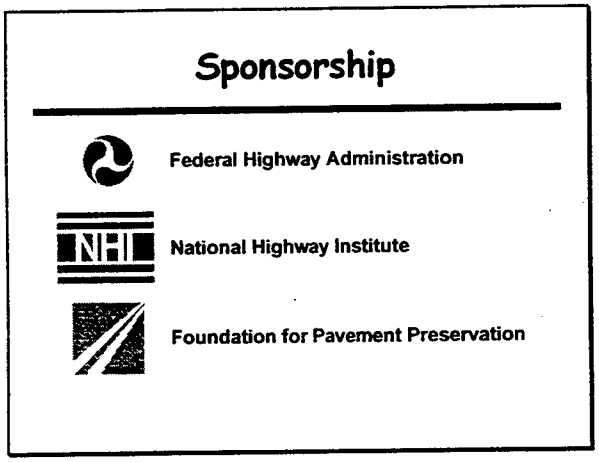
Presentation Graphics and Instructor Notes

Slide 1



The Executive Summary presents the key information from the "Pavement Preservation: The Preventive Maintenance Concept" *Reference Manual*. It is intended to summarize and highlight the points in a succinct manner.

Slide 2



This course presents the fundamental principles beyond the concept of pavement preventive maintenance. Furthermore, it provides guidance for agencies interested in implementing a preventive maintenance program.

The course was developed under the joint sponsorship of the National Highway Institute (NHI) of the Federal Highway Administration (FHWA) and the Foundation for Pavement Preservation (FPP). The partnership between a public agency and industry has been formed as both parties recognize that "there is a growing and significant need to develop and deliver a comprehensive training program in the area of pavement preservation policy, programming, and techniques."

Slide 3

Preventive Maintenance

The planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system.

- AASHTO's Standing Committee on Highways

Preventive maintenance is a completely different approach to pavement preservation. It is a concept that has really only come to light in this country in the last decade or so. This course focuses on planned rather than reactive maintenance activities.

Slide 4

Philosophy of Preventive Maintenance

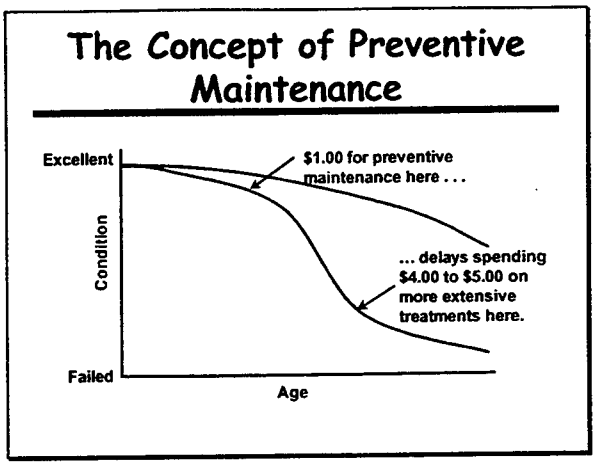
Applying the right treatment

. . . To the right pavement

. . . At the right time

This is the basic philosophy behind pavement preventive maintenance. All three elements are critical to success.

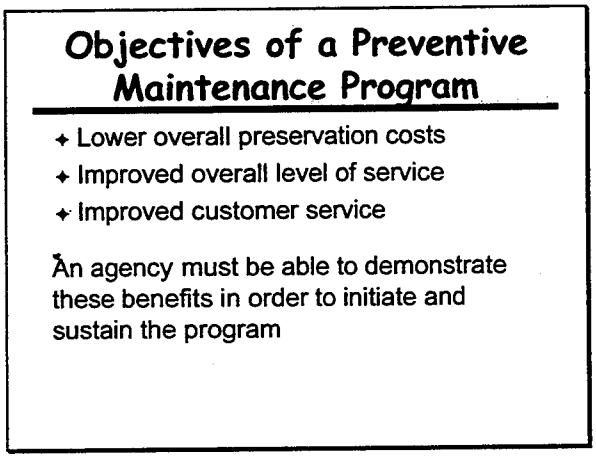
Slide 5



This chart illustrates why we can not afford to keep doing things the same old way. As the pavement first begins to deteriorate, the cost of repair is relatively inexpensive (like an oil change or tune up). However, as the progression deteriorates further, the costs increase exponentially (like an engine overhaul).

Spending money to apply preventive maintenance treatments to pavements in good condition is much cheaper than waiting until the pavement is in poor condition. The concept is that by conducting preventive maintenance activities, we can slow the deterioration process and end up with a flatter curve. However, this figure is rarely presented with any supporting information to suggest that it is anything other than an idealized representation of the costs of different strategies.

Slide 6



Need to be able to sell the program to management. One way of doing this is to prove that money spent now will save money in the long run. If the benefits can not be demonstrated, it will be difficult to get support to implement the program.

What are some means of improving customer service? Improved ride quality and lower user costs are two examples.

Slide 7

Treatment Types (Michigan example)

- AC Pavements
  - Thin overlay
  - Mill and overlay
  - Chip seal
  - Microsurfacing
  - Crack treatment
  - Shoulder ribbons
  - Ultrathin Overlay
- PCC Pavements
  - Joint resealing
  - Spall repair
  - Crack sealing
  - Diamond grinding
  - Shoulder ribbons
  - Drain cleanout
  - Dowel retrofit
  - CPR

Need to be able to sell the program to management. One way of doing this is to prove that money spent now will save money in the long run. If the benefits can not be demonstrated, it will be difficult to get support to implement the program.

What are some means of improving customer service? Improved ride quality and lower user costs are two examples.

Slide 8

Importance of Preventive Maintenance

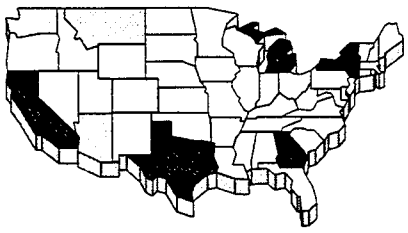
As we move towards the 21st century, it is clear that the Federal-Aid highway program is undergoing a significant transition from its original focus on new construction to that of preservation of the highway system.

- FHWA Program Development Office

With the majority of the pavement infrastructure in place, it is now time to turn to preserving that investment. Recent FHWA initiatives, such as ISTEA and TEA-21 (discussed in detail in Module 2), have supported a change toward preservation of the pavement system. AASHTO is also committed to preventive maintenance. Approximately 20 percent of their program is devoted to preventive maintenance. Preventive maintenance definitely falls within the future plans.

Slide 9

State Initiatives In Preventive Maintenance



The five DOTs visited were California, Georgia, Michigan, New York, and Texas. Each of these organizations is unique in its structure, geography, and approach to implementation. Each have been practicing preventive maintenance for different lengths of time as well.

The course materials also include references to preventive maintenance practices in Washington, Montana, and Arizona.

Slide 10

Washington State Survey

- Roadway surface maintenance is the highest priority maintenance activity
- Public is willing to pay more:
  - to achieve desired levels of maintenance
  - to reduce future costs

Two states, Washington and Arizona, are among the states that have conducted customer surveys to determine the public's needs. The results have consistently been that surface maintenance is a high priority, the public wants smoother roads, and they are willing to pay for it.

Washington DOT commissioned a study to evaluate maintenance management and administration. These findings support pavement maintenance. They developed an approach to understand and improve customer satisfaction. Bonds were issued to help compensate the program but a tax increase was not needed.

Slide 11

Arizona Survey

- #1 priority: safety (85 %)
- #2 priority: preservation (74 %)
- Over 60 % would be willing to pay more taxes to improve maintenance service levels
- 90 % would be willing to spend more now to save money in the long term

An Arizona DOT survey also showed a concern for maintenance. The findings are presented here. The public doesn't perceive that the government will spend the money well.

A focus on customer satisfaction should be a part of every preventive maintenance program.

Slide 12

California Survey

- Ranking of public priorities
  - Maintenance response to accidents/disasters
  - Safety
  - Pavement conditions
  - Traffic flow

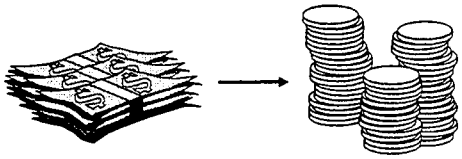
An Arizona DOT survey also showed a concern for maintenance. The findings are presented here. The public doesn't perceive that the government will spend the money well.

A focus on customer satisfaction should be a part of every preventive maintenance program.

Slide 13

One Objective of Preventive Maintenance

- Reduce the overall life cycle cost of preservation

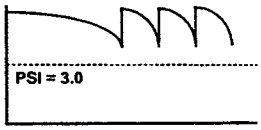


One of the objectives of a preventive maintenance program is to reduce the overall life cycle costs of the preservation program. The following slides provide a few examples of the findings of states that have analyzed their program.

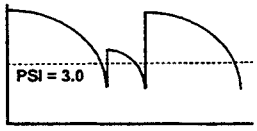
Slide 14

Indiana Preventive Maintenance Study

Goal: Minimize Agency and User Costs



If seal coat when PSI > 3.0, then apply 3 chip seals



If seal coat when PSI < 3.0, then apply 1 chip seal

This slide summarizes the results of a study conducted by Purdue University and the Indiana DOT. They found that the ideal program to minimize agency and user costs is to apply three chip seals before rehabilitation if applied before at PSI above 3.0. If the PSI drops below 3.0, then only one chip seal can be applied cost effectively.

Slide 15

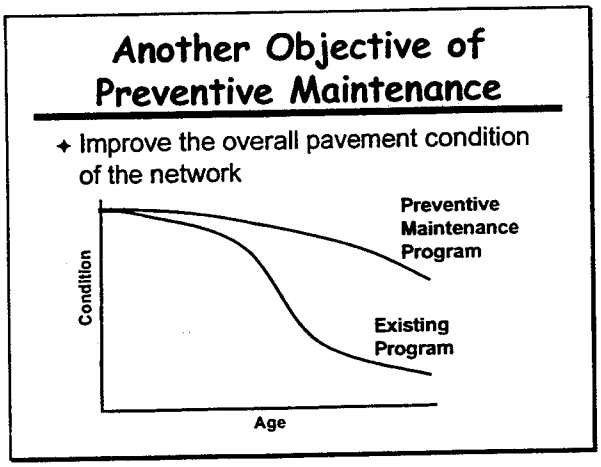
Michigan DOT Example

$315 million Rehabilitation and Reconstruction	=	$190 million Rehabilitation and Reconstruction + $10 million Preventive Maintenance

Achieved same results for $115 million less

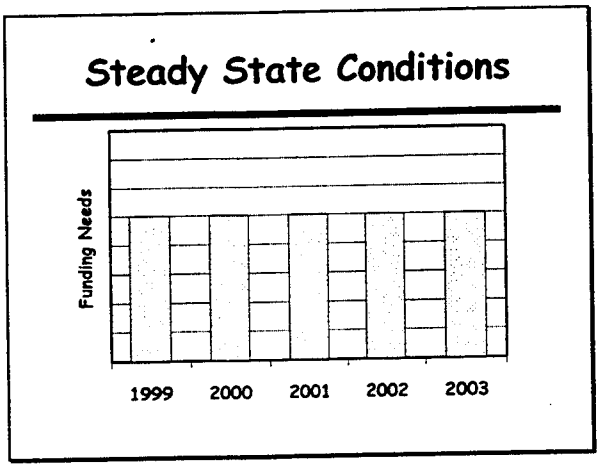
Michigan used a remaining life analysis within its PMS to demonstrate the long-term effects of several different funding scenarios. One such analysis evaluated the effect of supplementing their traditional rehabilitation and reconstruction program with a small preventive maintenance program. The results indicated that $315 million is needed for a rehabilitation and reconstruction program to match the same performance of a $200 million program that included $10 million for preventive maintenance. That is, $10 million spent on preventive maintenance saved $115 million annually.

Slide 16



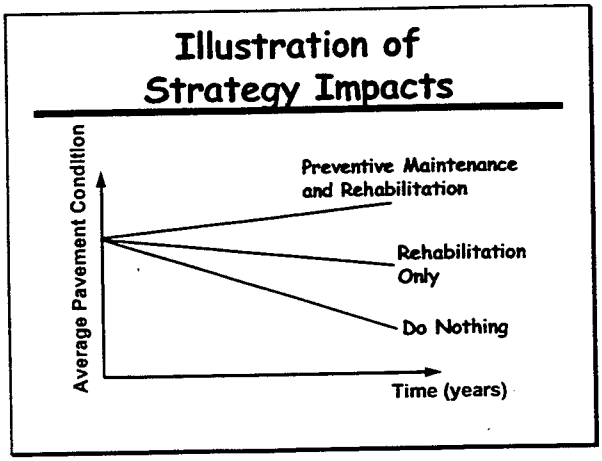
Another objective of preventive maintenance is to improve the overall condition of the network. A pavement management system is a useful tool for illustrating the long-term impact of a preventive maintenance program on the overall network condition.

Slide 17



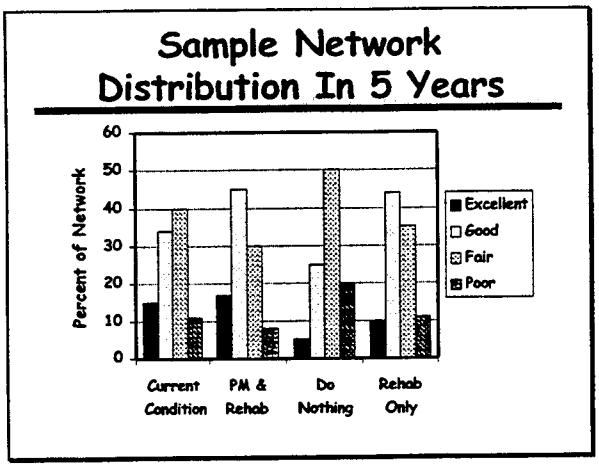
For instance, Georgia has reached a point referred to as a steady-state condition where the overall network condition can be maintained for a constant level of funding.

Slide 18



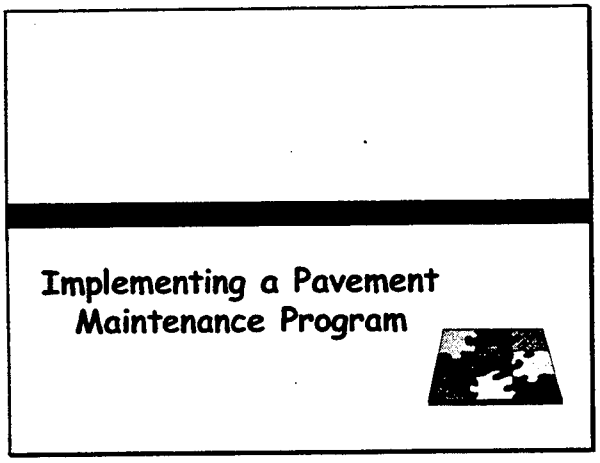
A PMS can be useful for graphically displaying the average network condition over time. This figure plots the average condition of the pavement over time for three alternatives. Instead of pavement condition, other factors that can be evaluated are percentage of pavements in various categories or remaining service life.

Slide 19



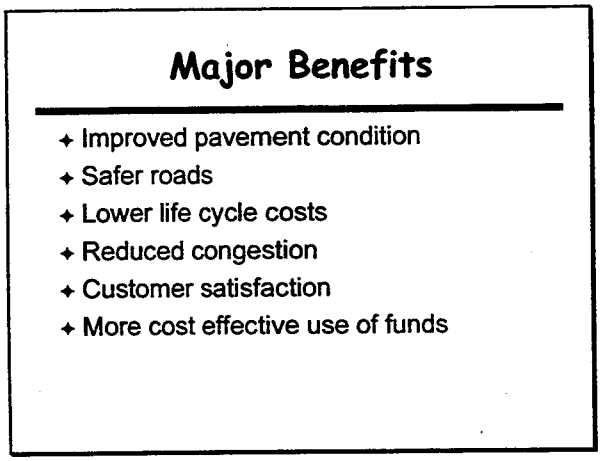
Similarly, the network conditions can be displayed in terms of the percentage of the network in each condition category. This example looks at the percentage of pavements in various categories after 5 years of following a given strategy. The preventive maintenance strategy results in the highest percentage of pavements in the excellent and good categories. The benefits could become more apparent over time until the pavement condition stabilizes.

Slide 20



The next set of slides looks at ways of implementing a pavement maintenance program as part of a pavement preservation program. The information is taken from success stories from states.

Slide 21



These are the three main benefits to implementing a pavement preventive maintenance program. These benefits represent those benefits that have a great enough impact that they should influence an agency's maintenance decisions. The first two benefits are critical to the users of the roads. These benefits translate to fewer repairs, less delay, more efficient roadway operations, and better long-term performance. The final benefit—lower overall costs for pavement preservation—is the most likely reason for agencies to implement a program

Slide 22

Challenges

- Dedicated funding challenges
- Management resistance
- Management's perception of public reaction
- Poor data tracking
- Lack of applicable research
- Absence of relevant training

The benefits of preventive maintenance are desirable and success stories within states have been documented. So why aren't more agencies applying preventive maintenance activities? There are many obstacles in the way, as listed here. Overcoming these obstacles requires a formidable effort. Some obstacles are easier to overcome than others. A previous obstacle was the lack of Federal legislation supporting funding for maintenance activities. Several events have helped remove this obstacle, such as the passage of ISTEA (1991), the clarification of treatments eligible for NHS Appropriations Act (1995), and the passage of TEA-21 (1998).

Slide 23

Keys to Successful Program

- Establish goals
- Document the benefits
- Promote the benefits
- Obtain dedicated funding
- Develop guidelines
- Identify champion
- Obtain top management support

These are several keys to implementing a successful program. Each will be discussed in detail in subsequent slides. Just mention them briefly here and move on.

Slide 24

Establish Goals

It is essential that a road agency select a long-term objective and structure its maintenance selection policy to achieve its objective.

- Rohde et al. 1997

Advocating a philosophy of preventive maintenance is the most important factor in developing a successful program.

- Galehouse 1998

These quotes emphasize the importance of setting goals. Any new program must have a purpose. To be effective, a goal should be something that can be measurable.

Slide 25

Simple, Effective Goals

- California - reduce pavements in need of rehabilitation (from 29 to 11 percent)
- Wisconsin - provide the highest quality service possible per unit of service
- Michigan - keep good roads good

The goals do not need to be complicated. The most successful programs have simple goals that developed out of necessity. Georgia began its program because a Commissioner believed that Georgia's roads were the worst in the southeast. California's program initiated when a Commissioner questioned whether the agency's practices were leading to a growing backlog of their pavement system. Wisconsin evaluates each maintenance or rehabilitation action by determining the effect on the customers' comfort, convenience, safety, and costs.

Slide 26

Measurable Goals

- Pavement condition
- Average rating
- Percent of pavements in condition category
- Cost savings

It is not enough to establish goals; there must also be a means of measuring the benefits. This list provides a few examples of benefits that can be measured. Monitoring one or more these indicators is one means of quantifying the benefits of the program.

Agencies that currently have a PMS will not have to develop a new system of monitoring. A PMS can track the pavement condition and other information that is required for monitoring purposes.

Slide 27

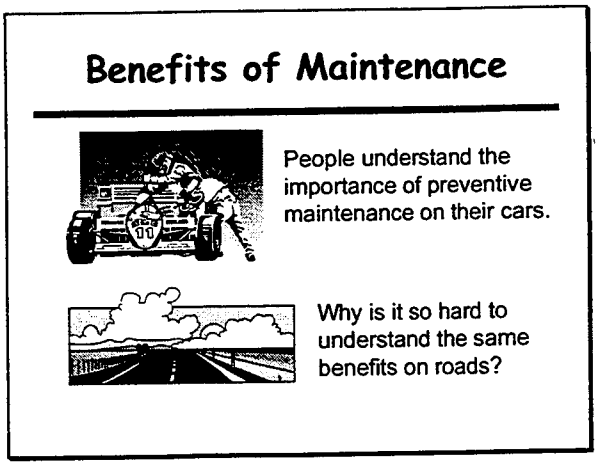
Document the Benefits

There is a need to conduct and publish the results of formal research on the cost-effectiveness of pavement preventive maintenance techniques.

- Geoffroy 1996

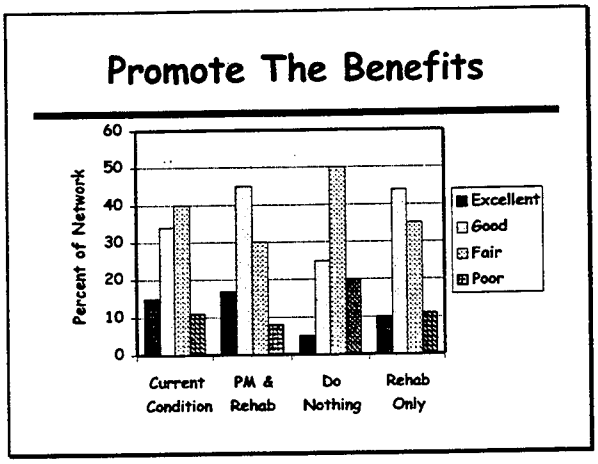
In order to maintain funding levels, an agency must be able to document the benefits of a preventive maintenance program.

Slide 28



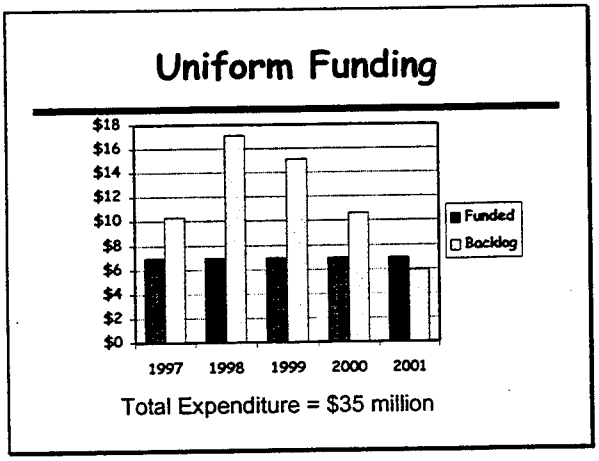
People understand the importance of preventive maintenance on their cars. People get oil changes and tune-ups to avoid more serious problems later.

Slide 29



This example was illustrated in a previous slide. It shows the percentage of the pavement network in each condition category 5 years after implementing the given programs.

Slide 30

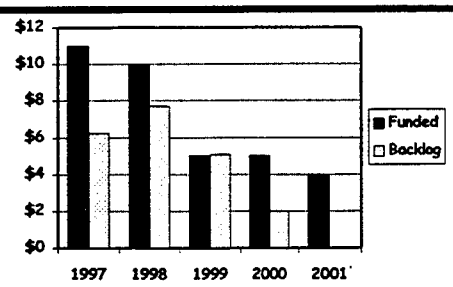


This example comes from the Public Services Department in Bedford, Texas. The engineering staff were seeking to secure a greater investment in a preventive maintenance program.

This figure illustrates a funding scenario in which the funds are distributed equally ($7 million per year) over the next 5 years. The total expenditure under this scenario is $35 million. This scenario reduced the backlog to about $6 million over the next 5 years.

Slide 31

Early Distribution of Funds



Total Expenditure = $35 million

The second scenario shifted more funding to the first 2 years, although the total expenditure remained the same at $35 million. However, this scenario completely eliminated the backlog of projects.

This illustration was persuasive enough that the City came up with an additional sales tax to both provide sufficient funding to improve the network condition to acceptable levels and to fund ongoing maintenance activities.

Slide 32

Obtain Dedicated Funding

Long-term support and financial commitment are the keys.

- Wayne Shackleford

Dedicated funding requires a strong commitment to the philosophy of preventive maintenance.

Since a preventive maintenance program requires a continuous level of effort for a period of time before the program's success can be realized, the most successful agencies have established dedicated funds for preventive maintenance.

The two quotes emphasize the importance of dedicated funding to the overall success of the program. The case study states in module 5 also point out the importance of dedicated funding.

Slide 33

Importance of Dedicated Funding

- Benefits take time to realize
- Allows for improved asset management

Funding levels should match preventive maintenance needs

Agencies that have succeeded in implementing preventive maintenance programs recognize the importance of obtaining an adequate and secure source of funding. The need for financial support over a long enough period of time to see program results requires support from top management and a commitment to the long-term goals of the program.

The case studies noted that patience is a key; these program take time before the benefits are realized. Dedicated funding ensures the program will not be eliminated before the benefits are realized. The funding can not be static either. Other costs are continuously rising and the funding must keep pace.

Slide 34

Use of a Pavement Management System

- Determine funding level to achieve an agency goal
- Determine the most cost-effective strategy for a given funding level
- Integrate with preventive maintenance (feedback)

The first example typically requires an iterative process in which multiple strategies and funding levels are programmed to determine the condition at the end of the analysis period. The current strategy will be used as the base case. Other strategies, such as worst-first and preventive maintenance, can also be analyzed. Preventive maintenance will usually prevail as the most cost effective strategy.

The second example is the more traditional approach, because funding levels are typically fixed. Again, multiple strategies can be analyzed to determine the strategy that provide the best condition at the end of the analysis period.

Slide 35

Sources of Funding

- New money (revenue enhancement)
- Transfer of funds from another program
- Increased flexibility with Federal funds

This list shows three available sources for funds. Federal participation on maintenance projects is now at an 80 percent reimbursement rate with fewer restrictions than ever. The other methods require support from top management to obtain funding.

New York recognized the "need for long-term financing that was stable, predictable, and adequate." Support from management helped established a Dedicated Fund. The fund included provisions for annual increases and an additional $88 million to give the program an aggressive start.

Slide 36

Develop and Improve Treatments and Timing

- Don't become complacent because it works; it could be better
- Monitor feedback
- Modify guidelines
- Develop Manuals of Practice
- Industry is constantly developing new treatments and better materials

The program can only be as successful as the treatments themselves. Even with adequate funding and support, the program will not be successful if the treatments do not work. Continuous research and monitoring are required to assess the effectiveness of the treatments. PMS can be used to effectively track the performance of the treatments. Where treatments are not performing up to standards, they can either be dropped from the program or modified.

Some states have developed their own Manuals of Practice for maintenance treatments. For example, Montana developed a *Maintenance Chip Seal Manual* to provide guidance on the proper design and construction of chip seals. Michigan has outlined all of their preventive maintenance treatments in a document entitled *Capital Preventive Maintenance Program.*

Slide 37

Innovative Practices to Promote Success

- Contracting
- Incentive-based financing (warranties)
- Innovative materials and techniques
- Training approaches
- Partnering

Preventive maintenance projects are quite different than typical projects that an agency is used to handling. Differences include the following:

--Reduced treatment costs.

--More timely application.

--Reduced manpower needs.

--Less construction time.

Agencies have developed innovative ways of dealing with preventive maintenance projects that result in lower overall costs.

Slide 38

Contracting

- Michigan
  - Simplified designs
  - Contractor responsible for quality control
- New York
  - Vendor-placed paving
  - Simplified contracts

Reduce costs for design and engineering

Michigan reduced its design costs from 5 to 2 percent of the project due to the simplicity of most preventive maintenance projects. In addition, by making the contractor responsible for quality control, they reduced their construction engineering costs from 15 to 5 percent of the project.

New York also implemented some innovative practices. Vendor-placed paving uses a combination of state and contractor forces to apply lower cost treatments. For example, the vendor hauls material to the site and state forces use their equipment and manpower to place the material. Simplified contracts have a simpler and quicker scoping process, limited number of pay items, restricted to less than 1 month of construction, and allow more flexible (longer) construction seasons.

Slide 39

Warranties (Michigan)

- Developed due to limited manpower
- Warranty periods of 2 to 3 years
- Contractors select projects suitable for preventive maintenance
- Benefits
  - Cost savings
  - Shift in liability

Michigan initiated warranties out of necessity due to loss of manpower, especially of field inspection personnel. The warranty periods are designed to last long enough to ensure that premature failures related to construction were covered. Chip seals, microsurfacing, slurry seals, crack sealing, and joint resealing have 2-year warranty periods. Thin overlays, cold milling and overlays, and PCC repairs have 3-year warranty periods.

Slide 40

Training

- Concepts of preventive maintenance are different than typical projects
- Training needs
  - Overall purpose
  - Treatments and timing
  - Integration with other strategies

The concepts promoted in preventive maintenance are often radically different from the usual way of doing business. Thus, training is essential.

Slide 41

Summary

- Must get away from a worst-first policy
- Preventive maintenance can extend pavement life and reduce costs
- Keys to success
  - Measurable goal
  - Assessing and promoting benefits
  - Dedicated and continuous funding
  - Feedback from PMS

Agencies must get away from a worst-first policy that is reactive rather than preventive in nature. Preventive maintenance programs have been successful in extending pavement life and reducing overall costs. They also promote flexibility with transportation budgets.

There are continuous barriers to the implementation and execution of preventive maintenance program. However, the barriers are not insurmountable. Studies have shown that the public is ready to embrace the philosophy of preventive maintenance.

Appendix A—Glossary

AADT – The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. AADT can also be approximated by adjusting the ADT count for daily (weekday versus weekend) and seasonal (summer versus winter) variations.

ADT – The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location.

ADTT – The average 24-hour truck traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. ADTT may be expressed as a percentage of ADT.

Annual Costs – Any costs associated with the annual maintenance and repair of the facility.

Asphalt Emulsion Mix – A mixture of emulsified asphalt materials and mineral aggregate usually prepared in a conventional hot-mix plant or drum mixer at a temperature of not more than 127 °C (260 °F). It is spread and compacted at the job site at a temperature above 93 °C (200 °F).

Cape Seal – A surface treatment that involves the application of a slurry seal to a newly-constructed surface treatment or chip seal. Cape seals are used to provide a dense, waterproof surface with improved skid resistance.

Chip Seal – A surface treatment in which a pavement surface is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low-volume roads.

Cold In-Place Recycling (CIR) – A process in which a portion of an existing bituminous pavement is pulverized or milled, the reclaimed material is mixed with new binder and virgin materials, and the resultant blend is placed as a base for a subsequent overlay. Emulsified asphalt is especially suited for cold in-place recycling. Although not necessarily required, a softening agent may be used along with the emulsified asphalt.

Cold Milling – A process of removing pavement material from the surface of the pavement either to prepare the surface (by removing rutting and surface irregularities) to receive overlays, to restore pavement cross slopes and profile, or even to re-establish the pavement's surface friction characteristics.

Crack Filling – A maintenance procedure that involves placement of materials into non-working cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in). Crack filling should be distinguished from crack sealing.

Crack Sealing – A maintenance procedure that involves placement of specialized materials, either above or into working cracks, using unique configurations to reduce the intrusion of incompressibles into the crack and to prevent intrusion of water into the underlying pavement layers. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in).

Dense-Graded Asphalt Overlay – An overlay course consisting of a mix of asphalt cement and a well-graded (also called dense-graded) aggregate. A well-graded aggregate is uniformly distributed throughout the full range of sieve sizes.

Diamond Grinding – A maintenance procedure for concrete pavements that involves the removal of a thin layer of concrete (generally no more than 6.4 mm [0.25 in]) from the surface of the pavement to remove surface irregularities (most commonly joint faulting), to restore a smooth riding surface, and to increase pavement surface friction.

Diamond Grooving – The establishment of discrete grooves in the concrete pavement surface using diamond saw blades to provide a drainage channel for water and thereby reduce the potential for hydroplaning and wet weather accidents.

Discount Rate – The rate of interest reflecting the investor's time value of money, used to determine discount factors for converting benefits and costs occurring at different times to a baseline date. Discount rates can incorporate an inflation rate, depending on whether real discount rates or nominal discount rates are used.

Emulsified Asphalt – An emulsion of asphalt cement and water, which contains a small amount of an emulsifying agent. Emulsified asphalt droplets, which are suspended in water, may be either the anionic (negative charge) or cationic (positive charge) type, depending upon the emulsifying agent.

Equivalent Uniform Annual Cost (EUAC) – The net present value of all discounted cost and benefits of an alternative as if they were to occur uniformly throughout the analysis period. Net Present Value (NPV) is the discounted monetary value of expected benefits (i.e., benefits minus costs).

Fog Seal – A light application of slow setting asphalt emulsion diluted with water. It is used to renew old asphalt surfaces and to seal small cracks and surface voids.

Heater Scarification – A form of Hot In-Place Recycling in which the surface of the old pavement is heated, scarified with a set of scarifying teeth, mixed with a recycling agent, and then leveled and compacted.

Hot In-Place Recycling (HIR) – A process which consists of softening the existing asphalt surface with heat, mechanically removing the surface material, mixing the material with a recycling agent, adding (if required) virgin asphalt or aggregate to the material, and then replacing the material back on the pavement.

Hot Mix Asphalt (HMA) – High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate thoroughly compacted into a uniform dense mass.

Hot Surface Recycling – See hot in-place recycling.

Inflation rate – The rate of increase in the general price levels, caused usually by an increase in the volume of money and credit relative to available goods. The inflation rate is also reflective of the rate of decline in the general purchasing power of a currency.

Initial Costs – All costs associated with the initial design and construction of a facility, placement of a treatment, or any other activity with a cost component.

International Roughness Index (IRI) – A ratio of the accumulated suspension motion to the distance traveled obtained from a mathematical model of a standard quarter car transversing a measured profile at a speed of 80 km/h (50 mph). Expressed in units of meters per kilometer (inches per mile), the IRI summarizes the longitudinal surface profile in the wheelpath.

Joint Resealing – The resealing of transverse joints in concrete pavements to minimize the infiltration of surface water into the underlying pavement structure and to prevent the intrusion of incompressibles into the joint.

Joint Sealant Reservoir – The channel sawed or formed at a joint that accommodates the joint sealant.

Load Transfer Restoration (LTR) – The placement of load transfer devices across joints or cracks in an existing jointed PCC pavement. LTR is used on existing jointed PCC pavements that were constructed without dowel bars at transverse joints.

Life Cycle Costing – An economic assessment of an item, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars.

Microsurfacing – Microsurfacing is a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed and spread on a paved surface.

Mineral Filler – A finely divided mineral product, at least 70 percent of which will pass a 0.075 mm (No. 200) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

Nominal Dollars – Dollars of purchasing power in which actual prices are stated, including inflation or deflation. Hence, nominal dollars are dollars whose purchasing power fluctuates over time.

NOVACHIP™ – A maintenance treatment for AC pavements, sometimes called an ultrathin friction course: it consists of a layer of hot-mix material placed over a heavy, polymer modified emulsified asphalt tack coat; the total thickness of the application being typically between 10 and 20 mm (0.40 and 0.80 in). It can be used to reduce deterioration caused by weathering, raveling, and oxidation, and can be used to fill ruts and to smooth corrugations and other surface irregularities.

Open-Graded Friction Course (OGFC) – An overlay course consisting of a mix of asphalt cement and open-graded (also called uniformly-graded) aggregate. An open-graded aggregate consists of particles of predominantly a single size.

Partial-Depth Recycling – See cold in-place recycling.

Pavement Preservation – The sum of all activities undertaken to provide and maintain serviceable roadways; this includes corrective maintenance and preventive maintenance, as well as minor rehabilitation projects.

Pavement Preventive Maintenance – Planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retard future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity).

Pavement Reconstruction – Construction of the equivalent of a new pavement structure which usually involves complete removal and replacement of the existing pavement structure including new and/or recycled materials.

Pavement Rehabilitation – Work undertaken to extend the service life of an existing pavement. This includes the restoration, placing an overlay, and/or other work required to return an existing roadway to a condition of structural and functional adequacy.

Pavement Serviceability Index (PSI) – A subjective rating of the pavement condition made by a group of individuals riding over the pavement.

Periodic Costs – Costs associated with rehabilitation activities that must be applied periodically over the life of the facility.

Present Worth Method – Economic method that requires conversion of costs and benefits by discounting all present and future costs to a single point in time, usually at or around the time of the first expenditure.

Real Dollars – Dollars of uniform purchasing power exclusive of general inflation or deflation. Real dollars have a constant purchasing power over time.

Recycling Agents – Organic materials with chemical and physical characteristics selected to address any binder deficiencies and to restore aged asphalt material to desired specifications.

Rejuvenating Agent – Similar to recycling agents in material composition, these products are added to existing aged or oxidized AC pavements in order to restore flexibility and retard cracking.

Retrofitted Load Transfer – See Load Transfer Restoration.

Rubberized Asphalt Chip Seal – A variation on conventional chip seals in which the asphalt binder is replaced with a blend of ground tire rubber (or latex rubber) and asphalt cement to enhance the elasticity and adhesion characteristics of the binder. Commonly used in conjunction with an overlay to retard reflection cracking.

Salvage Value – The remaining worth of the pavement at the end of the analysis period. There are generally two components of salvage value: residual value – the net value from recycling the pavement and serviceable life – the remaining life of the pavement at the end of the analysis period.

Sand Seal – An application of asphalt material covered with fine aggregate. It may be used to improve the skid resistance of slippery pavements and to seal against air and water intrusion.

Sandwich Seal – A surface treatment that consists of application of a large aggregate, followed by a spray of asphalt emulsion that is in turn covered with an application of smaller aggregate. Sandwich seals are used to seal the surface and improve skid resistance.

Scrub Seal – Application of a polymer modified asphalt to the pavement surface followed by the broom-scrubbing of the asphalt into cracks and voids, then the application of an even coat of sand or small aggregate, and finally a second brooming of the aggregate and asphalt mixture. This seal is then rolled with a pneumatic tire roller.

Shape Factor – The width to depth ratio of a joint sealant reservoir. A proper shape factor is required to allow the sealant to effectively withstand repeated extension and compression as the temperature and moisture in the slab changes. Most commonly available sealants require a shape factor between 1 and 2.

Slurry Seal – A mixture of slow-setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to provide skid resistance.

Stockpiled Cold Mix – An asphalt maintenance mix consisting of aggregate and emulsified asphalt, which once prepared can be stored and readily used for a period up to six months depending on the formulation of the emulsion used and the aggregate characteristics.

Stone Mastic Asphalt Overlay – An overlay course consisting of a mix of asphalt cement, stabilizer material, mineral filler, and gap-graded aggregate. A gap-graded aggregate is similar to an open-graded material but is not quite as open.

Surface Texture – The characteristics of the concrete pavement surface that contribute to both surface fiction and noise.

Undersealing – Also called subsealing, pressure grouting, or slab stabilization: this process consists of the pressure insertion of a flowable material beneath a PCC slab used to fill cavities beneath PCC slabs and occasionally to correct the vertical alignment by raising individual slabs.

User Costs – Costs incurred by highway users traveling on the facility and the excess costs incurred by those who cannot use the facility because of either agency or self-imposed detour requirements. User costs typically are comprised of vehicle operating costs (VOC), accident costs, and user delay costs.