AGENDA

PAVEMENT MANAGEMENT SYSTEMS

SEPTEMBER 9

8:00	AM	Introductions	Instructor
		Workshop Schedule and Logistics	Instructor
8:15	AM	Host Agency Presentation	Host Agency
8:45	AM	Module 1: Intro. to Asset Management Systems	Instructor
9:30	AM	Module 2: PMS Overview	Instructor
10:15	AM	BREAK	
10:30	PM	Module 3: Relational Databases and LRS	Instructor
11:45	AM	LUNCH	
12:45	PM	Workshop #1: Setting Up a PMS	Instructor
2:15	PM	Module 4: Inventory & History	Instructor
2:45	PM	BREAK	Instructor
3:00	PM	Module 5: Condition Surveys	Instructor
4:45	PM	Recapitulations	Instructor
5:00	PM	END	Instructor

This is a sample agenda for Day 1. Instructors will need to add short breaks every hour, especially in the afternoon.

AGENDA

PAVEMENT MANAGEMENT SYSTEMS

SEPTEMBER 10

Sample agenda for Day 2

8:00	AM	Recapitulations	Instructor
8:15	AM	Module 6: Pavement Condition Indices	Insturctor
9:00	AM	Module 7: ESAL Flow Maps	Insturctor
9:45	AM	BREAK	
10:00	AM	Module 8: Performance Models	Instructor
12:00	Noon	LUNCH	
1:00	PM	Workshop #2: Data Collection	Instructor
3:00	PM	BREAK	
3:15	PM	Module 9: Remaining Service Life	Instructor
4:15	PM	Recapitulations	Instructor
4:30	PM	END	Instructor

AGENDA

PAVEMENT MANAGEMENT SYSTEMS

SEPTEMBER 11

Sample agenda for Day 3

8:00	AM	Recapitulations	Instructor
8:15	AM	Module 10: Prioritization	Instructor
10:15	AM	BREAK	
10:30	AM	Module 11: Optimization	Instructor
11:00	AM	Module 12: Feedback	Instructor
12:00	Noon	LUNCH	
1:00	PM	Module 13: Institutional Issues & Implementation	Instructor
1:45	PM	BREAK	
2:00	PM	Workshop #3: Performance Models & Implemention	
4:00	PM	Module 14: Quality Management	Instructor
4:30	PM	Recapitulations, Summary & Evaluation	Instructor
4:45	PM	END	Instructor

INTRODUCTION

Course Description

The *Pavement Management Systems* (PMS) training course is a three-day course consisting of classroom lecture sessions as well as breakout sessions, or workshops, with groups of 5-8 people. The classroom sessions are used to introduce the participants on the importance and need for a PMS as well as the different components of a PMS. The workshops provide an opportunity for participants to interact with each other, and to work together to plan and develop a PMS for a fictional state.

The course will focus on new advances in the field and on cutting edge technology. Examples include new developments in automated survey methods, GIS, GPR and GPS applications and satellite techniques. The following is a brief summary of each module.

Module 1: An Introduction to Asset Management Systems - introduces the fundamental principles common to other industries (e.g. trucking, rail) that are applicable to a PMS and how they can be applied to pavements. This module will demonstrate that a systems approach is not only limited to pavements but can also be applied to other elements of the roadway infrastructure.

Module 2: Pavement Management Systems Overview - describes the basic components of a PMS and how the products of that system can be used as a tool to aid in the development and decision-making for the pavement maintenance and construction program for an agency.

Module 3: Relational Databases and Location Referencing Systems - details the principles and concepts behind a relational database including the available technology. The participants will also gain an understanding of the basic concepts of how a location referencing system works, how a GIS and GPS work, and how these elements are used in a PMS.

Module 4: Inventory and History - defines what types of data should be collected, how it should be collected and how it is used in a PMS. The importance of inventory data, project history and location referencing systems will be emphasized.

Module 5: Pavement Condition Surveys - describes the use of pavement condition survey data in the PMS, how it can be collected and the state-of-the-art of data collection equipment. In addition, the need to establish basic quality control procedures to insure that the data is truly representative, accurate and repeatable from year to year is included. A discussion on the basic pavement distress categories and methods will also include guidance on how an agency can select the best approach for their present and future needs.

Module 6: Pavement Condition Indices - includes the historic development of pavement distress indices, their basic functions, how they are computed, the different types available along with their advantages and disadvantages, and a discussion of the International Roughness Index (IRI).

Module 7: ESAL Flow Maps - participants will be able to more fully appreciate the use and application of ESALs rather than basic traffic volumes in a PMS. They will better understand how to produce sufficiently accurate ESAL estimates considering daily, monthly and seasonal truck flows for use in pavement management systems and in pavement design.

Module 8: Performance Models - this module will emphasize the importance of predicting the change in level of service in order to estimate future rehabilitation needs and introduce the tools used to predict future conditions

Module 9: Remaining Service Life - participants will gain an understanding of what the remaining service life of a pavement is, how it is used, why it is important, and how it is calculated.

Module 10: Prioritization - will give the participants an understanding of the methodology and its disadvantages. The focus will be on the priority assessment techniques for prediction models to forecast conditions and prioritization as tools to identify the most cost-effective strategies for various funding levels.

Module 11: Optimization - will familiarize the participants with optimization techniques used in a PMS. An optimization analysis evaluates network strategies first, and specific rehabilitation projects and treatments to fit the strategy second.

Module 12: PMS Feedback Process - the importance of a PMS feedback process will be emphasized. This will provide an effective loop for the agency to evaluate the effectiveness of its pavement design and construction practices through an ongoing analysis of its pavement performance models.

Module 13: Institutional & Implementation Issues - discusses the importance of institutional issues for a successful PMS implementation. These include non-technical items such as insufficient funding, communications, personnel turnover, training, as well as many others. Solutions to these problems will be offered.

Module 14: Quality Management - presents the work currently being performed in some states to improve quality in highway pavements.

Course Objectives

At the end of this course, participants will be able to:

- Identify what a PMS is and the benefits of implementation for an agency
- Identify and understand the components of a PMS
- Become familiar with the types of data collected and reasons for their collection
- Be aware of new technologies used in collecting PMS data
- Understand optimization and prioritization techniques and algorithms
- Understand the role of a PMS in quality management

Format and Organization of Course Materials

This document is the Instructor's Guide and is used by the course instructors. It provides guidelines for setting up a course, including the format of the course, lesson plans for each module, and instructions for conducting the workshops.

The course materials are divided into 14 modules as indicated in the table of contents. There is also a section on workshop materials, of which there are three. Each module contains copies of the Microsoft PowerPoint® slides, together with notes to the instructor on special items that should be emphasized during instruction.

Note that there should be a recapitulation every morning and at the end of the day. Ten minutes should be allocated to ask the following three questions:

1. What do you remember?

2. How is it related to what you do now?

3. How will it be used in the future?

Course Agenda

A sample agenda for the three days of the training course is included at the end of this section. Note that on the first day, introductions are made so that participants and the instructors know each other's names. The introductory remarks will welcome the participants and provide them with a briefing on the objectives of the workshop and how it will be conducted. Other housekeeping and administrative details will also be covered at this time.

The host agency will then be invited to make a brief presentation on their PMS. This will include information on the current PMS status, types of data collected, analysis used, types of outputs and how the results are used. It is important to bring in, as much as possible, local or regional experiences.

After the introductions, the instructor will begin with *Module 1: An Introduction to Asset Management Systems*. A laptop computer together with a multi-media projector will be used to project slides created in Microsoft PowerPoint®. Almost the entire course will be presented with slides. A total of three workshops are also included, and these are intentionally scheduled to take place in the afternoons, immediately after lunch. (This assumes that the course will begin in the morning.)

The format of the attached agenda should be used, substituting the names and dates as appropriate.

Audience

The intended audience for this course is the experienced highway or pavement engineer. These are the individuals responsible for all aspects of implementing, operating and maintaining a PMS in their respective agencies. They have been exposed to PMS and are considered to be knowledgeable on the subject.

Materials and Equipment

As was mentioned previously, almost the entire course will be taught with the use of Microsoft PowerPoint® slides. The slides will be available in both CD and floppy disk, although it is highly recommended that CDs be used due to the extensive storage required (approximately 20 MB). Therefore, it will be necessary to include a laptop computer. The minimum requirements are:

- Pentium 133 MHz CPU laptop
- 32 MB RAM
- 1 GB hard drive
- 3.5 inch FDD
- SVGA capabilities
- 8x CD drive (either internal or external)
- Microsoft PowerPoint® 97

Other equipment needs include:

- Multimedia projector
- Projection screen (typically provided by host agency)
- Extension cords
- Laser pointer
- Overhead projector (typically provided by host agency)
- Blank transparencies
- Transparency pens
- Flipcharts

Alternatively, 35 mm slides are also available for instruction. In this case, the following equipment is needed:

- 35 mm carousel slide projector (typically provided by host agency)
- Projection screen
- Extension cords
- Laser pointer
- Overhead projector
- Blank transparencies
- Transparency pens

Finally, the instructors will also need the following:

- Instructor’s Guide (this document)
- Participant’s Workbook
- Agenda
- Sign-in sheets
- NHI Evaluation forms
- Continuing education unit (CEU) forms

Coordination with Host Agency

Prior to the course, various planning and coordination activities must be undertaken by the instructors to ensure the success of the course. Issues related to the course must be addressed, including:

- Preparation of agenda to meet host agency’s needs
- Point of contact with host agency
- Date of course
- Classroom space (include breakout rooms)
- Classroom logistics
- Equipment needs
- Hotel facilities
- List of participants
- Other administrative details e.g. shipping sites

In addition, initial contacts with the host agency should include a determination of their PMS status and needs. It is desirable to locate a representative from a host agency to make a brief presentation during the workshop.

Finally, one of the instructors will arrive half a day early to meet with the course coordinator and ensure that all materials and equipment have arrived, and that the classroom facilities are adequate.

General

Initial contact with the host agency will be as directed by the National Highway Institute (NHI). Once contact has been established, it is necessary to maintain close coordination in order to ensure logistics requirements are completely understood and a firm schedule is developed.

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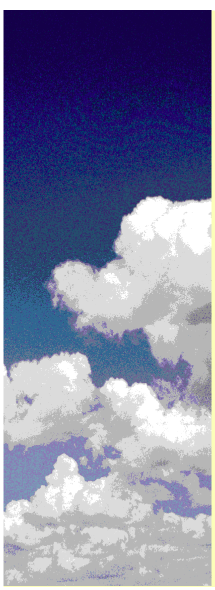
Introduction-1

Introduction-1

Notes:

Title slide

Introduction-2



Introduction

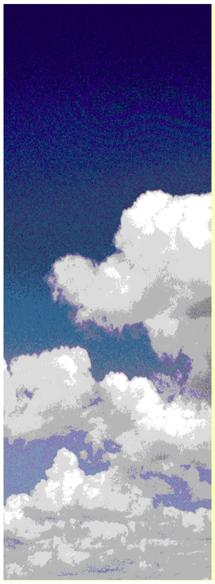
- Agenda
- Introductions
- Course description
- Format & organization
- Administrative

Introduction-2

Notes:

This slide outlines the information that will be presented in the Introduction.

Introduction-3



Agenda - Day 1

- Introductions
- Host agency presentation
- Modules 1 & 2
- Module 3
- Lunch
- Workshop 1
- Modules 4 &5

Introduction-3

Notes:

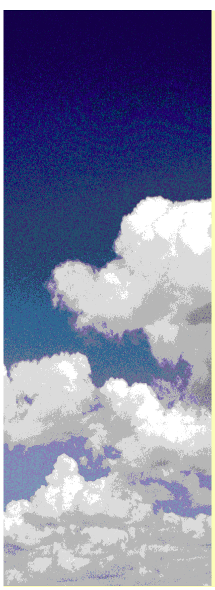
Sample Agenda for Day 1.

Host agency will be asked to make a brief presentation on their PMS.

Modules 1-3 will be covered first, followed by Workshop 1.

Instructor may want to modify this to fit changes in Agenda.

Introduction-4



Agenda - Day 2

- Modules 6, 7, 8 & 9
- Lunch
- Workshop 2
- Modules 9 & 10

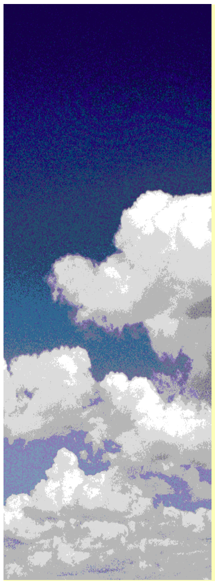
Introduction-4

Notes:

Sample Agenda for Day 2.

Modules 4-7 should be covered prior to Workshop 2.

Introduction-5



Agenda - Day 3

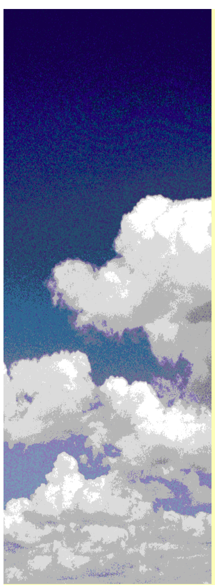
- Modules 11, 12 & 13
- Lunch
- Module 14
- Workshop 3
- Summary & Evaluation

Introduction-5

Notes:

Sample Agenda for Day 3.

Introduction-6



Introductions

- Instructors
  - Margot Yapp
  - Newt Jackson
  - Katie Zimmerman
  - Sue McNeil
  - Rick Deighton

Introduction-6

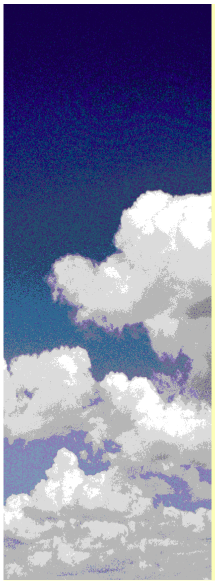
Notes:

Introduce instructors and their backgrounds in PMS and pavement engineering.

This slide may me modified, depending on instructor present.

Let each person introduce himself or herself.

Introduction-7



Introductions

- Your name
- Your agency
- Background
- What you would like to learn from this course

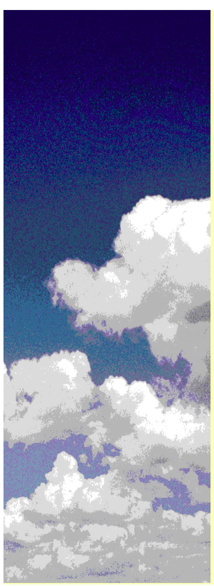
Introduction-7

Notes:

Ask participants to introduce themselves.

Keep note of their agency and background – this information will be used to break them out into groups for the workshops.

Introduction-8



Course Description

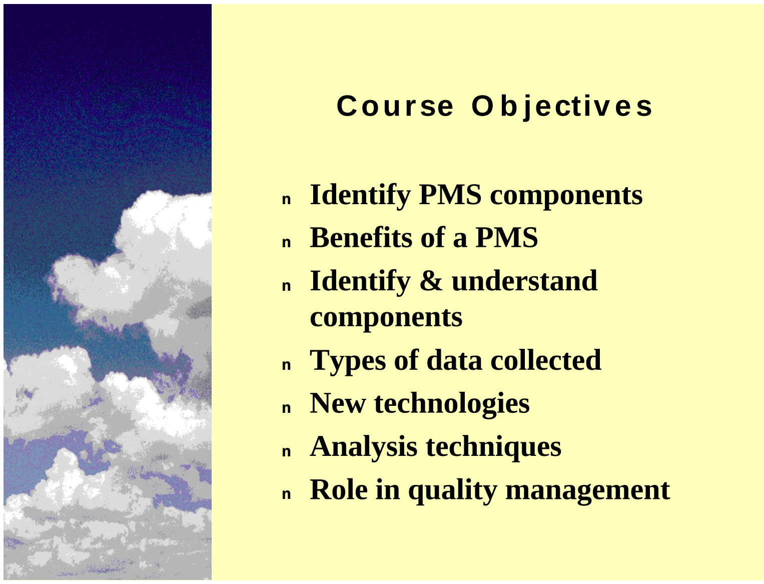
- 3 days
- 14 modules
- Slides and lecture/discussion
- 3 workshops
  - break into groups
  - plan and develop a PMS

Introduction-8

Notes:

Describes the course structure.

Introduction-9

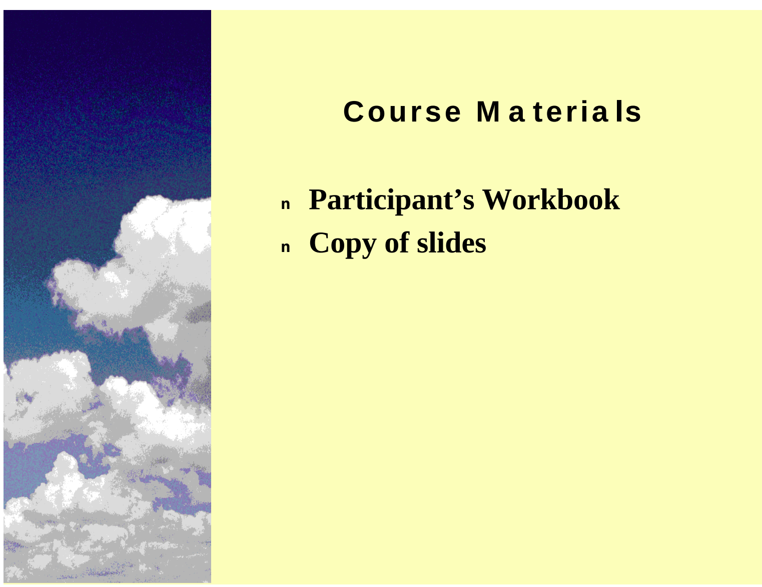


Introduction-9

Notes:

Course Objectives.

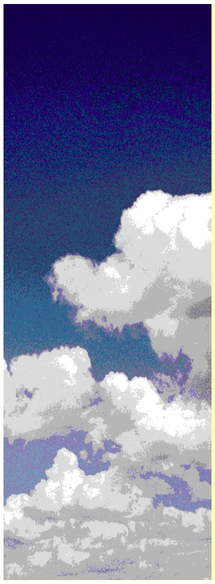
Introduction-10



Introduction-10

Notes:

- Course materials.
- Indicate margins for notes.



Administrative

- Sign-up sheets
- Evaluation forms
- CEU forms
- Name tag

Introduction-11

Notes:

Administrative details.

TABLE OF CONTENTS

MODULE 1

AN INTRODUCTION TO ASSET MANAGEMENT SYSTEMS

Purpose:

The purpose of this module is to introduce the participants to the fundamental principles of an asset management system. These principles are common to agencies managing integrated infrastructures as well as other industries. The applicability of these principles should be presented through a systems approach. This module forms the background for the information to be taught in subsequent modules, so the participants must develop an understanding of these principles.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Identify the fundamental principles involved in asset management.
- Understand the philosophy of asset management.
- Describe the issues affecting the success of asset management today and in the future.
- Understand the applicability of asset management concepts to other highway issues.

Reference:

Module 1 of the Course Notebook

Duration:

45 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

29 Microsoft PowerPoint® Slides

Approach:

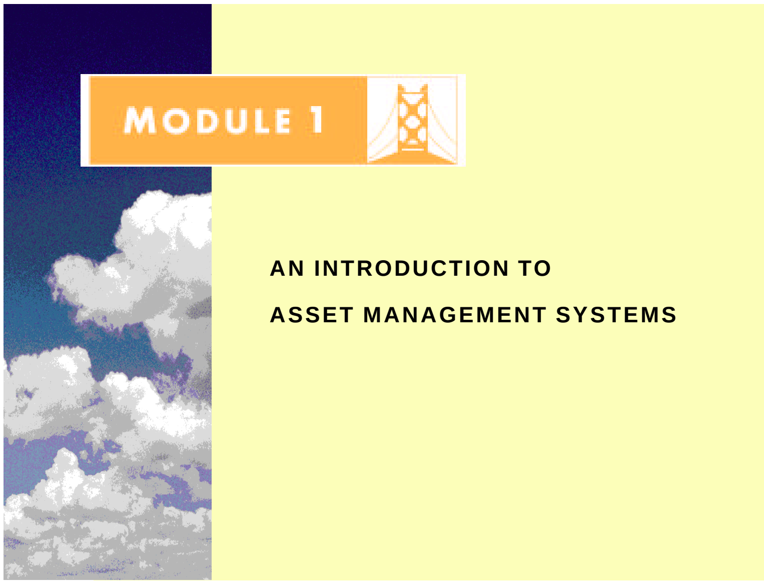
This module is taught through slide presentations and discussion with the participants.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared will also be applicable in a distance learning format.

Slide 1-1

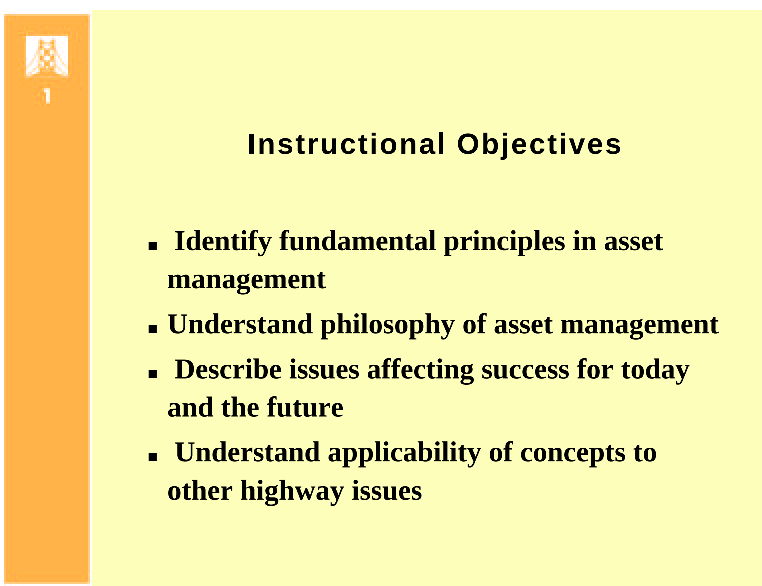


Slide 1-1

Notes:

Ask participants—who has heard the term, "Asset Management Systems," before?

Slide 1-2



Slide 1-2

Notes:

Instructional Objectives

- Identify fundamental principles in asset management
- Understand philosophy of asset management
- Describe issues affecting success for today and the future
- Understand applicability of concepts to other highway issues

Slide 1-3

Management Systems in Private Industry

- Managers of corporate assets (buildings, grounds, and equipment) face similar issues
- Focus is to increase corporate profits

Slide 1-3

Notes:

Similarities in the decision-making process have caused private industry to adopt AMS. These systems are being used to manage network inventories such as parking lots, buildings, transit facilities, waterways, and utilities.

Slide 1-4

Asset Management

- . . . is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively
- . . . Combines the use of sound engineering principles, accepted business practices, and economic theory to improve the decision-making process

Slide 1-4

Notes:

Emphasize that there is currently no universally accepted definition of AMS.

AMS provide the tools for monitoring and preserving a facility's assets to ensure the effective and efficient use of available resources.

Basically, AMS provide a means of analyzing the long-term impact in order to make short-term decisions.

Slide 1-5

Components of an AMS

- **A centralized database**
- **Performance prediction models**
- **Analysis tools**
- **Reporting tools**

Slide 1-5

Notes:

Components of an AMS

§ A centralized database

§ Performance prediction models

§ Analysis tools

§ Reporting tools

Slide 1-6

Quantifiable Objectives

- **Enhance knowledge of inventory and asset value**
- **Develop links that tie resource allocations to savings from replacement**
- **Establish standardized processes and protocols**
- **Consider life-cycle costing**

Slide 1-6

Notes:

These objectives were identified at a recent seminar on asset management.

The primary function of an AMS is to improve the decision-making process, although the benefits are often difficult to quantify. Improvements in performance or profitability are easier measures of success to demonstrate.

As a rule, the objectives should be measurable, although that is not always possible. Private industry typically has goals that are more clearly quantifiable due to the need to remain competitive and profitable and the lack of political constraints.

Slide 1-7

Objectives That Are Difficult To Quantify

- Recognize data as a corporate asset
- Create sense of ownership in assets by corporate managers and operators
- Improve credibility in decision-making
- Encourage processes where managers think globally, but act locally
- Improve teamwork, communication, and training

Slide 1-7

Notes:

At the same seminar, agency objectives that are difficult to quantify were identified.

Mention that these objectives require the coordinated application of a variety of technical principles as well as involvement of individuals from all levels of the organization.

Emphasize the importance of this type of coordinated effort for effective implementation.

Slide 1-8

Benefits of AMS

- Improve program quality
- Improve information and access to information
- Facilitate economic assessment of various tradeoffs
- Improve documentation of decisions
- Improve information on return on investment and value of investments
- Reduce short-and long-term costs

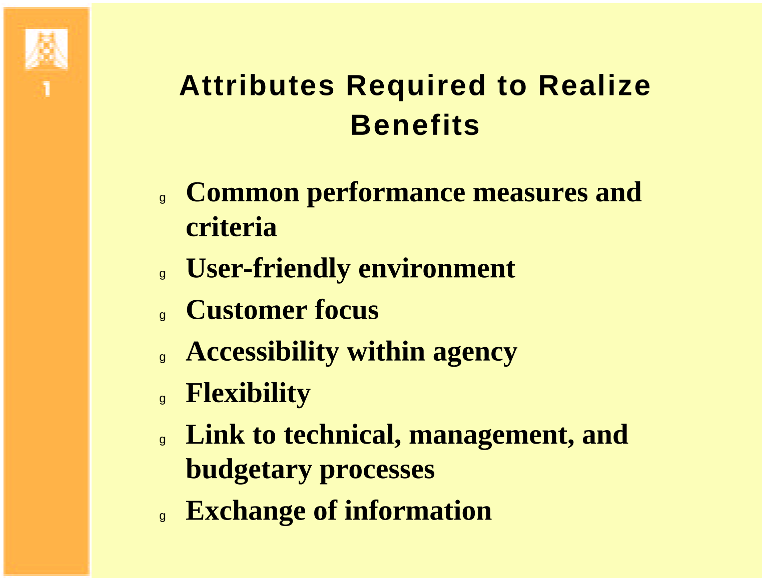
Slide 1-8

Notes:

These are some of the benefits realized by corporations through the use of AMS.

Note that many corporations no longer view these systems as optional, but rather as a necessary part of staying competitive in today’s environment (part of the cost of doing business).

Slide 1-9



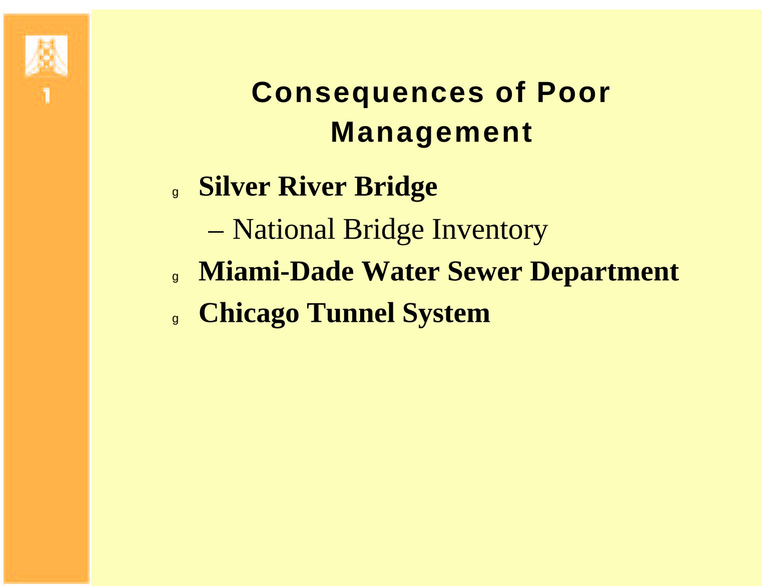
Slide 1-9

Notes:

These attributes are common to successful systems.

It is generally more common to recognize the benefits by identifying projects failures that could have been better managed with an AMS. The following slide presents three such failures.

Slide 1-10



Slide 1-10

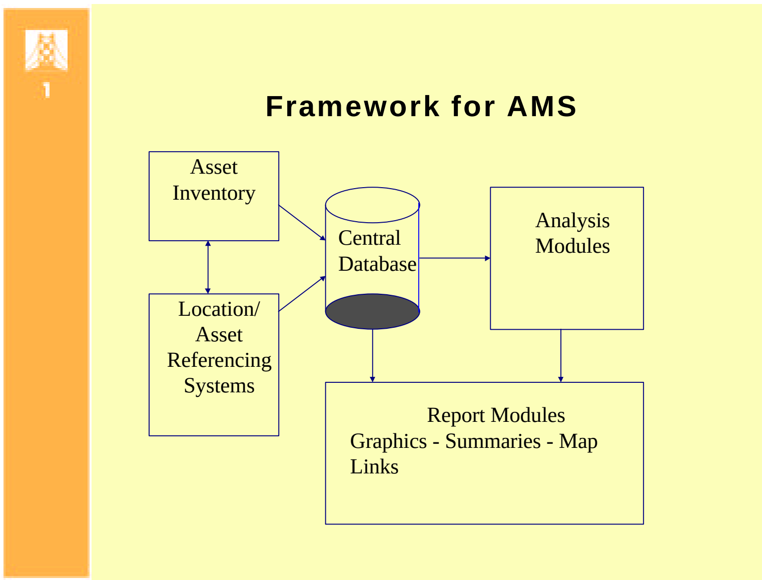
Notes:

The Silver River Bridge collapsed in 1967 killing 46 people and injuring 9 others. This, along with other similar bridge collapses in that time period, prompted Congress to mandate a National Bridge Inventory to identify the structural adequacy of all bridges.

Dade County received federal funds to bring all systems into compliance but used the money for capital expansion projects. The lack of maintenance to the sewer system led to infiltration and ultimately total collapse, causing raw sewage to spill into roads and the Miami River.

In 1992, a freight tunnel under the Chicago River ruptured, spilling 250 million gallons of water into the system. City information showed no record of the tunnels.

Slide 1-11



Slide 1-11

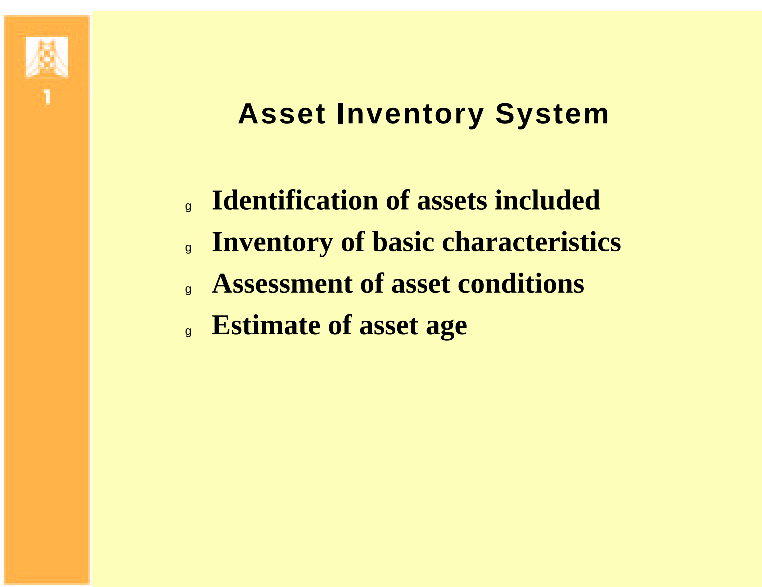
Notes:

This is Figure 1.1 in the Course Notebook. Highlight the flow of the components into and out of the central database. Each component will be discussed in more detail in subsequent slides.

The types of assets being managed, the organization using the system, and the available resources all influence the level of sophistication of the system.

Mention that agencies have had the most success with systems that are developed with modularity in mind so that the modules can be updated or replaced.

Slide 1-12



Slide 1-12

Notes:

<u>Asset Inventory System</u>

- Identification of assets included
- Inventory of basic characteristics
- Assessment of asset conditions
- Estimate of asset age

Slide 1-13

Location/Asset Referencing System

- Geographic location
- Reference system
- Identifiers for equipment

Slide 1-13

Notes:

It is imperative that the location of each asset be clearly identified, as can be seen through the example of the tunnel rupture under the Chicago River.

A referencing system is required to tie the segments of a facility to a geographical system.

Slide 1-14

Central Database

- Contains inventory information
- Facilitates exchange of information

Slide 1-14

Notes:

The centralized database is the key component of the system. All information is stored within this database and can be accessed throughout the organization.

A centralized database eliminates the need for developing and maintaining separate databases throughout the organization. Specific branches within the organization can extract only the information that they desire for analysis.

Slide 1-15

Analysis Modules

- **Forecast of Future Conditions**
- **Impact Analysis of Various Scenarios**

Slide 1-15

Notes:

The analysis modules represent the key component in the decision-making process.

Modules should be developed to forecast future asset conditions and conduct multi-year analyses to compare the impacts of various scenarios. The modules should also effectively allocate resources to different types of expenditures. Agencies with numerous assets also require modules that compare and contrast expenditures on one type of asset over another.

Slide 1-16

Reporting Modules

- **Presentation of Inventory Information**
- **Presentation of Analysis Results**
- **Formats:**
  – Graphics
  – Tables
  – Maps

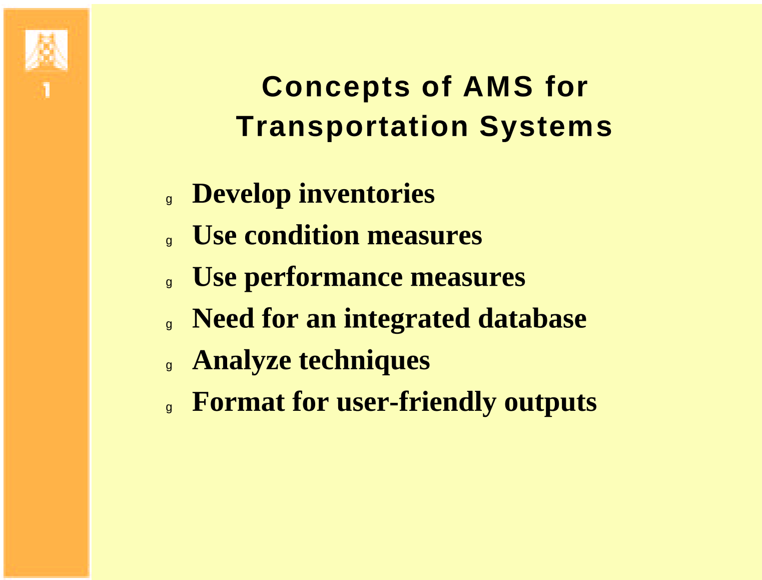
Slide 1-16

Notes:

Emphasize the need for the reporting mechanisms to present the information required to make decisions in a user-friendly format. Regardless of how well the other components perform, the money will be wasted if it is not presented clearly and cannot be utilized.

Some agencies have linked their management systems to geographical information systems (GIS) that visually display information on agency maps.

Slide 1-17



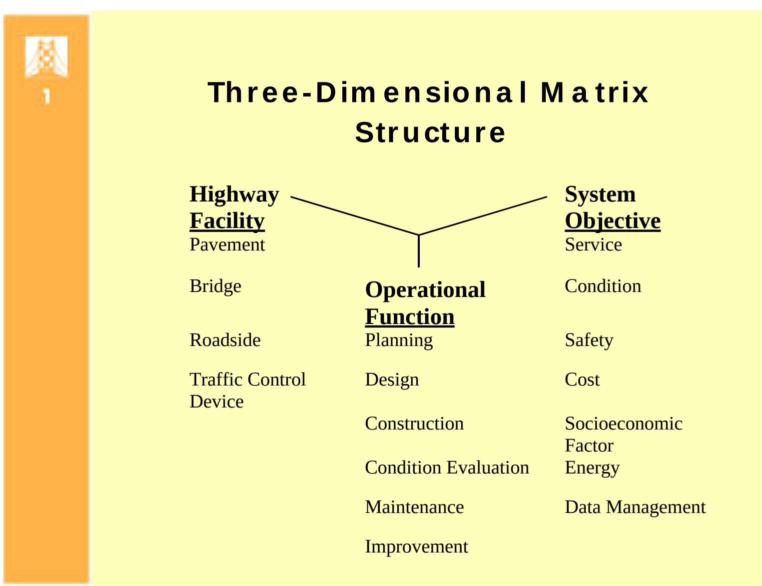
Slide 1-17

Notes:

<u>Concepts of AMS for Transportation Systems</u>

- § Develop inventories
- § Use condition measures
- § Use performance measures
- § Need for an integrated database
- § Analyze techniques
- § Format for user-friendly outputs

Slide 1-18



Slide 1-18

Notes:

This information is presented in Table 1.1 (on Page 1-5) of the Course Notebook.

This approach uses a multi-criteria decision process in which each facility is managed to achieve overall system objectives. Coordination and interaction are an essential element in the success of this approach.

Indicate that this approach also includes the application of risk management principles, which consider the probability of occurrence and evaluation of varying conditions.

Slide 1-19

Issues In Asset Management

- Adherence to worst-first policy
- Outside influences
- Large backlog of needs
- Lack of cooperation and coordination between users

Slide 1-19

Notes:

These issues represent some common reasons why a management system may not perform to its fullest capabilities.

Some agencies have multiple databases, which leads to a duplication of effort, the use of different data, and a differentiation in the referencing systems.

Emphasize the importance of periodically reviewing and updating the system.

Slide 1-20

Hurdles to Asset Management

- Technical
- Institutional
- Implementation

Slide 1-20

Notes:

The implementation of an AMS often endures many obstacles. These obstacles, or hurdles, can be classified into these three types. Each type will be discussed in subsequent slides.

Slide 1-21

Systems Approach to Pavements

- Identify key links between one or more strategies, where investment in one affects another
- Define various strategies for improving the effectiveness of these interactions
- Evaluate and implement the strategies to enhance the overall performance of the transportation system

Slide 1-21

Notes:

Indicate that the remainder of the course will focus on the application of the principles to pavement management.

These tasks must be performed in a systematic process.

Slide 1-22

Systems Approach (cont'd)

- Define system elements and boundaries
- Define agency goals and objectives
- Develop system models
- Outline analysis procedures
- Develop output formats

Slide 1-22

Notes:

A systematic process involves the steps outlined here.

The systems approach has been successfully used by numerous organizations.

The approach must account for the availability of useful information, the ability to forecast future conditions, and the results of an economic analysis. This often requires a change in the agency's traditional way of thinking.

Slide 1-23

Benefits

- Improve decision-making process
- Improve productivity
- Improve client responsiveness

Slide 1-23

Notes:

Indicate that agencies using structured management systems claim the use of structured processes to be beneficial.

State highway agency personnel identified the benefits listed on this slide.

The benefits are typically the results of improved access to information about the facility.

Private industry has reported improvements to the delivery of client services, which is critical to building good long-term working relationships.

Slide 1- 24

Agency Factors Contributing to Realization of Benefits

- Understand philosophy
- System recommendations must reflect benefits to agency
- Strategy to match agency goal
- Systems as a tool to complement agency experience and expertise

Slide 1-24

Notes:

Consideration of these factors will help derive the greatest benefit from a management system.

Emphasize the importance of integrating the system within the agency. The agency's culture must be conducive to and accepting of the information available.

Slide 1- 25

Future Issues

- Strategic investment analysis tools
- Training
- Shift in management approaches
- Knowledge in multiple disciplines (engineering, business, economics)
- Changes in technology

Slide 1-25

Notes:

Future Issues

§ Strategic investment analysis tools

§ Training

§ Shift in management approaches

§ Knowledge in multiple disciplines (engineering, business, economics)

§ Changes in technology

Slide 1-26

What is PMS?

- A decision support tool
- Identifies sections needing treatment
- Finds cost-effective treatments to apply at any given time to meet desired level of service
- Within imposed constraints

Slide 1-26

Notes:

What is PMS?

§ A decision support tool

§ Identifies sections needing treatment

§ Finds cost-effective treatments to apply at any given time to meet desired level of service

§ Within imposed constraints

Slide 1-27

What is PMS?

- Planning and programming
- Analysis
- Design
- Construction
- Maintenance
- Research

Slide 1-27

Notes:

<u>What is PMS?</u>

§ Planning and programming

§ Analysis

§ Design

§ Construction

§ Maintenance

§ Research

Slide 1-28

Need for PMS

- Agencies traditionally focused on new construction
- Maintenance & rehabilitation managed with less formal methods
- Crisis management
- Plan maintenance & rehabilitation
- Structured and documented procedures for spending money

Slide 1-28

Notes:

<u>Need for PMS</u>

§ Agencies traditionally focused on new construction

§ Maintenance & rehabilitation managed with less formal methods

§ Crisis management

§ Plan maintenance & rehabilitation

§ Structured and documented procedures for spending money

Slide 1-29

Need for PMS

- Transportation and world changes
- Need to continually update information
- Necessary to make informed decisions

Slide 1-29

Notes:

Need for PMS

§ Transportation and world changes

§ Need to continually update information

§ Necessary to make informed decisions

Slide 1-30

Instructional Objectives

- Identify fundamental principles in asset management
- Understand philosophy of asset management
- Describe issues affecting success for today and the future
- Understand applicability of concepts to other highway issues

Slide 1-30

Notes:

Review the objectives for this module.

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MODULE 2

PAVEMENT MANAGEMENT SYSTEMS OVERVIEW

Purpose:

The purpose of this module is to describe the basic components of a Pavement Management System, as well as provide a historical perspective on the evolution of PMS over the last 20 years. In addition, it will discuss how the products of that system can be used as a tool to aid in the development and decision making process for the pavement maintenance and construction program.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Describe the basic components of a PMS
- Understand the evolution of PMS since the 1970's
- List and describe some of the more prevalent products of a basic PMS
- Be able to describe in some detail the current state of practice in PMS

Reference:

Module 2 of the Participant's Workbook

Duration:

45 minutes

Equipment:

Laptop computer, multi-media projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

38 Microsoft PowerPoint® Slides

Approach:

This module is taught through Slide presentations and discussion with the partipants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

Encourage questions from and promote discussion with the participants.

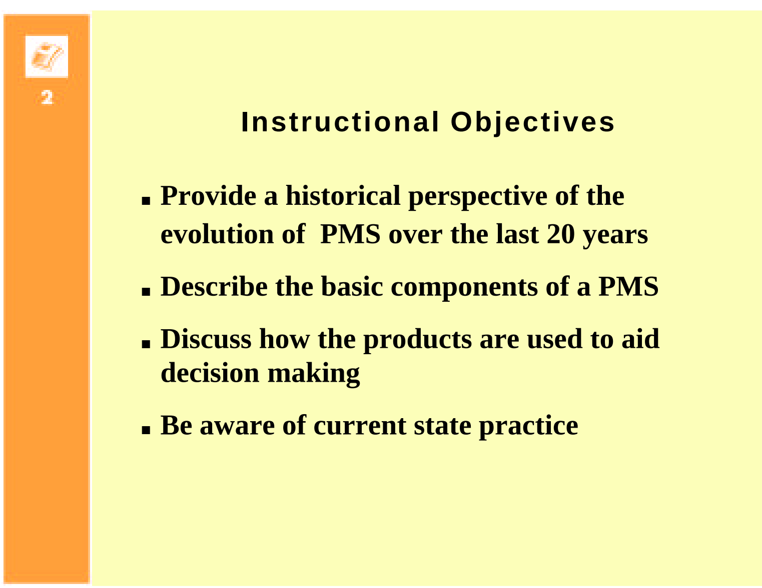
Slide 2-1

Slide 2-1

Notes:

Module 2 introduction slide.

Slide 2-2



Slide 2-2

Notes:

This module describes the basic components of a Pavement Management System, as well as providing some historical perspective on the evolution of PMS over the last 20 years. In addition, it will discuss how the products of that system can be used as tools to aid in the development and decision making process for the pavement maintenance and construction program.

Slide 2-3

Importance of Transportation System

- Transportation Statistics
- Economic Importance
- Movement of Freight

Slide 2-3

Notes:

Importance of Transportation System

§ Transportation Statistics
- Largest in the world
- Serves 260 million people
- 6 million businesses
- Over 6 million km of roads

§ Economic Importance
- Transportation is 11% of GDP
- International trade is 25% of GDP
- Employs 9.9 million people
- 7% of labor force

§ Movement of Freight
- Trucks dominate freight transportation
  - Under 800 km
- Number of trucks increased 24%
- Moved 5.5 billion tons in 1992
- Approx. 50% of all freight
- Moved 75% of value of goods
  - $4.5 billion in 1993

Slide 2-4

Importance of Pavements

- Pavements deteriorate with time
- Utah study
- Good roads cost less
  - If maintained at a reasonable level of service
  - If responsive to preventive maintenance

Slide 2-4

Notes:

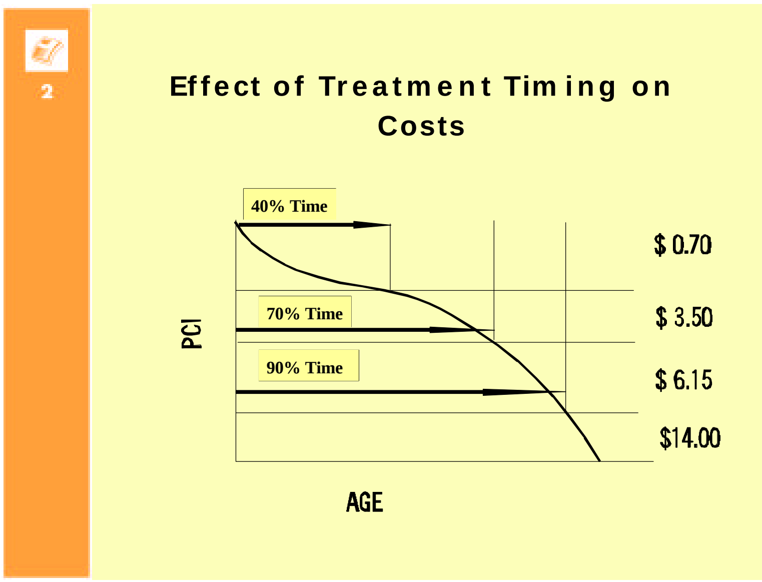
Importance of Pavements

§ Pavements deteriorate with time

§ Utah study

§ Good roads cost less
- If maintained at a reasonable level of service
- If responsive to preventive maintenance

Slide 2-5



Slide 2-6

Support for PMS

- FHWA
  - Training courses
  - Seminar and workshops
  - Technical assistance
- AASHTO
  - Guidelines in 1985, 1990
  - New guidelines 1999?

Slide 2-5

Notes:

Effect of Treatment Timing on Costs

Figure 2.1 is a curve that has often been used in presentations on pavement management systems (PMS). It shows the average rate of deterioration for an agency and the change in repair costs as the pavement deteriorates. It is evident from Figure 2.1 that if the earlier treatments were to be applied more often, the overall costs will be smaller if the pavement is repaired earlier rather than later.

Slide 2-6

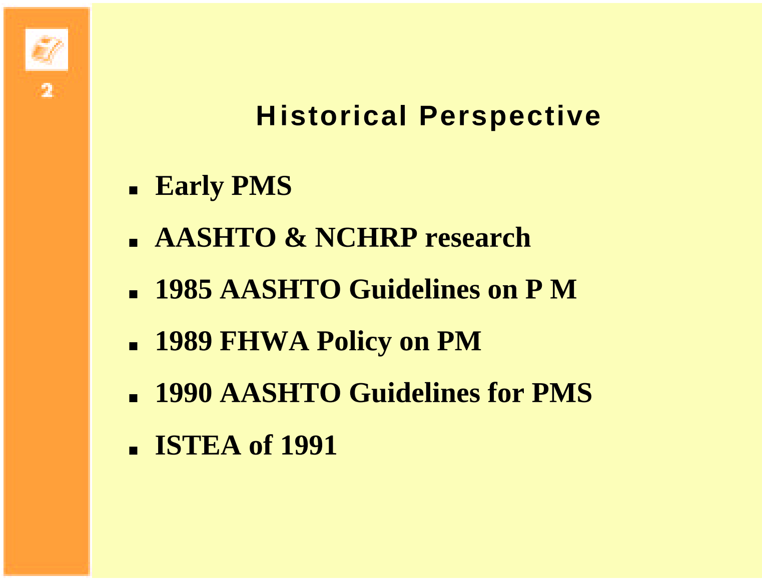
Notes:

Support for PMS

§ FHWA
- Training courses
- Seminar and workshops
- Technical assistance

§ AASHTO
- Guidelines in 1985, 1990
- New guidelines in 1999?

Slide 2-7



Slide 2-7

Notes:

Historical Perspective

§ Early PMS
§ AASHTO & NCHRP research
§ 1985 AASHTO Guidelines on PM
§ 1989 FHWA Policy on PM
§ 1990 AASHTO Guidelines for PMS
§ ISTEA of 1991

Slide 2-8

Slide 2-8

Notes:

In the mid 1960s, a few agencies began to develop pavement condition surveys, and used the information from the surveys to help develop the project lists. The pavement condition data was stored and manipulated as part of the agencies management information system. By the mid 1970s a "systems" approach to managing pavements began to be envisioned and actively developed. Within a couple of years several states and the US Army Corps of Engineers had developed and implemented full PMS.

Slide 2-9

1986 AASHTO Guidelines

- **Introduced and defined PMS**
- **Supported development and implementation of PMS**

Slide 2-9

Notes:

In 1985 the American Association of State Highway and Transportation Officials published their first "Guidelines on Pavement Management". These Guidelines were prepared between 1982 and 1983 by a few specific members of the AASHTO Joint Task Force on Pavements who were involved in the development and implementation of a PMS in their respective state. The 1985 AASHTO "Guidelines" provided only minimal guidance as the body of the text consisted of only seven pages that essentially introduced, defined, and supported the development and implementation of PMS.

Slide 2-10

1989 FHWA PMS Policy

- **Required all states to have PMS to manage their Federal Aid Highways (Interstate, Principal)**
- **Condition of funding**

Slide 2-10

Notes:

In March of 1989 the FHWA established a policy that all states must have a PMS to manage their Federal Aid Primary Highway System (Interstate and Principal Highways). As a result of this policy, all states were required to have, and to use, a PMS as a one of the many conditions for federal funding.

Slide 2-11

1990 AASHTO Guidelines for PMS

- Developed under guidance of AASHTO Task Force on Pavement Management
- Specific project with limited scope
- Prepared by F. Finn and D. Peterson
- Limited to 35 pages

Slide 2-11

Notes:

In 1989 AASHTO formed a small Task Force on Pavement Management. Their task was to guide the development of a new and more complete set of guidelines on PMS. The new guidelines were prepared through a special NCHRP project.

The new "1990 AASHTO Guidelines for PMS" provided a more detailed set of descriptions and recommendations than the 1985 guide but the new guidelines were still limited in size as the authors were, from the beginning, limited to only 35 pages by the Task Force.

Compare with this workbook 500+ pages!

Slide 2-12

Scope of 1990 AASHTO Guidelines

- Described the basic characteristics
- Identified the components of a PMS and role
- Described development, implementation and operation steps
- Described the products
- Defined the role of communications

Slide 2-12

Notes:

The final guidelines totaled 48 pages with the body of the text consisting of a concise but complete 34 pages. The primary scope of the 1990 Guidelines for PMS was to:

Slide 2-13

2

Intermodal Surface Transportation Efficiency Act of 1991

- **Required all States to have a PMS that covered all Federal - Aid Highways**
- **Tripled network covered**
  - **- 916,200 centerline miles**
- **Rescinded in 1995**
- **Regulations**
- **Components**

Slide 2-13

Notes:

<u>Intermodal Surface Transportation Efficiency Act of 1991</u>

§ Required all States to have a PMS that covered all Federal – Aid Highways

§ Tripled network covered
- 916,200 centerline miles

§ Rescinded in 1995

§ Regulations
- Non-prescriptive
- Federal-aid funds eligible for development, implementation, and annual operations of PMS
- States to develop work plan by Oct. 1994
- Standards for the NHS

§ Components

Slide 2-14

2

Data Collection

- **Inventory**
- **History**
- **Condition Survey**
- **Traffic**
- **Data Base**

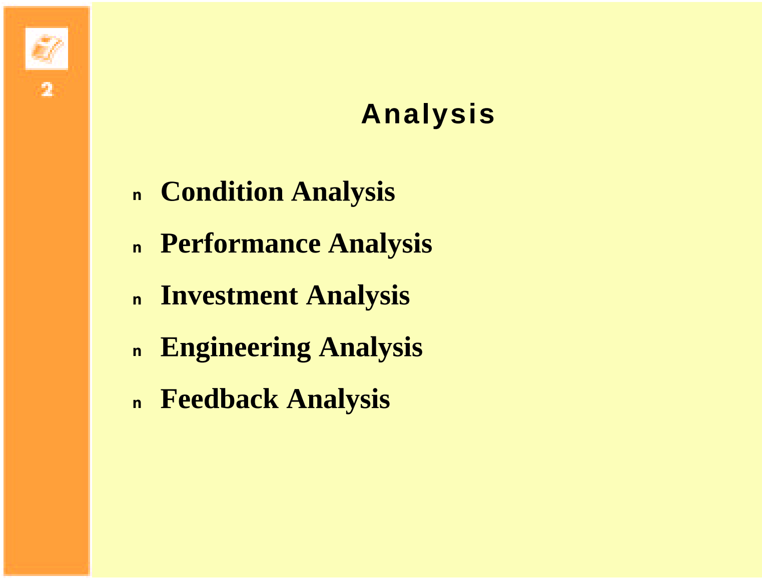
Slide 2-14

Notes:

Section 500.207, PMS Components, contains the components of a PMS for highways on NHS. There are three primary components: data collection, analyses, and update. The components under data collection include the following:

1. *Inventory*: physical pavement features including the number of lanes, length, width, surface type, functional classification, and shoulder information;
2. *History*: project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance;
3. *Condition survey:* roughness or ride, pavement distress, rutting, and surface friction;
4. *Traffic*: volume, vehicle type, and load data; and
5. *Data base*: compilation of all data files used in the PMS.

Slide 2-15



Slide 2-15

Notes:

The components under analyses include the following:
1. *Condition analysis:* ride, distress, rutting, and surface friction;

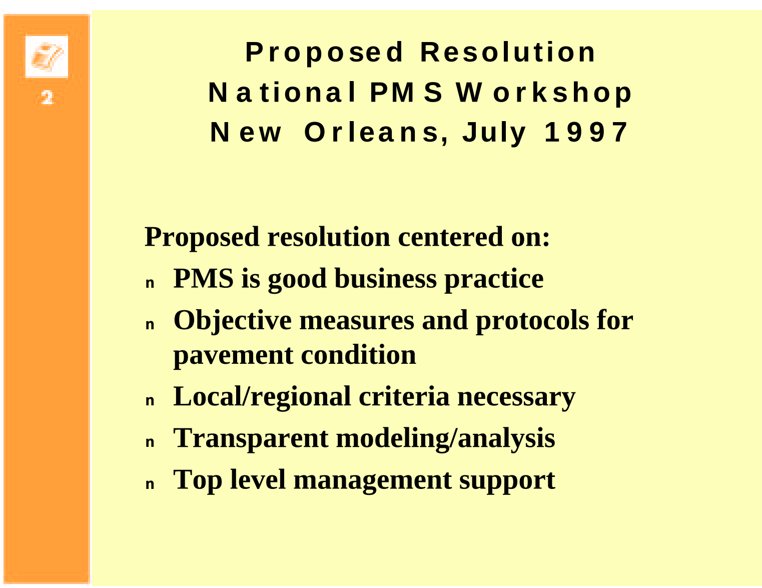
2. *Performance analysis:* pavement performance analysis and an estimate of remaining service life;

3. *Investment analysis:* an estimate of network and project level investment strategies. These include single- and multi-year period analyses and should consider life-cycle cost evaluation;

4.*Engineering analysis:* evaluation of design, construction, rehabilitation, materials, mix designs, and maintenance; and

5.*Feedback analysis:* evaluation and updating of procedures and calibration of relationships using PMS performance data and current engineering criteria.

Slide 2-16



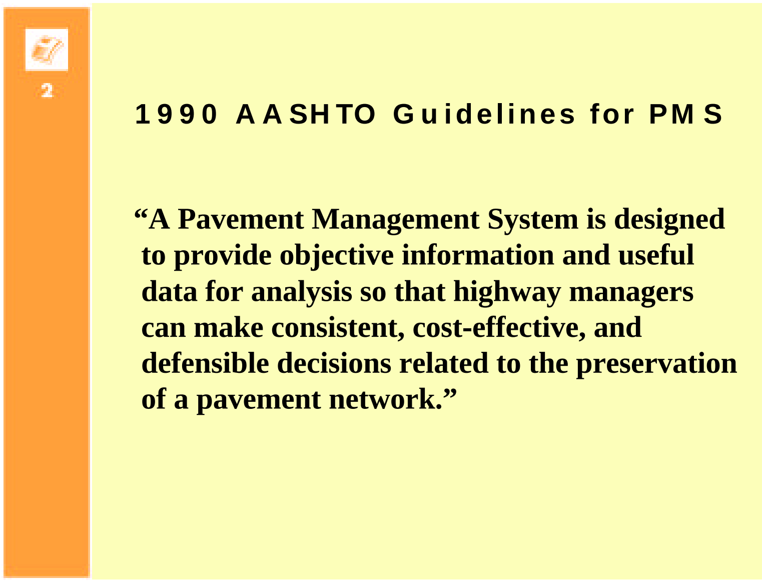
Slide 2-16

Notes:

Proposed Resolution National PMS Workshop New Orleans, July 1997

- § Proposed resolution centered on:
- § PMS is good business practice
- § Objective measures and protocols for pavement condition
- § Local/regional criteria necessary
- § Transparent modeling/analysis
- § Top level management support

Slide 2-17

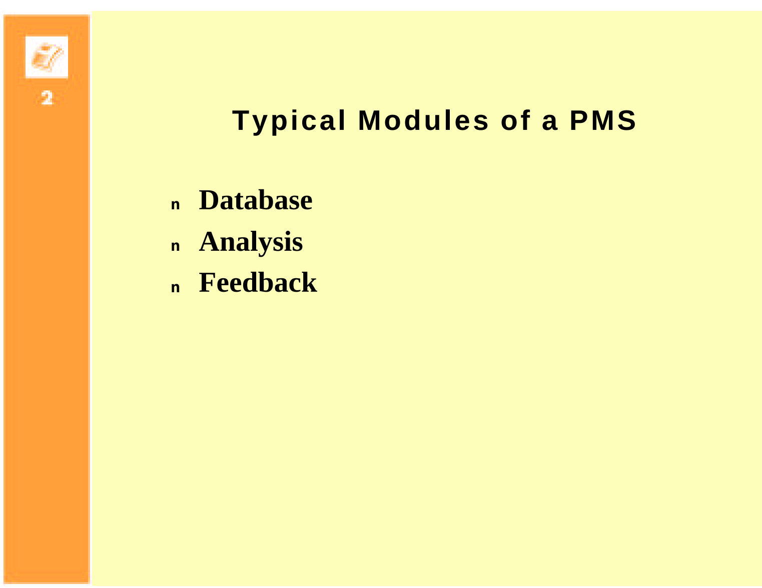


Slide 2-17

Notes:

Read Statement.

Slide 2-18



Slide 2-18

Notes:

The AASHTO Guidelines discussed three basic modules of a PMS. These modules are:

1. database which contains, as a minimum, the data required for PMS analysis;
2. analysis methods to generate products useful for decision-making; and,
3. feedback process which uses on-going field observations to improve the reliability of PMS analysis.

Slide 2-19

2

Types of Data

- Inventory
- Information relative to pavement condition
- Construction, maintenance, and rehabilitation history
- Traffic
- Cost data

Slide 2-19

Notes:

The database is the first building block of any management system, since the analysis used and recommendations made by a management system should be based on reliable, objective, and timely (current) information. The major categories of input data essential for a PMS are shown on this slide:

Slide 2-20

2

Database Reports

- Pavement Condition Deficiency Reports
- Pavement Condition Performance Histories
- MR&R Actions
- Pavement Inventory and Ranking

Slide 2-20

Notes:

The database module supports the information needs of the other two PMS modules; i.e., analysis method and feedback process. It may also be useful to other information systems, which may be or have been developed by a SHA. (1) *deficiency reports*, which identify pavement segments with a given type of distress exceeding a specified threshold level, (2) *performance histories*, which display the variation of a given type of distress as a function of age and traffic for specific pavement segments, (3) *MR&R actions*, and (4) *pavement inventory* by type and area as examples.

Slide 2-21

Analysis Methods

- **Pavement Condition Analysis**
- **Priority Assessment Models**
- **Network Optimization Models**

Slide 2-21

Notes:

The three categories, with an increasing degree of formal analysis, are: (1) pavement condition analyses, (2) priority assessment models, and (3) network optimization models. Modules 6, 10, and 11 cover this in more detail.

Slide 2-22

Condition Analysis

- **Combines the pavement distress data into a score or index**
- **Represents overall pavement condition**
  - **Describes system condition**
  - **Uses priority ranking scheme**
  - **Uses decision tree approach as primary criteria to select project, timing, and treatments**

Slide 2-22

Notes:

This method of analysis combines the pavement condition data for individual distress types, with or without roughness, into a score or index representing the overall pavement condition.
A combined index has several useful applications: (1) as a relatively simple way to communicate the health of the system to upper management, planners, and legislators, (2) as one factor, or the only factor, in a priority rating scheme, and (3) as a technique for estimating average costs to maintain, rehabilitate, or reconstruct a candidate project; e.g., pavements with condition score of 50 will, on average, require x dollars to repair. Modules 6 and 10 cover this in more detail.

Slide 2-23

Condition Analysis Outputs

- **Ranking of pavement segments by condition index**
- **Identification of MR&R strategies and timing for individual pavement segments**
- **Estimate of funding needs for selected treatments**

Slide 2-23

Notes:

The outputs from this module can include:

(1) ranking of all pavement segments according to types of distress and condition scores as a function of traffic or road classification;
(2) identification of MR&R strategies, which define a set of criteria (e.g., combinations of different distress levels and traffic) for assigning a particular action to each pavement segment; and
(3) estimates of funding needs for the selected treatments.

The outputs are indicative of current needs based on current conditions.

Slide 2-24

Prioritization Models

- **Optimal MR&R strategies based on life cycle costs**
- **Projects are prioritized at the network level**
- **Benefit/cost ratio and cost effectiveness are more prevalent methods**

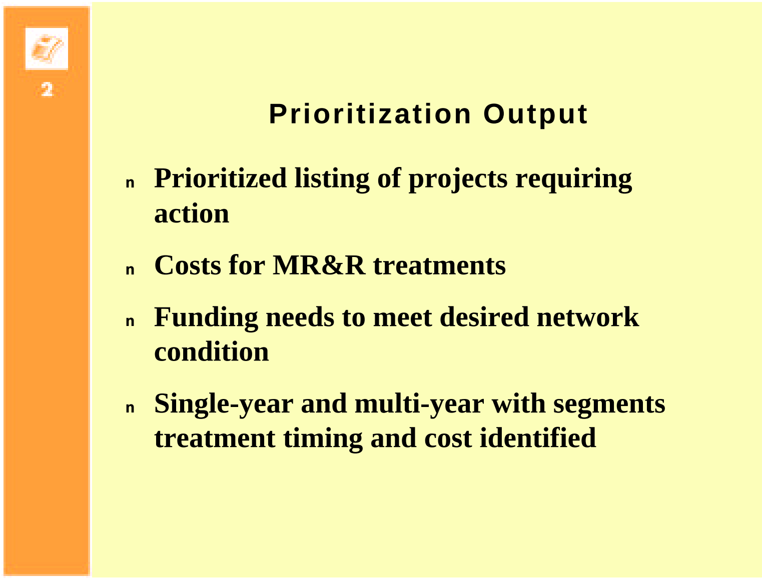
Slide 2-24

Notes:

<u>Prioritization Models</u>

§ Optimal MR&R strategies based on life cycle costs
§ Projects are prioritized at the network level
§ Benefit/cost ratio and cost effectiveness are more prevalent methods

Slide 2-25



Slide 2-25

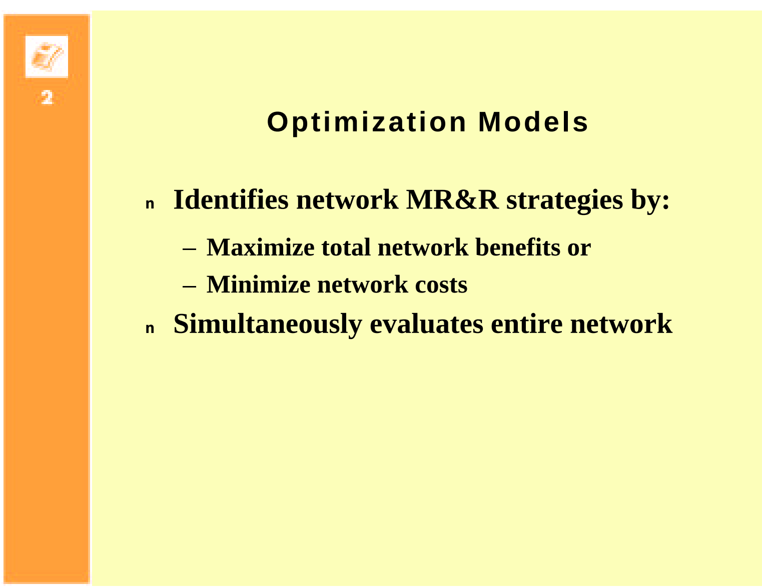
Notes:

The outputs from optimization models are essentially the same as those obtained from the prioritizing model, with only slight variations. For example, the optimization model does not identify segment priorities; instead, it identifies an optimally balanced MR&R program for an entire network to meet specified budget and policy constraints.

<u>Prioritization Output</u>

- Prioritized listing of projects requiring action
- Costs for MR&R treatments
- Funding needs to meet desired network condition
- Single-year and multi-year with segments treatment timing and cost identified

Slide 2-26



Slide 2-26

Notes:

Optimization models provide the capability for a simultaneous evaluation of an entire pavement network. The objective is to identify the network MR&R strategies which maximize the total network benefits (or performance), or minimize total network costs subject to such network-level constraints, such as available budget and desired performance standards. A network MR&R strategy defines the optimal treatment for each possible combination of performance variables such as: roughness, physical distress, traffic, environment, and functional class. This is a “top down” approach in which optimal network strategies are first determined and specific treatments for individual projects are then identified considering site-specific conditions and administrative policies. Module 11 covers this in more detail.

Slide 2-27

Optimization Output

- **Similar to prioritizing model**
- **Identifies an optimally balanced MR&R program**
- **Optimization models do not normally identify segment priorities**

Slide 2-27

Notes:

Use example of airline companies and their optimization techniques regarding ticket pricing.

Slide 2-28

Feedback Process

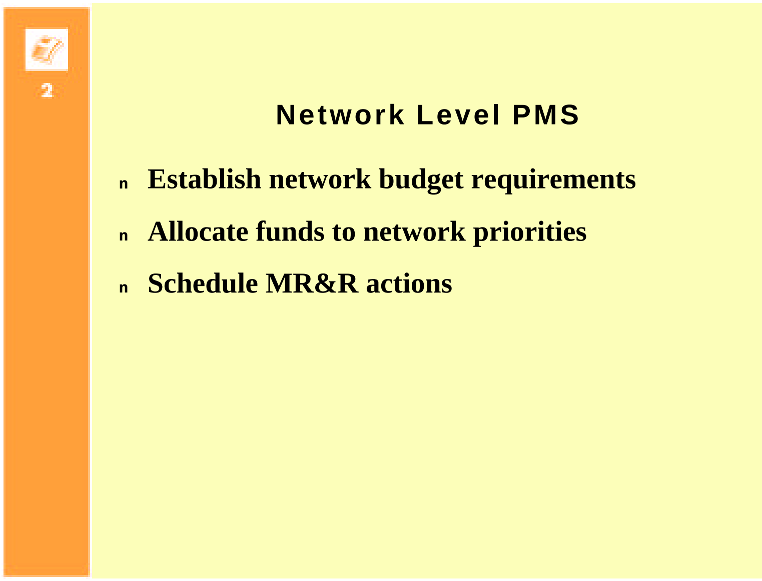
- **A variety of processes are used to confirm reliability of PMS**

Slide 2-28

Notes:

Pavement management systems, similar to any other engineering tool, must be reliable in order to be credible. The feedback process is crucial to verify and improve the reliability of a PMS. Module 11 covers this in more detail.

Slide 2-29



Slide 2-29

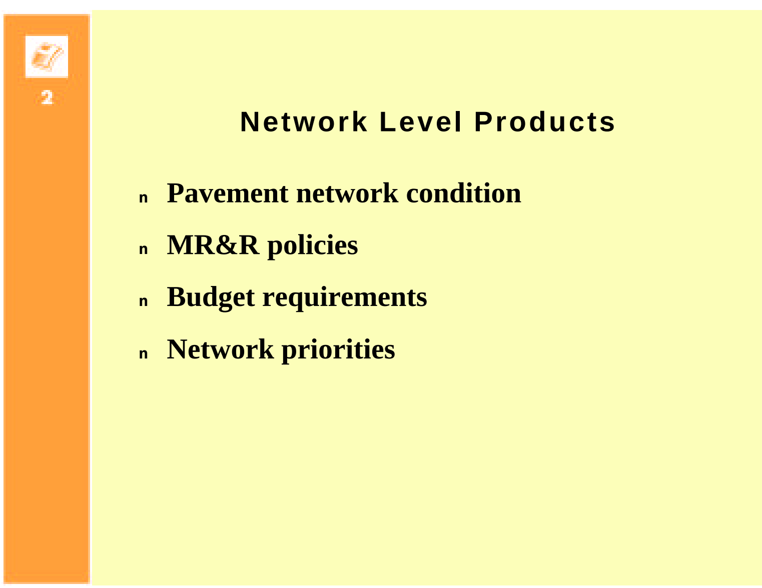
Notes:

At the network level, the primary objective is to provide information pertinent to establishing network budget requirements, allocating funds according to priorities, and scheduling MR&R actions.

Network Level PMS

- Establish network budget requirements
- Allocate funds to network priorities
- Schedule MR&R actions

Slide 2-30



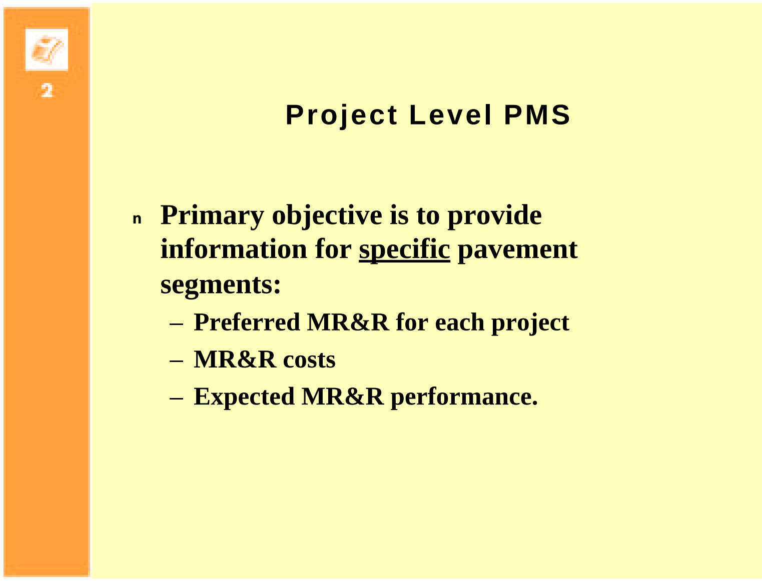
Slide 2-30

Notes:

Network Level Products

- Pavement network condition
- MR&R policies
- Budget requirements
- Network priorities

Slide 2-31



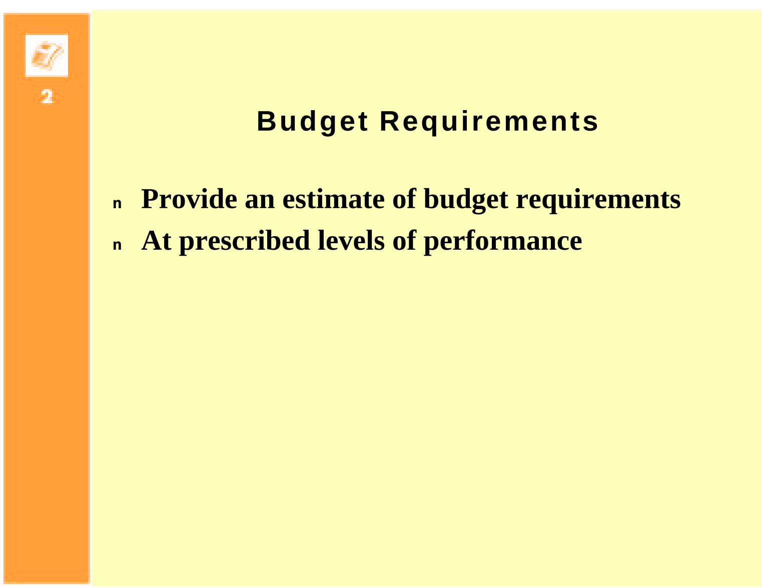
Slide 2-31

Notes:

Project Level PMS

- Primary objective is to provide information for specific pavement segments:
  - Preferred MR&R for each project
  - MR&R costs
  - Expected MR&R performance

Slide 2-32



Slide 2-32

Notes:

The PMS will provide an estimate of budget requirements to preserve the pavement network at prescribed levels of performance. In most cases, the PMS will provide a one-year and multi-year estimate of requirements. In many cases the budget requirements will exceed the funding available. In such cases, one of the methods of prioritizing or optimizing will be needed in order to prepare a candidate MR&R program.

Slide 2-33

Data Collection Needs

- Inventory
- Traffic/ Load
- Pavement Condition Survey

Slide 2-33

Notes:

Inventory and identification data are generally obtained only once. Updates are required only when pavements are reconstructed to new standards and dimensions. Roadway geometrics, pavement type, location, and design traffic loads are other examples of data that do not require a yearly update.

Information relative to pavement condition, actual traffic, surface friction, and others which may change with time, are collected on an established schedule or frequency.

Slide 2-34

Inventory Data

- Route Number
- Functional Class
- Length
- Pavement Type
- Pavement Width
- Lane number and width
- Shoulder Type and Width
- Layer Thickness
- MR&R History

Slide 2-34

Notes:

Specific types of information to be collected should be carefully considered during the planning phase. Information required for analysis, interpretation, and for preparation of reports, should be included in the inventory.

Information not considered necessary for the PMS should be avoided.

Some items to be considered for inclusion as part of the inventory are shown on this slide.

Module 4 covers this in more detail.

Slide 2-35

2

Traffic/Load Data

- ADT (used to establish priorities)
- ESAL (for prediction and treatment selection)

Slide 2-35

Notes:

Traffic and load information is important for three reasons:

(1) to determine priorities
(2) to develop, calibrate, and use pavement performance models
(3) to select the maintenance, rehabilitation, or reconstruction treatment

Module 7 covers this in more detail.

Slide 2-36

2

Pavement Condition Survey

- Ride quality or roughness
- Physical distress
- Structural capacity
- Safety

Slide 2-36

Notes:

Monitoring pavement condition over time is essential for a PMS.

Condition surveys provide information needed to evaluate the health of the network and the condition of any specific segment.

Module 5 covers this in more detail.

<u>Pavement Condition Survey</u>

§ Ride quality or roughness

§ Physical distress

§ Structural capacity

§ Safety

Slide 2-37

Pavement Condition Survey (other issues)

- **Historical**
  - Rate of deterioration over time under accumulated traffic loads
- **Frequency**
  - Depends on the type and age of pavement measured as well as the cost of the survey and the need for timely data
- **Quality Control**
  - Inventory and condition data is essential to the success of a PMS

Slide 2-37

Notes:

Pavement Condition Survey (other issues)

§ Historical
- rate of deterioration over time under accumulated traffic loads

§ Frequency
- depends on the type and age of pavement measured as well as the cost of the survey and the need for timely data

§ Quality Control
- Inventory and condition data is essential to the success of a PMS

Slide 2-38

Current State of Practice in PMS

- **Different PM methodologies Used**
- **50% use**
  - pavement condition analysis
- **50% use**
  - network optimization
  - priority assessment
  - other approach
- **FHWA 1996 Survey**
  - Detailed survey of state in workbook

Slide 2-38

Notes:

NCHRP Synthesis of Highway Practice 222 "Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments", authored by Kathryn A. Zimmerman provides a very good review of the more current state practice. In her summary, Mrs. Zimmerman made the following observation on presently used PMS methodologies.

In addition to the NCHRP Synthesis 222, the FHWA conducted a survey of all the states in 1996 to document in some detail the status of their existing pavement management systems.

A summary of the responses to the 1996 survey are included in the Students Manual.

Tables 2.1 to 2.9

Slide 2-39

2

Instructional Objectives

- Provide a historical perspective of the evolution of PMS over the last 20 years
- Describe the basic components of a PMS
- Discuss how the products are used to aid decision making
- Be aware of current state practice

Slide 2-39

Notes:

Review the objectives for this module.

MODULE 3

RELATIONAL DATABASES AND LOCATION REFERENCING SYSTEMS

Purpose:

This module covers many diverse topics all in some way or another related to a PMS database. The module begins by introducing relational databases. This discussion starts with some of the basic concepts generally involved in a relational database then moves toward explaining some of the issues regarding roadway data in a database. Following this, the discussion addresses location referencing and presents the important issues involved in it. After this, the discussion introduces Geographic Information Systems (GIS) and how they relate to pavement management. Finally, the discussion gives a general description of Global Positioning System (GPS).

Objectives:

To expose participants to:

- The principles and concepts behind relational databases through example and theory
- The basic concepts behind the need for an effective location referencing system
- The basics behind the theory of GIS and GPS and their relationship to a PMS

Reference:

Module 3 of the Course Notebook

Duration:

75 minutes

Equipment:

Laptop computer, multi-media projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

36 Microsoft PowerPoint® Slides

Approach:

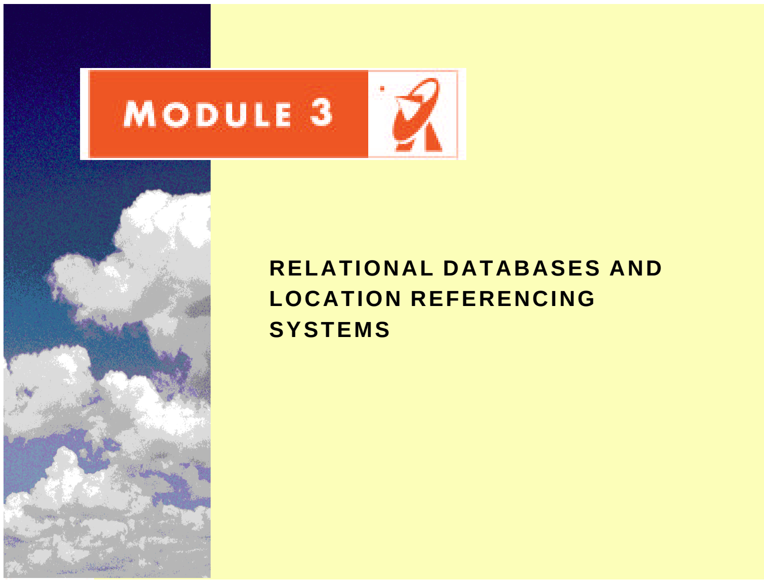
This module is taught through slide presentation and discussion with the participants. As an overall introduction to the principles of relational database and location referencing systems, it is important that the participants develop an understanding of these principles.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on distance learning for this module. All slides prepared will also be applicable in a distance learning course.

Slide 3-1

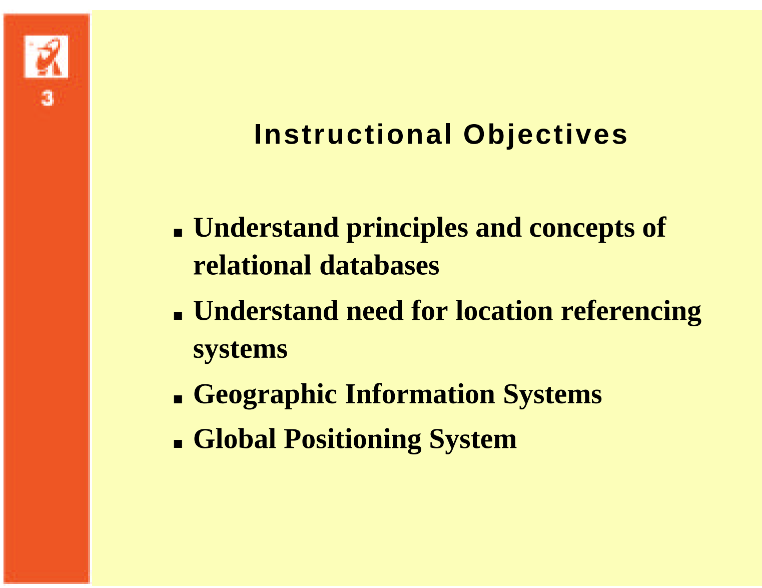


Slide 3-1

Notes:

Module 3 introduction slide.

Slide 3-2

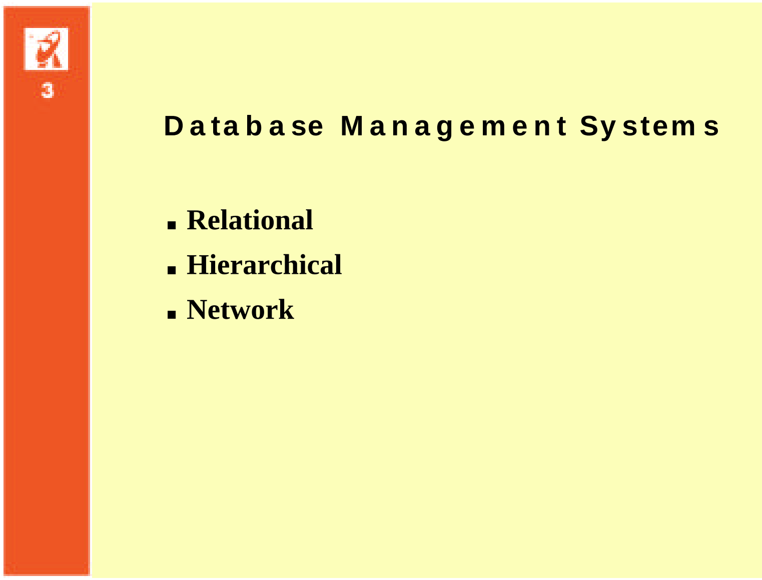


Slide 3-2

Notes:

This module covers four parts, all in some way or another related to a PMS database. The presentation begins by introducing relational databases. This discussion starts with some of the basic concepts generally involved in a relational database then moves toward explaining some of the issues regarding roadway data in a database. Following this, the presentation addresses location referencing and presents the important issues regarding it. After this the presentation introduces Geographic Information Systems (GIS) and how they relate to pavement management. Finally, the presentation gives a general description of Global Positioning System (GPS).

Slide 3-3



Slide 3-3

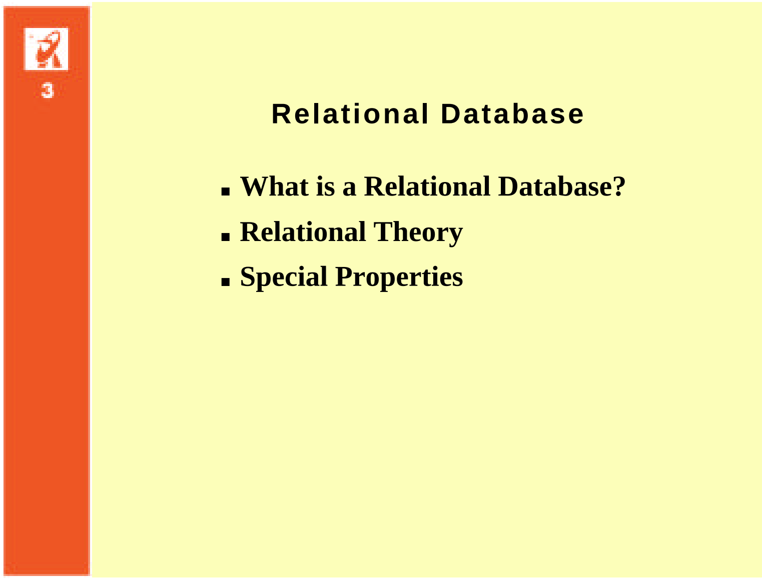
Notes:

<u>Database Management Systems</u>

- § Relational
- § Hierarchical
- § Network

There are many ways of organizing databases on a computer. Network databases, hierarchical databases, and relational databases are among the most popular. These types of databases differ in the way they physically manage the storage and retrieval of data. Of the three, the relational database is the only one that is based on mathematical theory.

Slide 3-4



Notes:

Instructor may wish to use transparency or flipchart to describe elements of relational database.

Slide 3-4

Notes:

What is a Relational Database?

1. In 1969 Dr. E.F. Codd published the first paper describing the application of relations (in a mathematical sense) to database management. Codd's most recent book, The Relational Model for Database Management, Version 2, (Codd, 1990) presents the relational model from a mathematical point of view.

2. In recent years, the relational model has generally become the de facto standard for database design. This is due both to the power of the relational model itself, and because it provides a standard interface called Structured Query Language (SQL) that allows many different database tools and products to work together in a consistent and understandable way.

Relational Theory

3. Relational database present the relational model to its users so they perceive the relation as a table, the tuple as a row and the attributes as columns.

Special Properties of a Relation

A relation has special properties in mathematics of which three are notable: First, all of its elements are tuples which consist of attributes. Second, all tuples must be distinct from one another in content. And, third, the order of tuples is immaterial.

Slide 3-5

3

Tables, Fields and Records

- **Example Road Section Table**

Road Section Table

Section ID	From	To	AADT	Func_Class	Min_Width
d	**0.0**	**1.0**	**1000**	**ART**	**1500**
e	**1.0**	**3.0**	**500**	**COLL**	**1000**
f	**3.0**	**5.0**	**100**	**ART**	**1500**

Slide 3-5

Notes:

Tables, Fields and Records

The database table can be viewed as a set of rows and columns. In a relational database, the rows are called records and the columns are called fields. For example, a table of road sections in a PMS database might look like this.

Each row in the table is a record that contains all of the information about a particular road section, and each record contains the same types and number of fields: Section ID, From, To, and so on.

Slide 3-6

3

Keys

- **A field or fields in table used to access data in table**
- **Can be unique or non-unique**
- **Only a unique key can be used as 'Primary Key'**
- **Section ID was Primary Key in Road Section Table**

Slide 3-6

Notes:

Keys

§ A field or fields in table used to access data in table

§ Can be unique or non-unique

§ Only a unique key can be used as 'Primary Key'

§ Section ID was Primary Key in Road Section Table

Slide 3-7

One-to-Many Relationships

Consider relating Condition Table to Road Section Table

Foreign Key

Condition Table

Survey Sheet No.	Section ID	Year	%_Cracking	Rut_Depth
1028347	d	1985	10	0.2
8472039	e	1985	20	0.2
8437620	f	1985	15	0.2
6778902	d	1986	15	0.3

One-to-Many Relationship

Road Section Table

Section ID	From	To	AADT	Func_Class	Min_Width
d	0.0	1.0	1000	ART	1500
e	1.0	3.0	500	COLL	1000
f	3.0	5.0	100	ART	1500

Primary Key

Instructor may wish to ask the participants to describe and therefore understand the table.

Slide 3-7

Notes:

<u>One-to-Many Relationships</u>

In this table, the Section ID field refers to the Section ID field in the Road Section Table, relating the condition to the road section on which it was measured. Notice that road section **d** (From 0.0 To 1.0) was surveyed in 1985 with a percent cracking of 10% and was surveyed again in 1986 with a percent cracking of 15%.

The type of relation shown here is called a 'one-to-many relation', because one road section can have many condition surveys performed on it, but a particular condition survey is performed on one and only one road section.

The key that establishes the relation from the Condition Table is called a *foreign key*, because it relates to the primary key of a "foreign" table (the Road Section Table).

Slide 3-8

Many-to-Many Relationships

Consider relating Construction History Table below to Road Section Table

Construction History Table

Contract Number	From	To	Year	Work_Type	Unit_Cost
100	**0.0**	**5.0**	**1955**	**Construct**	**100000**
200	**0.0**	**1.0**	**1986**	**Overlay**	**50000**
300	**1.0**	**3.0**	**1987**	**Overlay**	**50000**
400	**3.0**	**5.0**	**1988**	**Overlay**	**50000**

? ↕

Road Section Table

Section ID	From	To	AADT	Func_Class	Min_Width
d	**0.0**	**1.0**	**1000**	**ART**	**1500**
e	**1.0**	**3.0**	**500**	**COLL**	**1000**
f	**3.0**	**5.0**	**100**	**ART**	**1500**

Slide 3-8

Notes:

<u>Many-to-Many Relationships</u>

In a relational database it is also possible to facilitate relations that are *many-to-many*. For example, there may be an Construction History table that lists all of the contracts that are performed on the road network, as follows.

Here we can see that there is a many-to-many relationship between road sections and contracts. That is, one road section can have many contracts performed on it, and one contract can perform work on many road sections.

Slide 3-9

The Junction Table

Construction History Table

Contract Number	From	To	Year	Work_Type	Unit_Cost
100	**0.0**	**5.0**	**1955**	**Construct**	**100000**
200	**0.0**	**1.0**	**1986**	**Overlay**	**50000**
300	**1.0**	**3.0**	**1987**	**Overlay**	**50000**
400	**3.0**	**5.0**	**1988**	**Overlay**	**50000**

Junction Table

Contract Number	Section ID
100	**d**
100	**e**
100	**f**
200	**d**
300	**e**
400	**f**

Road Section Table

Section ID	From	To	AADT	Func_Class	Min_Width
d	**0.0**	**1.0**	**1000**	**ART**	**1500**
e	**1.0**	**3.0**	**500**	**COLL**	**1000**
f	**3.0**	**5.0**	**100**	**ART**	**1500**

Slide 3-9

Notes:

<u>The Junction Table</u>

A many-to-many relationship is facilitated by creating two separate one-to-many relationships, with the common "many" table containing foreign keys to both of the other tables. This relationship is clearer if we create a "junction" table by *joining* the Section ID field from the Road Section Table to the Contract Number field from the Construction History Table, as shown.

Notice that the location information **was not** used to form the relationship.

Slide 3-10

Normalization

- **Process of dividing database into separate tables which eliminates unnecessary duplication and facilitates all relationships as 'one-to-many'**
- **Rule of thumb: significantly reduce duplicate data**

Slide 3-10

Notes:

<u>Normalization</u>

The task of the database designer is to structure the tables and relationships between them in a way that eliminates unnecessary duplication and provides a rapid search path to all necessary information. The process of dividing the database into separate tables and relationships that meet these goals is called normalization.

However, normalizing most simple databases can be accomplished by following a simple rule of thumb: significantly reduce duplicate data. Notice the words "significantly reduce" are used rather than "eliminate." This is done because sometimes it may be more work than necessary to eliminate all occurrences of duplicate information, particularly in small databases.

Slide 3-11

Example of Normalization

Original Road Section Table

Section ID	From	To	AADT	Func_Class	Min_Width
d	0.0	1.0	1000	ART	1500
e	1.0	3.0	500	COLL	1000
f	3.0	5.0	100	ART	1500

Duplicate values

BECOMES:

Modified Road Section Table

Section ID	From	To	AADT	Func_Class
d	0.0	1.0	1000	ART
e	1.0	3.0	500	COLL
f	3.0	5.0	100	ART

Standards Table

Func_Class	Min_Width
ART	1500
COLL	1000

Slide 3-11

Notes:

<u>Example of Normalization</u>

To illustrate removing duplicate data we can remove the Minimum Width field from the Road Section Table because we know it is related to the functional class. For example, if there are 1000 arterial road sections in the network, each Arterial Minimum Width will appear 1000 times. To avoid this inefficiency, the table should be normalized by dividing it into two separate tables, one for Standards and one for Road Sections, as shown.

Slide 3-12

3

Structured Query Language (SQL)

- Official standard language for dealing with relational systems
- Defined by ANSI standard, though every vendor has own version
- 'Non-procedural' language

Slide 3-12

Notes:

Structured Query Language (SQL)

No discussion regarding relational databases would be complete without some mention of SQL (Structured Query Language.) SQL is commonly pronounced as "sequel" rather than "ess cue ell," although both pronunciations are acceptable.

SQL is supported by most commercial database products and the overall structure and functionality of the language is very consistent from vendor to vendor. If a programmer has used any implementation of SQL, they will have no difficulty making the transition from one product to another. SQL is a "non-procedural" language. This means that the programmer issues a command requesting a result, SQL decides how it can best achieve that result.

Slide 3-13

3

SQL (continued)

- Consists of commands, clauses, operators, and aggregate functions
- Data definition language (DDL) allows creation of new tables, fields and indexes
- Data manipulation language (DML) allows querying by sorting, filtering and extraction

Slide 3-13

Notes:

The SQL language is composed of commands, clauses, operators, and aggregate functions. These elements are combined into statements used to create, update, and manipulate databases. SQL provides both data definition language (DDL) and data manipulation language (DML) commands. Although there are some areas of overlap, the DDL commands allow a programmer to create and define new databases, fields, and indexes, while the DML commands let a programmer build queries to sort, filter, and extract data from the database.

Slide 3-14

Data vs Information

- **‘Data’ are values physically stored in database**
- **‘Information’ is meaning of those values as understood by some user**
- **For example, values in Min_Width field of Standards Table are not information until you know their units**

Slide 3-14

Notes:

<u>Data vs. Information</u>

This distinction between *data* and *information* is important because it highlights the need for software and the use of hardware. The term *data* refers to the values physically recorded on the hardware by the database management system. The term *information* refers to the meaning of those values as understood by the user. Software ought to allow the user to supply *information*, store that information as *data* and allow the user to retrieve that *data* as *information* again. *Data* as it exists in the database management system on the hardware is meaningless without software.

To help illustrate this point, the previous examples used the values of 1500 and 1000 for the minimum width and intentionally did not give the units. This minimum width data is therefore useless until the units are communicated.

Slide 3-15

The VIISA Rule

- **Validity**
- **Integrity**
- **Independence**
- **Security**
- **Accuracy**

Slide 3-15

Notes:

<u>The VIISA Rule</u>

The VIISA database rule is easily remembered by thinking of its acronym as the credit card. It says that database designers ought to consider the following items when designing and implementing a database: Validity, Integrity, Independence, Security and Accuracy. Any database that is designed and implemented without regard to these items is doomed.

Discuss each item.

Slide 3-16

3

Location Referencing Systems

Slide 3-16

Notes:

Location Referencing Systems

Slide 3-17

3

Definitions

- **Location:** position on road
- **Address:** string of characters uniquely identifying a location
- **Location Reference Method (LRM):** procedures used in field to find address of a location
- **Location Reference System (LRS):** procedures used to manage location referencing

Slide 3-17

Notes:

<u>Definitions</u>

When discussing location referencing it is very helpful to have define a clear set of terms and use them precisely

The **Location** of a point is the particular position that point exists on a road. The **Address** of a point on a road is a sequence of numbers and/or characters used to uniquely and unambiguously represent the **location** of that point. No two locations in the entire pavement network have the same address. Yet, the same location can have an infinite number of addresses. The **Location reference method** is a set of procedures used in the field to identify the **address** of any point. The **Location reference system** is a set of procedures used in an agency to manage all aspects of location referencing.

Slide 3-18

3

Location Reference System

- **From NCHRP Synthesis 21 (1974):**

Slide 3-19

3

Location Reference Methods

- Find address of a location
- Spatial
- Linear:
  - **- Mile Point**
  - **- Mile Post**
  - **- Reference Point**
  - **- Reference Post**

Slide 3-18

Notes:

Location Referencing System

To manage location referencing a highway agency must have one, and only one, location reference system. A location reference system, like all information systems, requires separate components to acquire, store, manipulate, retrieve and distribute information. Typical location reference systems are a mixture of manual procedures for data acquisition and distribution, and computerized procedures for data storage, manipulation, and retrieval.

Slide 3-19

Notes:

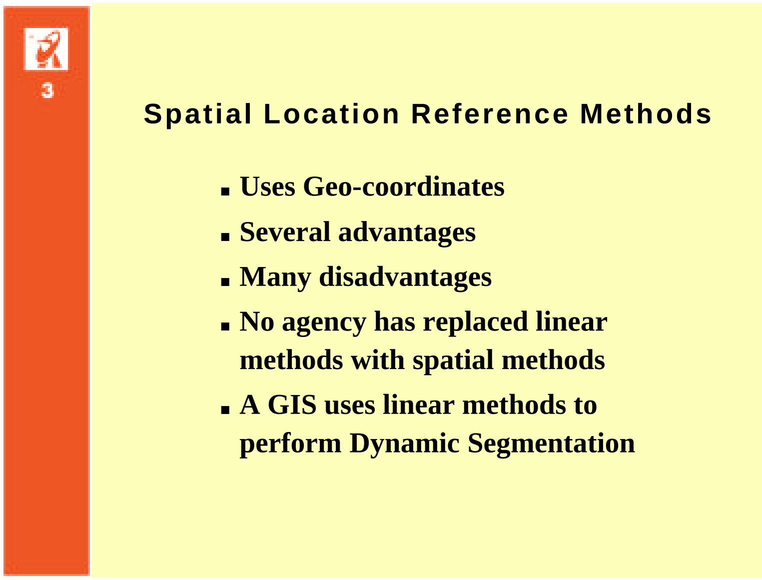
Location Reference Methods

§ Find address of a location

§ Spatial

§ Linear
- Mile Point
- Mile Post
- Reference Point
- Reference Post

Slide 3-20



Slide 3-20

Notes:

Spatial Location Reference Methods

Spatial location reference methods use "geo-coordinates" to identify the location of a point. These are commonly expressed in either longitude, latitude and elevation, or in state plane coordinates and elevation.

§ Uses Geo-coordinates

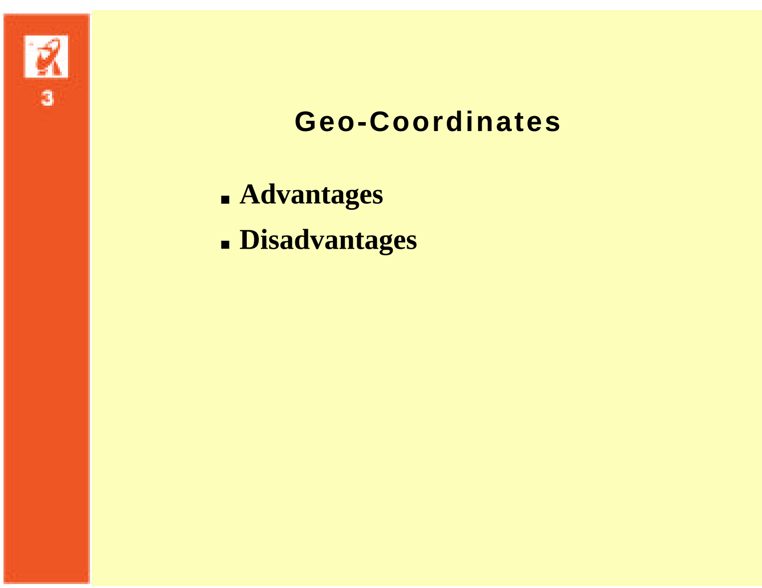
§ Several advantages

§ Many disadvantages

§ No agency has replaced linear methods with spatial methods

§ A GIS uses linear methods to perform Dynamic Segmentation

Slide 3-21



Slide 3-21

Notes:

Geo-Coordinates

§ Advantages

§ Disadvantages

Slide 3-22

Linear Location Reference Methods

- Fundamentally same; get address by getting distance from known point
- Problems associated with inability to reproduce distances between points

Slide 3-22

Notes:

Linear Location Reference Methods

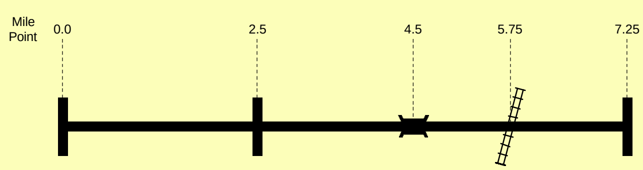
§ Fundamentally same; get address by getting distance from known point

§ Problems associated with inability to reproduce distances between points

Slide 3-23

Mile Point

- 'Known point' is the beginning of road
- Several advantages
- Many disadvantages



Slide 3-23

Notes:

Mile Point

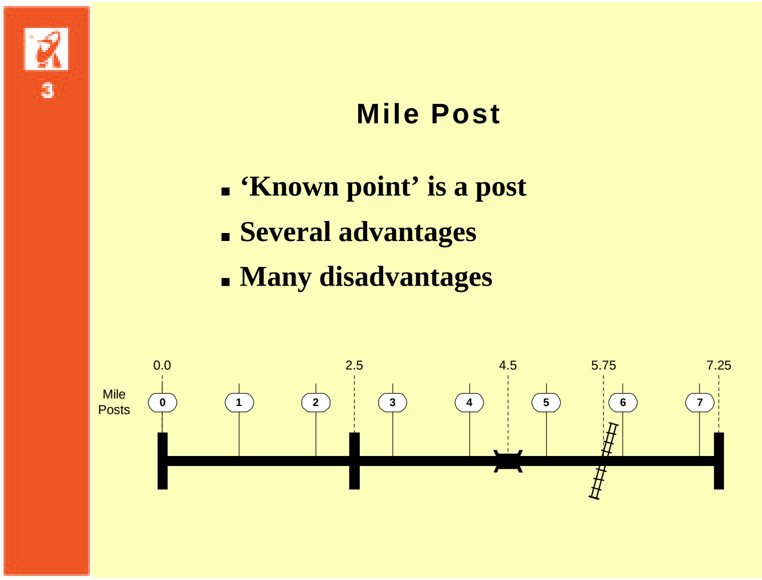
This method assumes each road has one reference point located at the beginning of the road. The address of any point along the road is given as an offset. The offset being the distance of the point from the beginning of the road. Mile points are not physically identified in the field.

§ 'Known point' is the beginning of road

§ Several advantages

§ Many disadvantages

Slide 3-24



Slide 3-24

Notes:

<u>Mile Post</u>

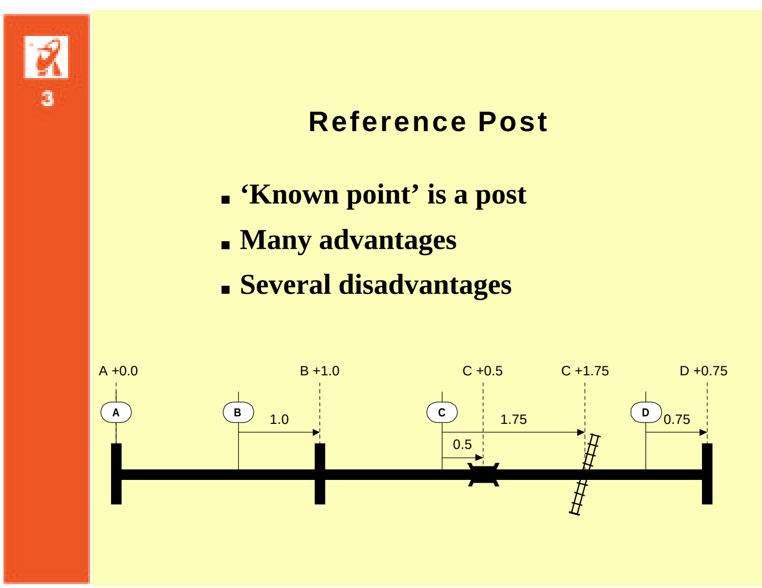
The theoretical difference between the mile post and the mile point method is in the physical placement of posts at even mile points along a road. Each mile post must be labeled with a number that represents the true mile point at the post. The address of any point, then, is given by adding or subtracting the distance traveled from any post to the point in question.

§ 'Known point' is a post

§ Several advantages

§ Many disadvantages

Slide 3-25



Slide 3-25

Notes:

<u>Reference Post</u>

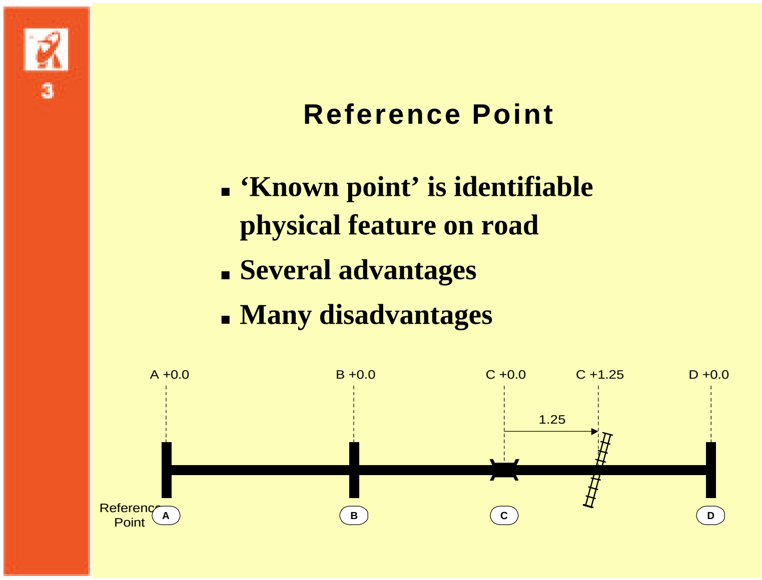
The reference post method uses posts physically placed at various locations along the road. Each post has a reference number. In this method the reference point is identified by the number on the post. The address of any point, then, is stated by giving the route number, the distance traveled from any reference post to the point in question, and the direction.

§ 'Known point' is a post

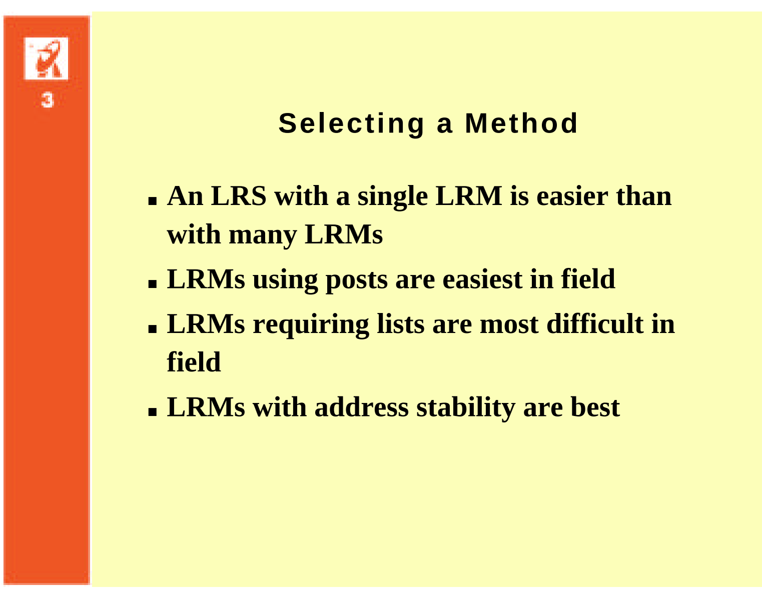
§ Several advantages

§ Many disadvantages

Slide 3-26



Slide 3-27



Slide 3-26

Notes:

Reference Point

The difference between the reference post and the reference point methods is physically placing posts in the field. The reference point method relies on assigning reference numbers to easily identifiable physical features such as bridges and intersections. The reference point is identified by a number contained on a list. Distance between any two consecutive points is given on the same list. The list is required in the field to find the number for any reference point.

§ 'Known point' is identifiable physical feature on road

§ Several advantages

§ Many disadvantages

Slide 3-27

Notes:

Selecting a Method

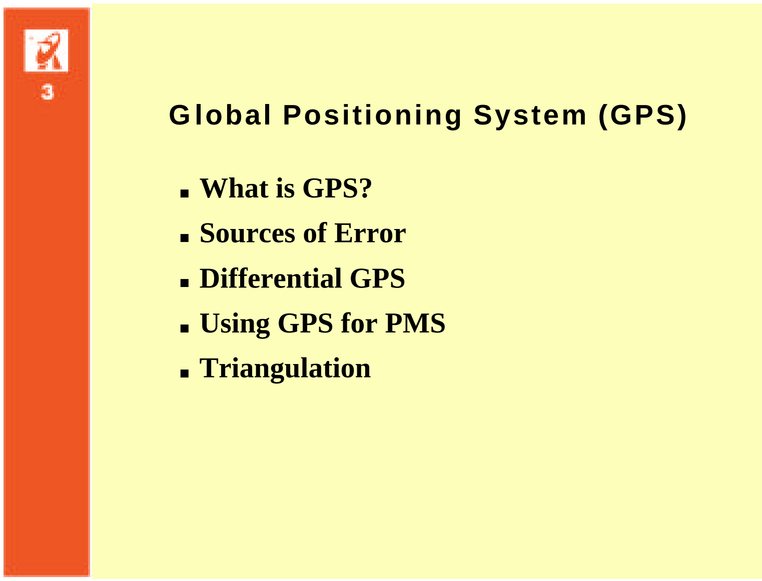
§ An LRS with a single LRM is easier than with many LRMs

§ LRMs using posts are easiest in field

§ LRMs requiring lists are most difficult in field

§ LRMs with address stability are best

Slide 3-28



Slide 3-28

Notes:

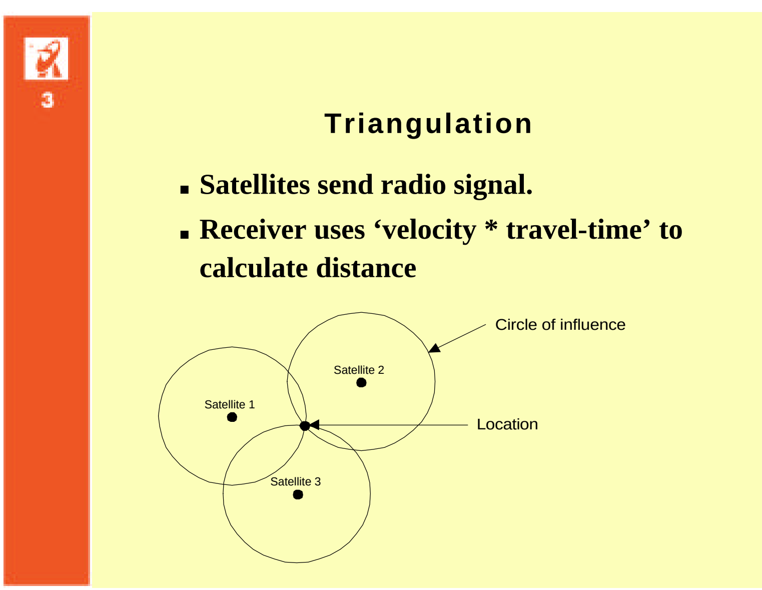
<u>What is GPS?</u>

Many years ago the US Department of Defense started placing a series of 21 satellites in orbit around the earth. These satellites form the basis of the Global Positioning System (GPS). At a cost exceeding $10 billion dollars, the GPS has the capability of giving the coordinates of locations to within 1 cm.

The basic idea behind using GPS is having a receiver that calculates its position using triangulation. The triangulation calculations require the receiver to know the exact position of at least four satellites.

- Sources of Error
- Differential GPS
- Using GPS for PMS
- Triangulation

Slide 3-29



Slide 3-29

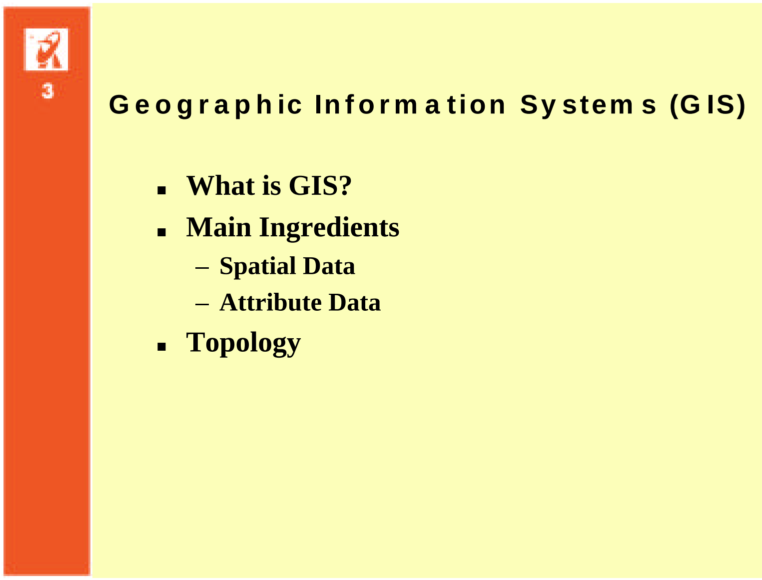
Notes

<u>Triangulation</u>

The diagram shows a much simplified two dimensional view of how the GPS receiver can calculate its position. In fact, the circles in this diagrams should have been drawn as spheres; in which case the fourth satellite would have to be added. However, the triangulation calculation can still be demonstrated using the much simpler two dimensional model and three satellites.

- Satellites send radio signal
- Receiver uses ‘velocity * travel-time’ to calculate distance

Slide 3-30



Slide 3-30

Notes:

A Geographic Information System (GIS) is defined as a system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. When a GIS is applied to transportation the generally accepted name is Geographic Information System for Transportation (GIS-T).

Main Ingredients of GIS

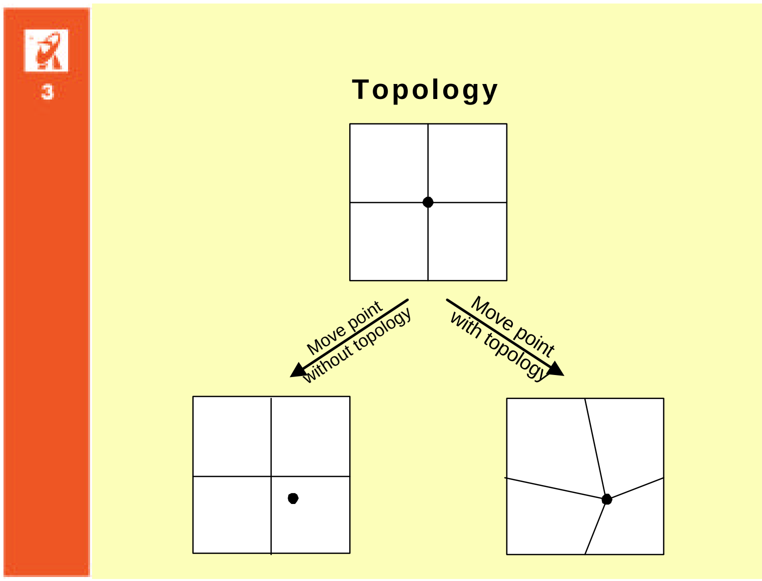
To begin with, a GIS consists of two broad categories of data: (1) attribute data and (2) spatial data. The GIS seamlessly integrates the two giving the user the capability of applying spatial analysis to the attribute data.

Topology

Topology is an area of mathematics used to enforce relationships between objects.

Topology is an inherent feature of a GIS. Automated mapping does not inherently have topology. Topology gives GIS the power to build and maintain complicated relationships between spatial objects. To effectively use topology, great care must be taken to ensure the locations of the objects are precise.

Slide 3-31

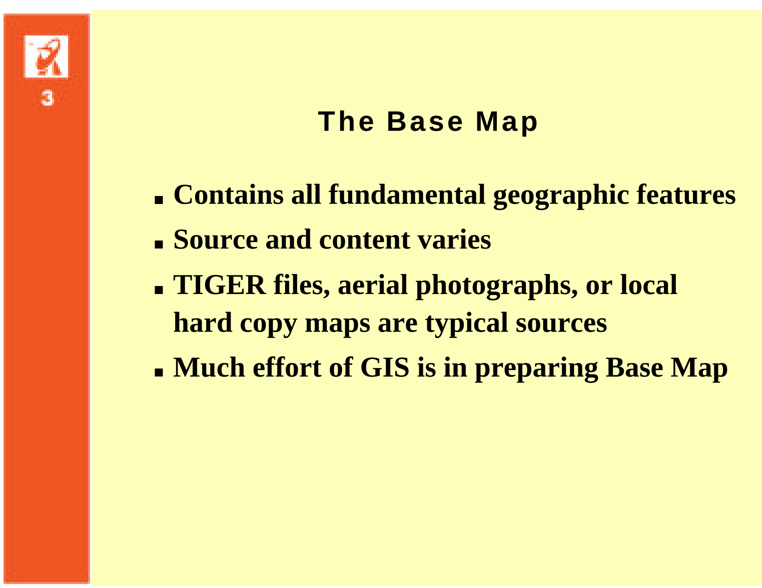


Slide 3-31

Notes:

For example, if two roads sections (line objects) meet at an intersection (point object) then the location of the ends of the road sections must be exactly the same as the location of the intersection. Because of this need, much of the effort in building a GIS goes into preparing a “Base Map.”

Slide 3-32



Slide 3-32

Notes:

<u>The Base Map</u>

§ Contains all fundamental geographic features

§ Source and content varies

§ TIGER files, aerial photographs, or local hard copy maps are typical sources

§ Much effort of GIS is in preparing Base Map

Slide 3-33

3

Integrating Data with a GIS

- Useful for integrating line objects (roads) with polygon objects (political boundaries)
- Dynamic Segmentation of line objects still requires linear referencing

Slide 3-34

3

Automated Mapping

- No topology
- Can plot lines in different colors
- Simply relates data to lines on map
- Only useful for “show me” maps
- Straight forward and inexpensive

Slide 3-33

Notes:

Integrating Data wit a GIS

The ability to integrate spatial data is the prime reason why an agency invests in a GIS. This integration is not limited to integrating road data. With a GIS all spatial related data such as land use and political boundaries can be integrated into the analysis. This expands the application of a GIS to the entire agency rather than for any specific department such as PMS within the agency.

Recall that the ability to perform Dynamic Segmentation and Concurrent Transformation are the two main requirements a PMS has with respect to road data. Both of these need a linear referencing system to be accomplished; whether performed by a GIS or just by an integrated database.

Slide 3-34

Notes:

Automated Mapping

§ No topology

§ Can plot lines in different colors

§ Simply relates data to lines on map

§ Only useful for “show me” maps

§ Straight forward and inexpensive

Slide 3-35

Application of GIS in PMS

- If PMS uses only traditional roadway data, then, GIS is not required for integration
- If it uses non-traditional data such as boundaries, then a GIS is required for spatial integration

Slide 3-35

Notes:

Application of GIS in PMS

§ If PMS uses only traditional roadway data, then, GIS is not required for integration

§ If it uses non-traditional data such as boundaries, then a GIS is required for spatial integration

Slide 3-36

Application of GIS in PMS (continued)

- Dynamic Segmentation and Concurrent Transformation are linear functions not GIS functions
- If PMS needs to show map, and no GIS exists, use Automated Mapping
- If GIS exists, use it

Slide 3-36

Notes:

Application of GIS in PMS (continued)

§ Dynamic Segmentation and Concurrent Transformation are linear functions not GIS functions

§ If PMS needs to show map, and no GIS exists, use Automated Mapping

§ If GIS exists, use it

Slide 3-37

3

Instructional Objectives

- **Understand principles and concepts of relational databases**
- **Understand need for location referencing systems**
- **Geographic Information Systems**
- **Global Positioning System**

Slide 3-37

Notes:

Review the objectives for this module.

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MODULE 4

INVENTORY AND HISTORY

Purpose:

The purpose of this module is to define what types of inventory and historical data should be collected, how it should be collected and how it is used in a PMS. Different types of data collected will be discussed as well as an introduction to ground pentrating radar for use in data collection.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Define types of inventory and historical data necessary for use in a PMS
- Be aware of different methods of collecting data
- Understand the use of ground penetrating radar (GPR) in a PMS to supplement construction layer history
- Understand the importance of drainage on the structural adequacy of the pavement
- Develop and use strip maps
- Understand the importance of quality control (QC) on data collected

Reference:

Module 4 of the Participant’s Workbook

Duration:

45 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

31 Microsoft PowerPoint® Slides

Approach:

This module is taught through Slide presentations and discussion with the participants.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

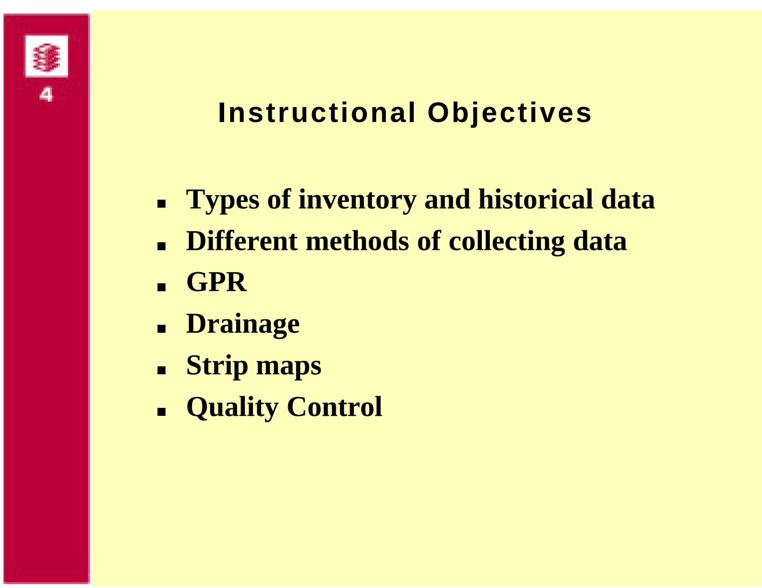
Slide 4-1

Slide 4-1

Notes:

Module 4 introduction slide.

Slide 4-2



Slide 4-2

Notes:

- Define types of inventory and historical data necessary for use in a PMS
- Be aware of different methods of collecting data
- Understand the use of ground penetrating radar (GPR) in a PMS to supplement construction layer history
- Understand the importance of drainage on the structural adequacy of the pavement
- Develop and use strip maps
- Understand the importance of quality control (QC) on data collected

Slide 4-3

4

Inventory Plan

- **Inventory process is foundation of a PMS**
- **Data must be:**
  - **Relevant**
  - **Reliable**
  - **Cost effective to collect**
  - **Cost effective to maintain**

Slide 4-3

Notes:

The inventory plan is critical to the development of the inventory. All of the necessary data must be available to make PMS decision. Excess data should be kept to a minimum to control data collection and data storage costs. Each data element should have a purpose, a plan to use each data element should be developed

Data collection is expensive! Optimize the available data collection budget to get the best data possible.

Data will be collected continually. Data maintenance costs should also be considered when developing the inventory plan

Slide 4-4

4

Inventory Plan Factors

- **What decisions are to be made?**
- **What data is necessary to make decisions?**
- **Size of pavement network**
- **Type and characteristics of agency**

Slide 4-4

Notes:

Before collecting any data, agencies must ask themselves these questions.

Slide 4-5

4

Inventory Plan Factors

- **Type and cost of data acquisition and processing**
- **Required accuracy of data**
- **Required frequency of data collection**
- **Database capabilities**

Slide 4-5

Notes:

1. Discuss briefly the automated data collection versus manual data collection
2. Accuracy of the data will impact the data collection method, schedule and cost.
3. How much of the data is collected only once and how much of the data must be collected periodically.
4. What are the limitations of the database system that is going to be used.

Ask participants: Has anyone compared a windshield survey to a walking survey?

Slide 4-6

4

Two Important Rules

- **Collect only the data you need!**
- **Collect the data only when you need it!**

Slide 4-6

Notes:

Two important rules of thumb.

§ Discuss problems of collecting too much data, i.e.

  - Cost
  - Labor/time

§ Avoid trap of, “Oh, I might as well collect this if I’m out here.”

Slide 4-7

4

Typical Data Elements

- Identification
- Location
- Geometry
- Cost
- Pavement Structure & History
- Traffic

Slide 4-7

Notes:

There are certain data elements that are commonly used in PMS inventory. Each of these items are necessary to develop a M&R plan.

Review the data element types and discuss their relationship with the decision making process.

e.g. Geometry – length, width, area, number of lanes

Pavement structure/history – layer thickness, year of construction, M&R history

Traffic – ADT, number of trucks, ESAL's

Slide 4-8

4

Additional Data Elements

- Drainage information
- Geographical/environmental classification
- Proposed work / work-in-progress
- Other information

Slide 4-8

Notes:

Several other data elements are commonly found in PMS systems. Drainage information is becoming more common in project level systems. GIS is new technology within PMS and the uses of GIS data are still being explored and developed.

§ Review the application of drainage with respect to PMS

§ Briefly identify the application of GIS and its application to PMS.

§ Identify other elements that can be applied to PMS such as Structural factors and User costs

Slide 4-9

Data Sources

- Pavement structure/historical data
- Geometric data
- Other inventory data

Slide 4-9

Notes:

Data is available from many sources within an agency. These sources include as-built records, existing inventory databases, construction records, maintenance records, and many others. The more data that can be collected in house the less time needs to be spent in the field collecting data. If video inventory logs are available they should be reviewed before field data collection.

Review each of the data types and the potential sources for data.

This review will be dependent on the type of field data collection to be used. If automated data collection is to be used less preparation is necessary before the filed data collection.

Slide 4-10

Field Data Collection

- Photographic/Video logs
  - Fast
  - Less expensive
  - Limited viewing area
  - Requires more post processing
- Field survey teams
  - Slower
  - More expensive
  - Better reporting of field conditions
  - Requires more preparation

Slide 4-10

Notes:

Review each field data collection process and discuss the work involved.

Discuss the advantages and disadvantages of each process.

Slide 4-11

4

Drainage

- Drainage affects pavement performance
- How does drainage impact the maintenance and rehabilitation policy?
- Can drainage data be used in decision making?
- What information should be collected?
  - Drainage type
  - Drainage system condition

Slide 4-11

Notes:

Pavement performance is greatly affected by the quality of drainage along a pavement section. Inventory data concerning the type of drainage systems used and the condition of that drainage system can be very useful in the development of maintenance and rehabilitation options. Drainage systems are complex and the development of drainage inventory data is complex and often difficult.

Slide 4-12

4

Drainage Inventory Data

- Drains & roadside ditches
  - Depth
  - Width
- Drainage structures
  - Culverts
  - Curb & Gutter
  - Drainage inlets

Slide 4-12

Notes:

Drainage types can be broken into two basic areas: roadside ditches and drainage structures.

Slide 4-13

Drainage Condition Data

- Difficult to assess all drainage systems
- Adequate cross-slope
- Capacity of drainage structures
- Debris in drains / culverts / inlets

Slide 4-13

Notes:

Drainage condition data is very difficult to assess. The condition of the drainage system can be affected by a wide variety of conditions. Much of the rating must be performed by experienced personnel. Some factors that can be considered include road cross-slope, roadside ditch condition and drainage structure condition.

Slide 4-14

Defining Sections

- The length or size of sections will determine volume of data to be collected
- Large sections
- Small sections
- Section requirements

Slide 4-14

Notes:

How segments are defined within the inventory will be critical to the success of the system. The size of the sections controls the amount of data collected and how the data actually represents the field conditions. Large sections require more generalized data and make it difficult to represent the variability within a section. Homogeneous behavior is a goal, not reality. Small sections better represent the network but increase the cost of data collection and may not represent real project sections.

1. Review the impact of section size on the inventory and the data collection efforts.

2. Discuss the impact of variability with the pavement sections.

Slide 4-15

Homogeneous Sections

- Change in pavement type
- Change in pavement structure
- Change in traffic
- Boundary between previous construction
- Change in subgrade
- Geographical of political boundaries
- Change in pavement condition

Slide 4-15

Notes:

These elements are commonly used to define a homogeneous section. Definition becomes more complex as each criteria is added and the size of the sections also decreases.

Review each of the criteria used to develop a homogeneous section.

Slide 4-16

Section Identification

- Purpose
- Requirements
- Methods

Slide 4-16

Notes:

Section Identification

§ Purpose
  - Provides a link to the database
  - Provides a link to the location referencing system
  - Link to a GIS

§ Requirements
  - Unique identifier for each section
  - Easy to understand
  - Can be used agency wide

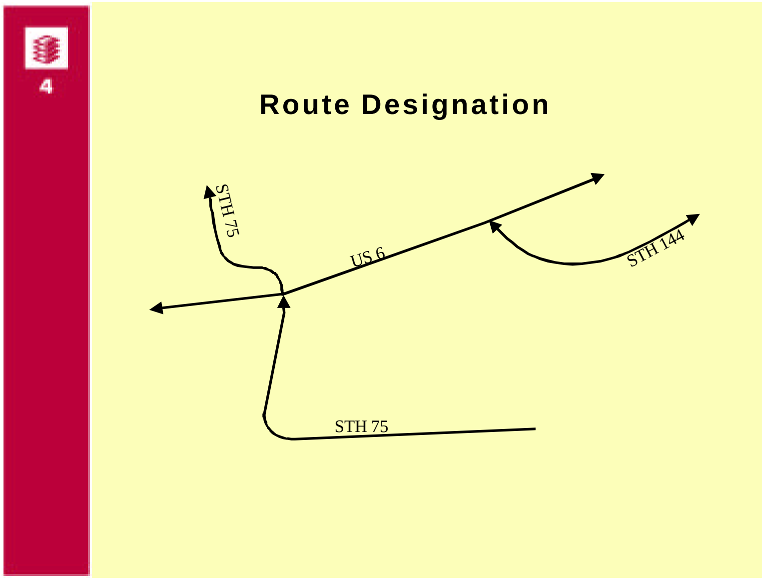
Methods

§ Existing route numbers

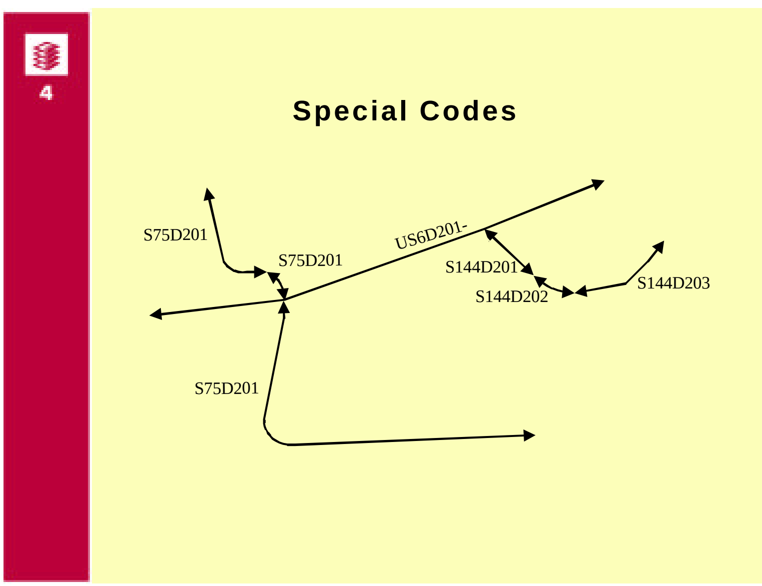
§ Assign special codes

§ Link node system - GIS

Slide 4-17



Slide 4-18



Slide 4-17

Notes:

These are generic examples of several of the section identification methods. Each method has advantages and disadvantages. Each method should be reviewed and tested for each agency to determine which method work the best for them. Agencies that are heavily based on GIS may want to use a link-node system to identify the location of the node points.

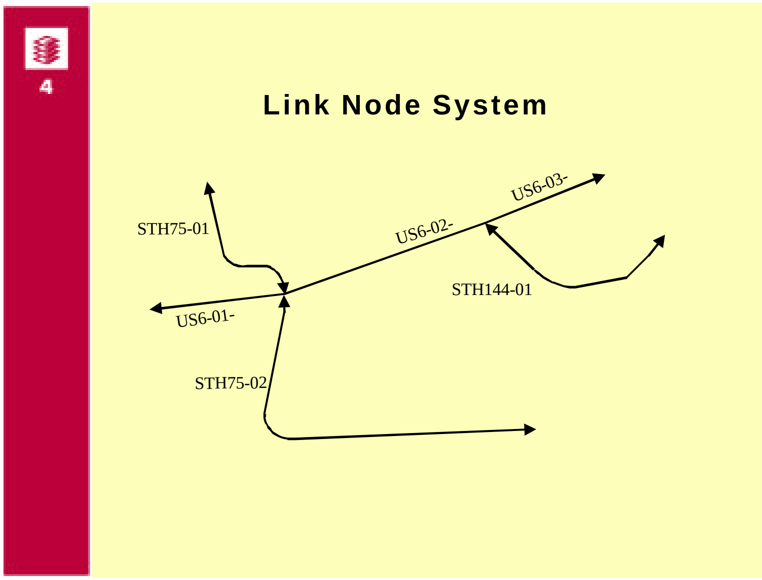
1. The route designation system provides little information about the individual sections and the individual pieces of the route. It will be easily recognized by agency staff.

Slide 4-18

Notes:

2. The special codes method can be developed in many ways, is particularly useful, and provides a great deal of flexibility for the computer database. This method may not communicate well with people who are not familiar with the organization of the PMS.

Slide 4-19



Slide 4-19

Notes:

3. The link node method works very well with GIS and can be very effective for many types of networks. This method is also particularly useful for dynamic segmentation and other automatic sectioning methods.

Slide 4-20

Collecting Inventory Data

- **Office data**
- **Field data**
- **Time consuming**
- **Expensive**
- **MANDATORY**
- **Gathering process**

Slide 4-20

Notes:

The data gathering process will be a large work effort and will be an ongoing part of the PMS. A properly developed inventory plan will make the process as efficient as possible.

1. Review the office data collection process
   - Records review
   - Historical data
   - Pavement inventory
   - Other data

2. Review the field data collection efforts
   - Distress data
   - Roughness data
   - Inventory data

3. Gathering process
   - Identify data source
   - Collect/process data

Slide 4-21

4

Ground Penetrating Radar

- Used to determine the depth of pavement layers and other items
  - Reinforcing steel in PCC pavements
  - Voids
- Uses the same technology as aircraft and marine radar
- Energy is reflected from the interface between two materials

Slide 4-21

Notes:

Ground Penetrating Radar (GPR) can be used to measure pavement thickness. The technology works the same as Marine and Aircraft radar. The radar energy is reflected by an interface between two materials with different dielectric properties. The reflected energy is received and the travel time of the signal allows the calculation of distance from the antenna. GPR requires accurate ground truth to provide accurate results. The more dissimilar materials are the more effective GPR is. For example the interface between PCC and steel is very easy to identify. The interface between aggregate base and gravelly soils is not.

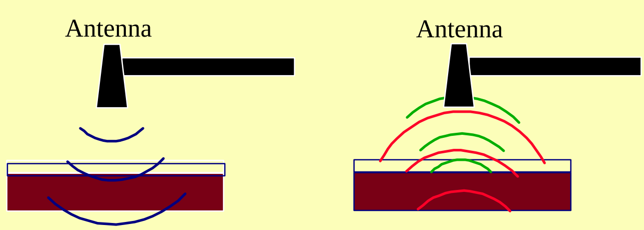
1. Review the limitations of the technology.

2. This technology is used most often at the project level.

Slide 4-22

4

GPR Basics



Slide 4-22

Notes:

GPR Basics

Slide 4-23

4

Ground Penetrating Radar

- NCHRP Synthesis 255 on *"Ground Penetrating Radar for Evaluating Subsurface Conditions for Transportation Facilities"*

Slide 4-23

Notes:

§ This is referenced in notebook.

§ Discuss 1998 studies.

Slide 4-24

4

Ground Penetrating Radar

- NCHRP Synthesis 255
  - **Asphalt layer thickness determination: GPR results are used to estimate thickness to within 10 percent and thicknesses of up to 0.5 m are accurately measured**

Slide 4-24

Notes:

GPR

§ Asphalt layer thickness determination

Slide 4-25

4

Ground Penetrating Radar

- NCHRP Synthesis 255 on
  - <u>Base thickness determination</u>: thicknesses are estimated, provided that there is a dielectric contrast between the base and subgrade
  - The best results occur when subgrade is made up of clay soils which are highly conductive compared to sands or gravels

Slide 4-25

Notes:

<u>GPR</u>

§ Base thickness determination

Slide 4-26

4

Ground Penetrating Radar

- NCHRP Synthesis 255
  - <u>Concrete thickness determination</u>: depth constraints and accuracy are not yet well defined. This is because portland cement concrete attenuates GPR signals more than asphalt, PCC conductivity changes as the cement hydrates, slabs that contain steel make interpretation more difficult

Slide 4-26

Notes:

<u>GPR</u>

§ Concrete thickness determination

Slide 4-27

Ground Penetrating Radar

- NCHRP Synthesis 255
  - __Void detection__: GPR has detected air-filled voids as thin as 6 mm, while the detection of water-filled voids is more problematic

Slide 4-27

Notes:

GPR

§ Void detection

Slide 4-28

Quality Control of Data

- Integrity
- Accuracy
- Validity
- Security

Slide 4-28

Notes:

Data quality control is essential to the development of the inventory. Some data elements are collected only once. If this data is not correct the decisions made in the future will be flawed. This will undermine the confidence in the PMS and it's results. Data quality control is based upon four principles:

- Integrity
- Accuracy
- Validity
- Security

Each of these principles must be addressed in the inventory plan.

Illustrate the necessity for data quality control and the potential impacts on decision making. Discuss each principle briefly.

Slide 4-29

Strip Maps

- Profiles of inventory data
- Requires a well developed linear referencing system
- Must be able to perform dynamic segmentation
- Common uses
  - traffic data
  - pavement structure
  - section boundaries

Slide 4-29

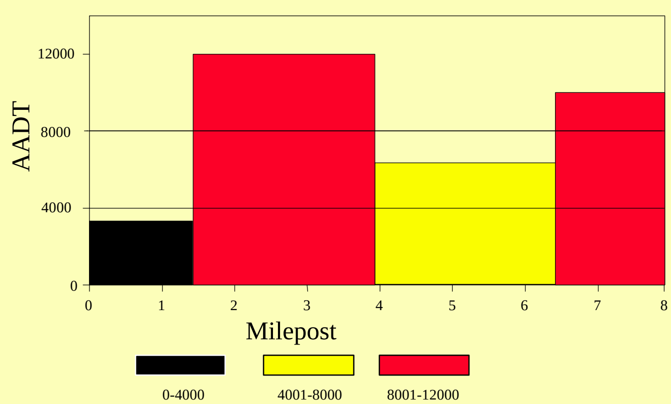
Notes:

Strip maps are profiles of inventory data. Data is depicted as a point element or as a value covering a portion of the profile shown. Strip maps can be used to compare data that does not have the same section definition or the same beginning and end points. To use strip maps effectively data must be developed with a well defined linear referencing system.

Review the uses of a strip map

Slide 4-30

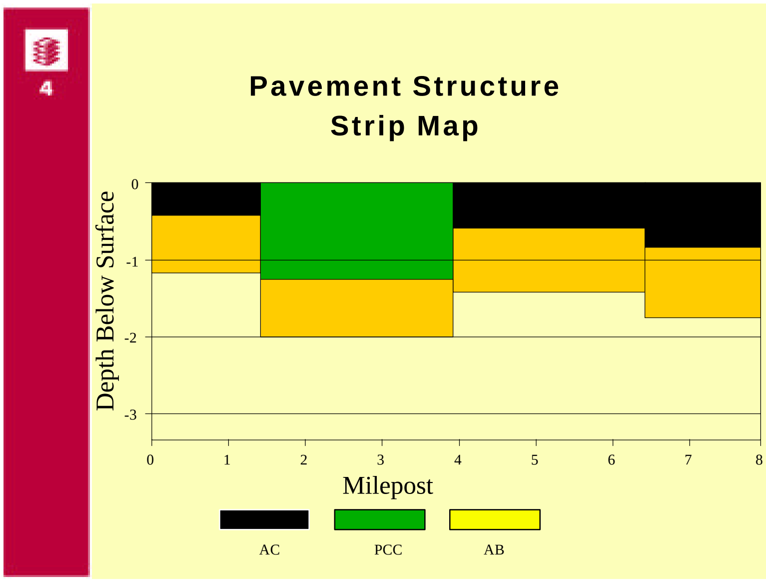
Traffic Strip Map



Slide 4-30

Notes:

Slide 4-31



Slide 4-31

Notes:

Slide 4-32

Instructional Objectives

- Types of inventory and historical data
- Different methods of collecting data
- GPR
- Drainage
- Strip maps
- Quality Control

Slide 4-32

Notes:

Review the objectives for this module.

MODULE 5

PAVEMENT CONDITION SURVEYS

Purpose:

This module introduces the use of pavement condition surveys to collect data to determine the structural integrity, distresses, skid resistance, and overall riding quality of the pavement. The types of surveys are introduced and examples of procedures and equipment are provided.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Understand the need for condition surveys.
- Be familiar with the four basic types of condition surveys.
- Be acquainted with the different procedures and equipment available.
- Be aware of the purpose, advantages, and disadvantages of different procedures.

Reference:

Module 5 of the Participant's Workbook

Duration:

90 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

47 Microsoft PowerPoint® Slides

Approach:

This module is taught through slide presentations and discussions with the participants. The module provides an overview of the use of pavement condition surveys in pavement management and introduces the data collection techniques and equipment.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

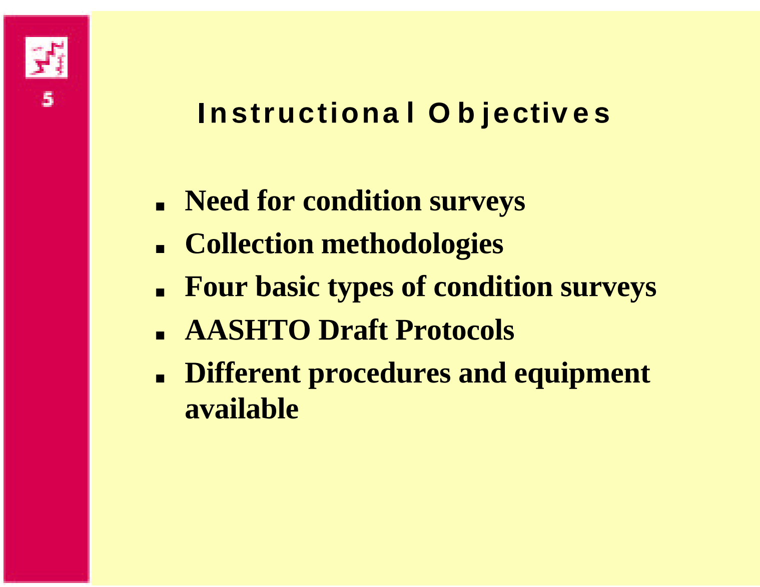
Slide 5-1

Slide 5-1

Notes:

Describe the purpose of this module and the approach that will be used.

Slide 5-2



Slide 5-2

Notes:

Describe the objectives for this module.

Slide 5-3

5

Need for Condition Surveys

- Evaluate current condition of pavement
- Determine rates of deterioration
- Project future conditions
- Determine maintenance & rehabilitation needs
- Determine costs of repairs
- Prepare plans for repairs

Slide 5-3

Notes:

Discuss why condition surveys are needed.

Slide 5-4

5

Collection Methodologies

- Costs of collecting condition data
  - Accuracy
  - Precision
  - Resolution

Slide 5-4

Notes:

<u>Collection Methodologies</u>

Collecting condition information is generally the most costly part of the initial implementation of a PMS and of continued operation. Condition data can be collected using very expensive or relatively inexpensive methods.

§ The methods that are more costly are also usually more accurate, more precise, and have the greatest resolution.

Slide 5-5

Types of Surveys

- **Distress Surveys**
- **Structural Capacity**
- **Roughness (Ride Quality)**
- **Skid Resistance (Surface Friction)**

Slide 5-5

Notes:

Types of Surveys

- Distress Surveys
- Structural Capacity
- Roughness (Ride Quality)
- Skid Resistance

Slide 5-6

Distress Surveys

- **Type of distress**
- **Severity**
- **Quantity of distress present on the pavement**

Slide 5-6

Notes:

The type of distress tells us what type of damage has developed; the severity tells how bad the damage is; and the quantity gives us the extent of the type and severity of the damage that is present. All three of these factors are required to get a full picture of the damage that has developed on the pavement surface and are used to determine the type and timing of maintenance, rehabilitation, and reconstruction.

Slide 5-7

5

AASHTO Distress Survey Protocols

- **Cracking protocols for:**
  - **Asphalt pavements**
  - **Jointed concrete pavements**
  - **Continuously reinforced concrete pavements**
- **Faulting protocols for concrete pavements**
- **Rut depth protocols for asphalt pavements**
- **Roughness protocols**

Slide 5-7

Notes:

AASHTO Distress Survey Protocols

The FHWA is in the process of developing data collection protocols for pavement distress. The reason for developing the protocols was that recent surveys found the greatest variable in pavement distress data – both the collection and their use. A final draft was completed in October 1996 and distributed to the states for comments. The protocols were developed with the input for 5 states (Georgia, Pennsylvania, Massachusetts, Kentucky and South Dakota) as well as AASHTO and ASTM.

Introduce topic and give background for following slides.

Appendix 5B contains data for protocols.

Slide 5-8

5

PAVEMENT MANAGEMENT CONDITION DATA PROTOCOLS

Stuart W. Hudson, President

Texas Research and Development Incorporated

Slide 5-8

Notes:

These slides were developed by TRDI as part of their contract with the FHWA.

Slide 5-9

5

VISION STATEMENT

- **Consistent and effective condition data for** Network Level Pavement Management
- **Effective state pavement management with coordinated technology and communication**
- **Synergize and standardize network level PMS data collection and reporting nationwide**

Slide 5-9

Notes:

Explain Vision Statement.

The 1994 study found a list of variations, i.e. collection and use of pavement distress data.

Slide 5-10

5

GOALS AND OBJECTIVES

- **Goal is effective and accepted PMS data collection protocols**
- **Objectives Include:**
  - **Synthesize state PMS data methodologies**
  - **Determine appropriate data guidelines**
  - **Develop protocols with state input**
  - **Ensure acceptance**

Slide 5-10

Notes:

Explain goals and objectives.

Slide 5-11

5

PROTOCOL DEFINITION

A procedure for the <u>objective measurement</u> of a pavement characteristic which defines a minimum standard and a set of parameters regarding the type, precision, quantity, location, reporting, and quality of a measurement to be made

Slide 5-11

Notes:

Give protocol definition

Slide 5-12

5

PROTOCOLS DEVELOPED

- **Six Protocols developed**
  - **Roughness (Automated only)**
  - **Rut Depth (Automated only)**
  - **Faulting (Automated & Manual)**
  - **Automated & Manual Cracking Protocols**
    - Asphalt (Automated & Manual)
    - CRCP (Automated & Manual)
    - JCP (Automated & Manual)

Slide 5-12

Notes:

Six protocols developed.

Highlight automated as new idea for a protocol.

Slide 5-13

5

PROTOCOLS

- **Roughness**
  - **Profile 2 WPs 150 mm (6”) spacing**
  - **Report average of two wheelpath IRI**
- **Rut Depth -**
  - **Three point measurement every 15 meters**
- **Faulting**
  - **Each transverse joint (Automated)**
  - **10% Sample of joints (Manual)**

Slide 5-13

Notes:

Protocols

- § Roughness
- § Rut depth
- § Faulting

Slide 5-14

5

IRI ROUGHNESS PROTOCOL

IRI is calculated from longitudinal profile measured with a road profiler in both wheelpaths. The average IRI of the two wheelpaths is reported as the roughness of the pavement section.

Slide 5-14

Notes:

Discuss how IRI is calculated.

Section 5.8 has a detailed description of IRI calculation procedure.

Slide 5-15

ROUGHNESS SURVEY

- **Survey the outside lane.**
- **For undivided highways survey one direction.**
- **For divided highways survey the outside lane in both directions.**
- **For each survey cycle use the same direction(s) of travel and survey lane(s).**

Slide 5-15

Notes:

Describe how a roughness survey is performed.

Slide 5-16

IRI CALCULATION

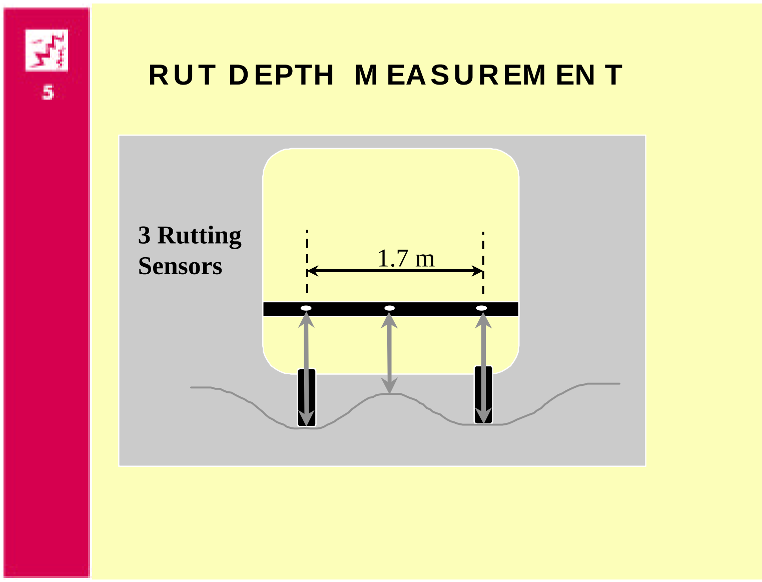
International Roughness Index (IRI) **- The IRI is computed from a single longitudinal profile using a quarter-car simulation as described in the report, "On the Calculation of IRI from Longitudinal Road Profile." [Sayers 95]**

Slide 5-16

Notes:

Define IRI calculation per Sayers, 1995.

Slide 5-17

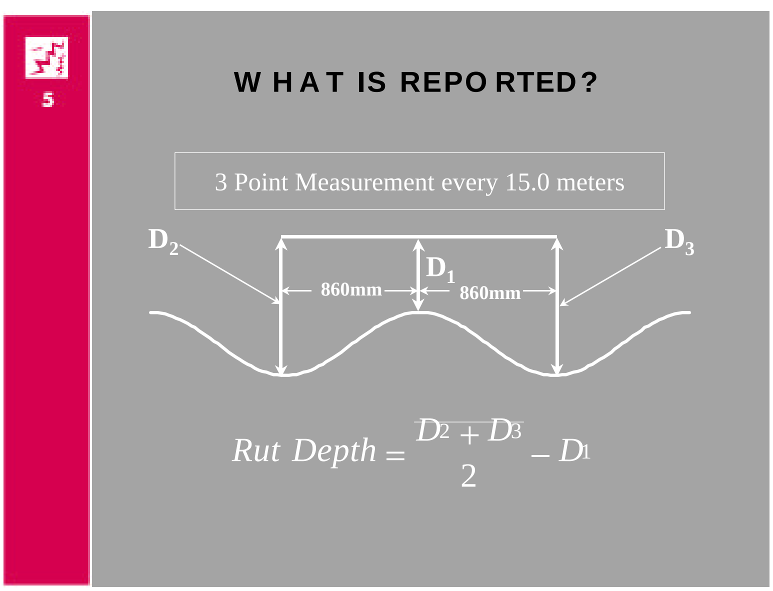


Slide 5-17

Notes:

Describe diagram of rut depth measurement.

Slide 5-18

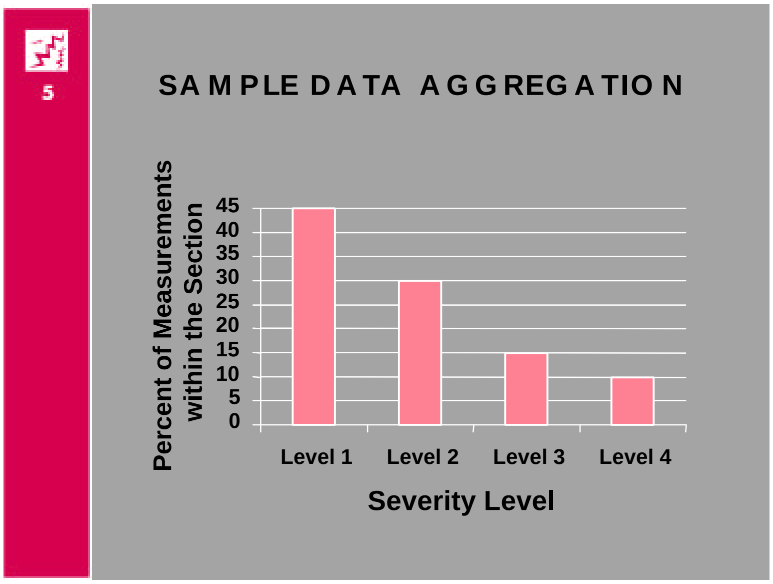


Slide 5-18

Notes:

Describe how data is reported.

Slide 5-19



Slide 5-19

Notes:

Describe sample data aggregation.

Level 1 ≤ 6 mm

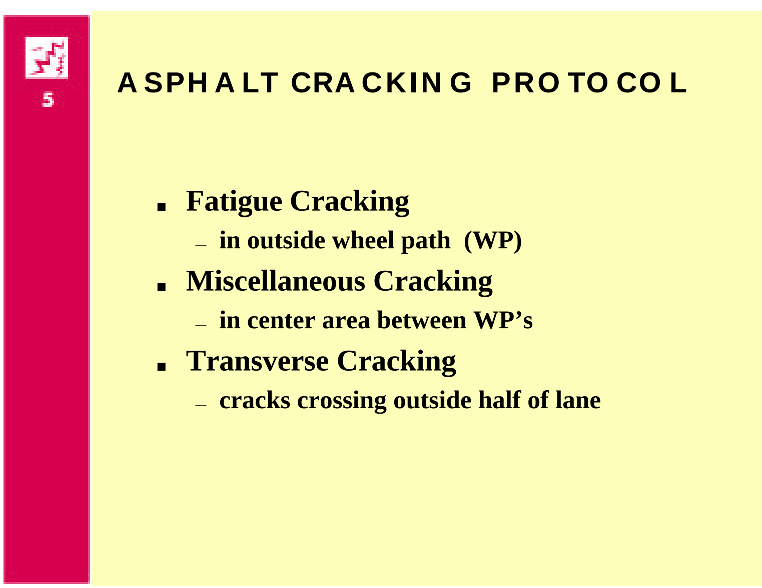
Level 2 > 6-12 mm

Level 3 >12-25 mm

Level 4 ≥ 25 mm

Note point at which you take action.

Slide 5-20



Slide 5-20

Notes:

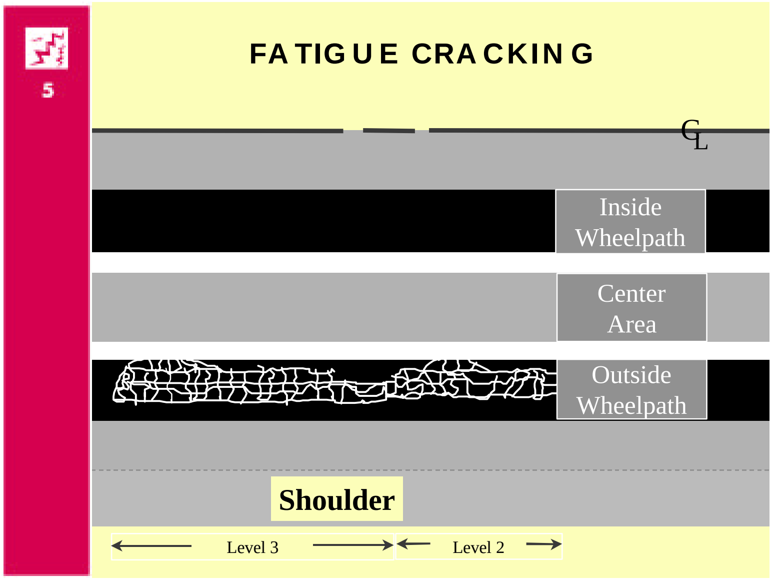
Asphalt Cracking Protocol

§ Fatigue Cracking

§ Miscellaneous Cracking

§ Transverse Cracking

Slide 5-21

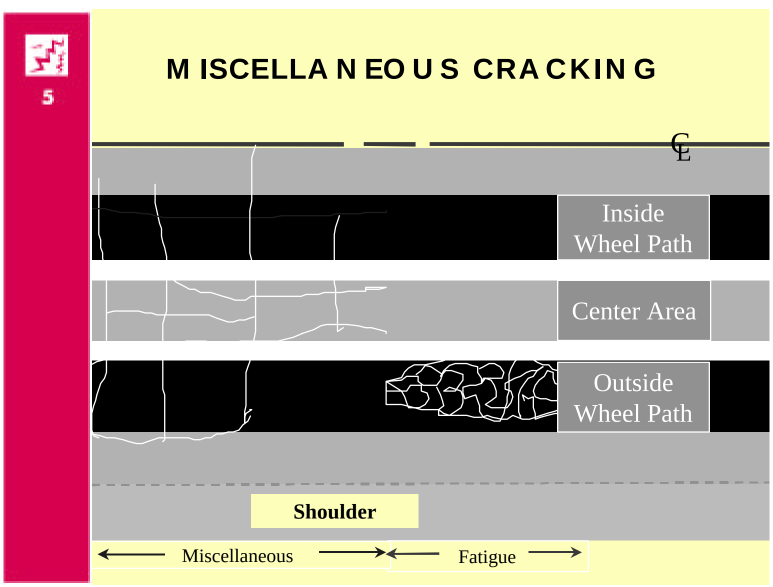


Slide 5-21

Notes

Describe fatigue cracking as shown in slide.

Slide 5-22



Slide 5-22

Notes:

Describe miscellaneous cracking as show in slide.

Slide 5-23

5

CRCP CRACKING PROTOCOL

- Transverse Cracking
- Longitudinal Cracking
- Punchouts

Slide 5-24

5

JCP CRACKING PROTOCOL

- Slab Distresses
  - Shattered Slab
  - Longitudinal and Transverse Cracking
  - Corner Breaks
  - Surface Disintegration & Asphalt Patches
- Joint Distresses
  - Spalling
  - "D" Cracking

Slide 5-23

Notes:

Ask participants, " What's your experience and how does it relate to development of protocols?

Draw picture on transparencies.

Slide 5-24

Notes:

Draw picture and ask participants for their experience.

Slide 5-25

WHAT THE PROTOCOLS DO

- Assist you in the implementation of data collection procedures
- Accommodate and assess many of your current procedures
- Facilitate data collection training and reduce data variability

Slide 5-25

Notes:

Describe what the protocols do.

Slide 5-26

WHAT THE PROTOCOLS DO (cont.)

- Gauge the accuracy of data collection procedures and equipment
- Provide a framework by which states' data and results will be compatible
- Improve the exchange of pavement information, experience, and results

Slide 5-26

Notes:

Describe what the protocols do.

Slide 5-27

PROTOCOL CONTENT

- **Purpose**
  - **Applies to Network Level Surveys on NHS**
- **Scope**
  - **Specifications for equipment not included**
- **Condition Measurements**
  - **Distresses defined**
    - Measurement (Severity and Extent)

Slide 5-27

Notes:

Protocol Content

§ Purpose

§ Scope

§ Condition Measurements

Slide 5-28

PROTOCOL CONTENT (cont.)

- **Recording of Data**
  - **Aggregation, Units, and Format**
  - **Section length between 0.15 and 1 km**
- **Quality Assurance**
  - **Survey crew training SHA procedures**
  - **Daily and periodic equipment calibration according to manufacturer's specifications**

Slide 5-28

Notes:

Protocol Content

§ Recording Data

§ Quality Assurance

Slide 5-29

PROTOCOL CONVENTIONS

- **Down the Road**
  - **Stable Measurement Definition in SI units**
  - **Uniform Data Collection Sections**
    - Uniform Lengths
    - Uniform aggregation of measurements
  - **Standard Aggregation per PM Section**
- **Across the Road**
  - **Collection in either outside lane**
  - **Collection in portion of lane (WP/Mid)**

Slide 5-29

Notes:

Protocol Conventions

§ Down the road

§ Across the road

Slide 5-30

Structural Capacity

- **Not routinely collected for pavement monitoring**
- **Mainly used for selecting and designing rehabilitation strategies**
- **Can reduce maintenance and rehabilitation costs**

Slide 5-30

Notes:

Introduce new topic of structural capacity.

Structural data is not routinely collected for pavement monitoring by most agencies. Surface deflection data is mainly used for selecting and designing specific rehabilitation strategies for pavement sections under consideration. Exact location and frequency of structural testing within specified road sections should be carefully determined prior to seeking testing services. The tests should be limited to locations where distress and roughness surveys indicate structural problems and areas where overlays are anticipated. The results of these tests reflect the degree of structural adequacy that exists in the pavement structure.

Slide 5-31

Structural Evaluation

Destructive Testing

- Coring
- Laboratory testing
- Excavation of pits
- Field CBR

Slide 5-31

Notes:

Discuss the different types of destructive testing and what information can be gathered from it.

Slide 5-32

Structural Evaluation

Non-Destructive Testing

- Benkelman Beam
- Dynaflect
- Road Rater
- FWD
- Rolling Deflectometer
- GPR

Slide 5-32

Notes:

Discuss the different types of non-destructive testing and what informtion can be gathered from it.

Slide 5-33

Rolling Weight Deflectometer

- In development through an SBIR
- Primary objectives are:
  - Develop an RWD suitable for network level analysis
  - Collect data at speeds of 50 mph
  - Output will be a structural index
  - Measure maximum deflection, pavement temperature, station numbers, and day and time of test

Slide 5-33

Notes:

Introduce new topic.

Describe development and objectives of RWD.

The FHWA initiated a Small Business Innovative Research (SBIR) contract with Applied Research Associates (ARA), Inc. in 1996 to develop a rolling wheel deflectometer (RWD) for structural assessment of pavements. Phase I of the SBIR has been completed and Phase II was recently initiated.

Slide 5-34

Rolling Weight Deflectometer

- Phase I
  - Identified deflection measurements
- Phase II
  - Highway speeds
  - Deflection response converted to a structural index

Slide 5-34

Notes:

Briefly describe the evaluation process.

Slide 5-35

Rolling Weight Deflectometer

- Objective is to compare relative structural strengths
- Identify weak links
- Deflection basins, magnitudes, loads and temperatures
- Processed in real time
- Continuously measured at 1 foot intervals

Slide 5-35

Notes:

Discuss the purpose and use of the rolling weight deflectometer.

Slide 5-36

Automated Distress Surveys

- Increase speed and ease of data collection
- Reduce transcription errors
- Increase consistency between classification and quantification
- Increase safety of field crews

Slide 5-36

Notes:

Introduce new topic.

An automated distress survey can be classified as any mehtod inw hich distress data is entered directly to the computer in the filed during the distress survey. This type of automation can greatly reduce errors associated with transcribing data from paper forms as collected in the field into computer files which will be used in road surface management. Other benefits of automated distress surveys include increased safety for survey crews, faster and more accurate surveys, less expensive data collection, and more repeatable surveys.

Slide 5-37

5

Classes of Automated Data Collection

- Distress images collected on film or high resolution video and:
  - analyzed while the vehicle collects data
  - analyzed in the office after data collection
  - analyzed after data collection by viewing the images
- Lasers are used to determine changes in surface texture

Slide 5-37

Notes:

Discuss classes of automated data collection.

Slide 5-38

5

Automated Condition Survey Equipment

- Used by most states to collect:
  - Pavement friction
  - Roughness
  - Profile
  - Rut depth
  - Deflection data

Slide 5-38

Notes:

Discuss how states use automated condition survey equipment.

Ask participants – what do you use?

Slide 5-39

5

Distress Data Collection

- Visual survey
- Laser technology
- Film-based systems
- Video systems

Slide 5-39

Notes:

- § Lots of vendors collect data with automated equipment.
- § Not possible to discuss all in here.
- § Talk to other agencies
  - pilot implementation
  - evaluate how other agencies do it
  - set up protocols
  - determine levels of precision/accuracy

Slide 5-40

5

Drainage Surveys

- Poor drainage causes poor pavement performance
- Water on a pavement can:
  - create a hazard to motorists
  - saturate the subgrade soil
  - deteriorate the pavement

Slide 5-40

Notes:

Discuss need for drainage surveys.

This is discussed in Module 4.

Slide 5-41

Pavement failure is caused by:

- Load
  - Load capacity can be increased by an overlay
- Moisture
  - If proper drainage is not provided during rehabilitation, the same moisture related distress will recur

Slide 5-41

Notes:

Any pavement designer knows that pavement failure is caused by:

- Load
- Moisture

Slide 5-42

Signs of Deficient Drainage

- Standing water in ditchlines
- Concentrated weed growth in ditchline or edge of pavement
- Evidence of water ponding on shoulder
- Deteriorated joint or crack sealants
- Any evidence of pumping

Slide 5-42

Notes:

Discuss signs of deficient drainage.

Slide 5-43

5

How Much Data to Collect?

- To support network-level analysis
  - Sampling processes
- Two sampling procedures:
  - Network sampling
  - Section sampling

Slide 5-43

Notes:

Discuss how much data to collect.

Slide 5-44

5

Network Sampling

- Less samples needed when total number in the whole increases
- To determine average condition:
  - Sample 2 - 5%
- To predict the distribution of condition:
  - Sample 10 - 25%
- To predict cost of repairs, restoration:
  - Sample 30 - 35%
- Most states survey 10%

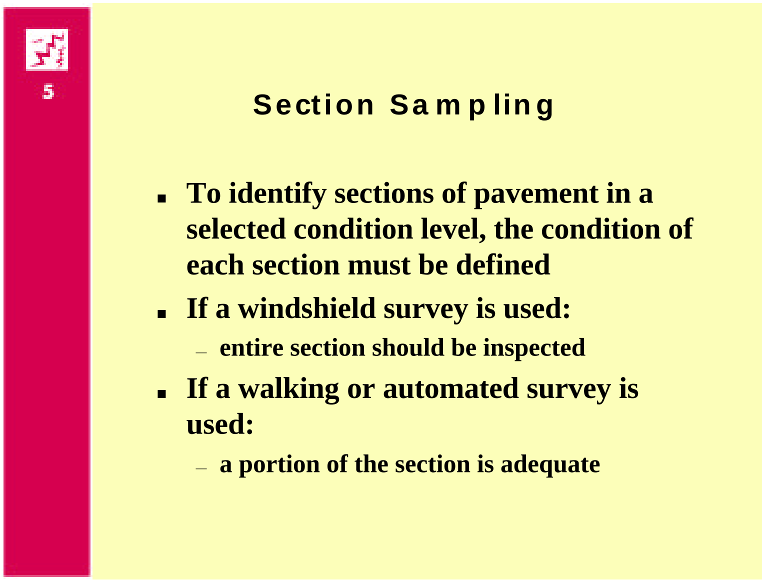
Slide 5-44

Notes:

Describe network sampling.

Reference: Lytton & Maloney

Slide 5-45

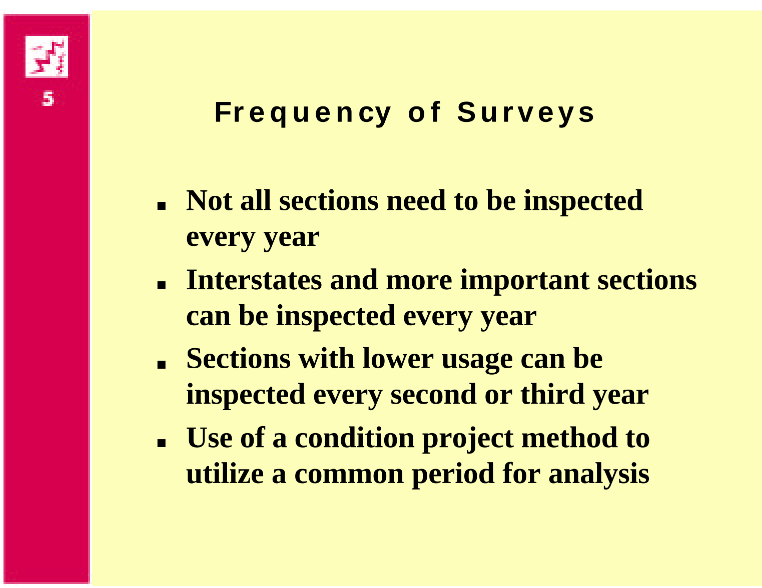


Slide 5-45

Notes:

Describe section sampling.

Slide 5-46



Slide 5-46

Notes:

Discuss frequency of surveys.

Slide 5-47

Summary

- Appendix 5A
  - Sample of distress evaluation charts used in New Mexico
- Appendix 5B
  - Reproduction of the draft AASHTO protocols for pavement condition data collection

Slide 5-47

Notes:

Make participants aware of information in Appendices 5A and 5B in Participant's Manual.

Slide 5-48

Instructional Objectives

- Need for condition surveys
- Collection methodologies
- Four basic types of condition surveys
- AASHTO Draft Protocols
- Different procedures and equipment available

Slide 5-48

Notes:

Review the objectives for this module.

MODULE 6

PAVEMENT CONDITION INDICES

Purpose:

The purpose of this module is to describe the historic development of pavement distress indices, the different types of indices, and their basic functions in a PMS. The module will also go into some detail as to how they may be developed and how they are computed. Several case studies are presented as examplesof the use of different indices in a PMS.

Objectives:

Upon completion of this module, the participant will be able to:

- Describe the different types of condition indices
- Describe how condition indices are used in a PMS
- Describe how a condition index is developed
- Determine if an index is satisfying its intended purpose

Reference:

Module 6 of the Course Notebook

Duration:

45 minutes

Equipment:

Laptop computer, overhead projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

27 Microsoft PowerPoint® Slides

Approach:

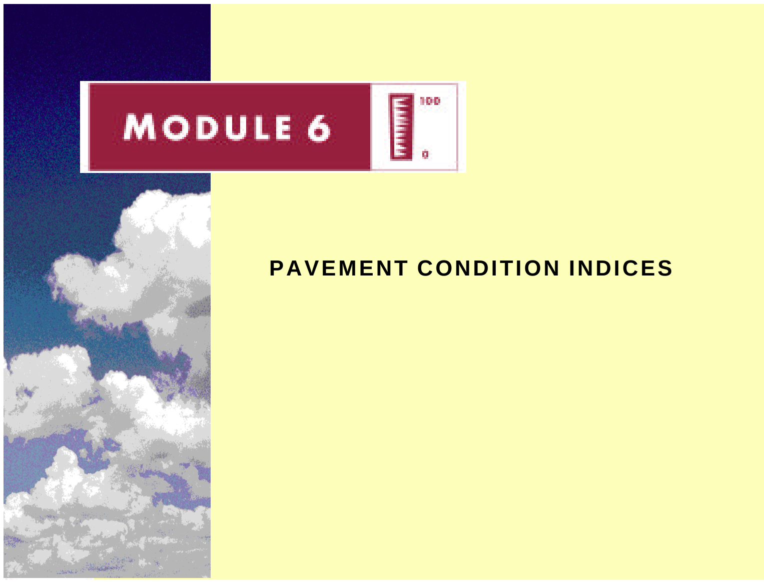
This module is taught through Slide presentations and discussion with the participants.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

Slide 6-1



Slide 6-1

Notes:

Slide 6-2

6

Instructional Objectives

- **Historic development of pavement condition indices**
- **The basic functions of condition indices in PMS**
- **Different types of condition indices**
- **Development of a pavement condition index**

Slide 6-2

Notes:

This module describes the historic development of pavement condition indices, the different types of indices, and their basic functions in a PMS. The module will also go into some detail as to how they may be developed and how they are computed. Several case studies are presented as examples of the use of different indices in a PMS.

Slide 6-3

6

Present Serviceability Rating

PSR	Description
5.0 to 4.0	Very Good
3.9 to 3.0	Good
2.9 to 2.0	Fair
1.9 to 1.0	Poor
0.9 to 0.0	Very Poor

Slide 6-3

Notes:

One of the earliest pavement condition indices was the Present Serviceability Rating (PSR). The PSR was developed at the AASHO Road Test by having raters assign a pavement condition value that indicated the level of service the pavement provided.

The PSR was based on a 5-point scale with 5 being very good and 1 being very poor. In actual operation however the effective range of the scale was more constrained. Most new pavements are seldom rated better than 4.2 to 4.5 and the AASHO Test Road's pavement sections were taken out of service at a PSR rating of 1.5 for safety reasons. Thus the effective range is about 3 points.

The FHWA guidelines for collecting the PSR by panel rating are shown in this slide.

Slide 6-4

6

Present Serviceability Index

$$PSI = 5.02 - \log(1+SV) - 1.38(RD)^2 - 0.01(C+P)^{1/2}$$

Where:

- **PSI** = Statistical estimate of the Mean PSR
- **SV** = Slope variance (roughness)
- **RD** = Rut Depth
- **C** = Cracking (ft^2 / 1000 ft^2)
- **P** = Patching (ft^2 / 1000 ft^2)

Slide 6-4

Notes:

Researchers wanted, however, to measure this index objectively. The new index, which was based on the values of pavement smoothness, rutting cracking and patching was called the Present Serviceability Index (PSI).

This equation for PSI predicts PSR based on the objective measurements of roughness, rut depth, cracking, and patching. Note that this equation is a product of a multivariate regression analysis of the panel ratings and the distress measurements for the various pavement sections on the Test Road. The coefficients before each independent variable indicates its relative contribution to the final index. PSI is primarily an indicator of pavement roughness. Though this index was not originally intended for use in PMS, it is now used in quite a few PMS.

Slide 6-5

Need for Pavement Distress Indices

- **Trigger treatments**
- **Calculating life-cycle costs**
- **Evaluate network conditions**
- **Compare roads with different distress**

Slide 6-5

Notes:

Need for Pavement Distress Indices

- Trigger treatments
- Calculating life-cycle costs
- Evaluate network conditions
- Compare roads with different distress

Slide 6-6

Pavement Condition Indices Development

Computed using a very simple deduct based formula:

- **$PCI = PCI_{max}$ - Deduct Value**
- ***Example***

100 - 40 = 60

Slide 6-6

Notes:

The concept of deduct values is described by its name. The index is calculated by deducting a number of points from the index value of a pavement in perfect condition. The value deducted from a perfect index depends on the condition of the pavement. The number of points deducted is called the deduct value. (Equation 6.2).

Slide 6-7

Pavement Condition Indices Development (cont'd)

- Transform pavement condition data into pavement condition indices
- Deduct values developed for various levels of distress severity and extent
- Two basic approaches
  - Expert opinion
  - Engineering criteria

Slide 6-7

Notes:

The relative value of the pavement distress index which represents the condition of the pavement and the shape of the resulting pavement deterioration curve (graph of the pavement distress index with time), depends entirely upon the development of the deduct values. Two basic approaches are often used to develop deduct value: (1) expert opinion, and (2) engineering or mathematical. Both approaches have many variations.

Development and calibration of deduct values is the most complicated and critical part of developing a pavement condition index.

Slide 6-8

Deduct Value Table

From Expert Opinion

Severity	Extent (%)				
	None	1 – 10	10 - 25	25 - 50	> 50
Low	0	20	30	40	50
Medium	0	35	40	60	75
High	0	50	60	80	100

Slide 6-8

Notes:

The next step now is to see how the distress index changed over time. To do this we need deduct values for each of the cells. This slide (Table 6.4) shows an assumed set of deduct values assigned by expert opinion.

Slide 6-9

Example: Pavement Distress Trend

Severity	Extent (%)				
	None	1 – 10	10 - 25	25 - 50	> 50
Low	a 2	a 4	a 6 a 8		
Medium			a 10	a 12 a 14	
High				a 16	

Slide 6-9

Notes:

Consider the following example of historic deterioration trends for a typical road. This slide shows pavement condition ratings over eight consecutive condition surveys. These eight surveys were conducted every two years, for sixteen years. Together, then, the eight condition surveys indicate how the condition of the road changed during those sixteen years. (Table 6.3)

Slide 6-10

Pavement Distress Curve

- **Plot condition index versus age**
- **Produces a pavement performance curve**
- **Shape and trend of resulting curve is dependent on deduct value developed**

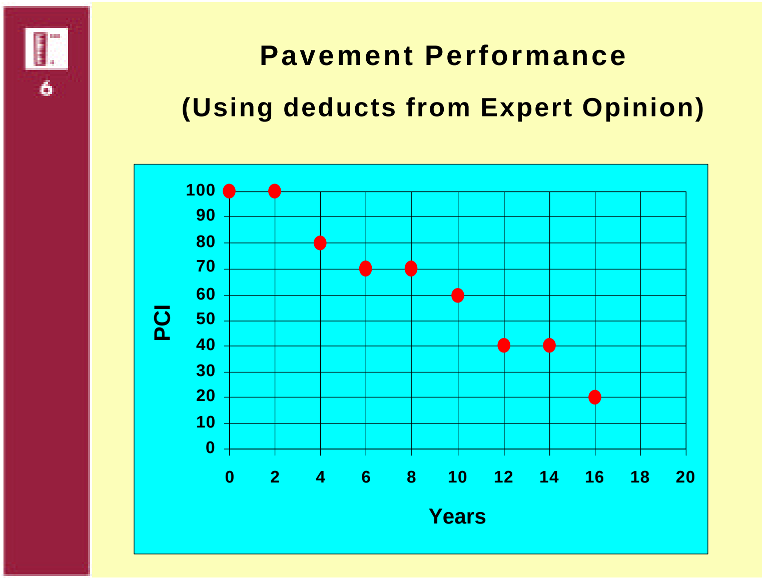
Slide 6-10

Notes:

<u>Pavement Distress Curve</u>

§ Plot condition index versus age
§ Produces a pavement performance curve
§ Shape and trend of resulting curve is dependent on deduct value developed

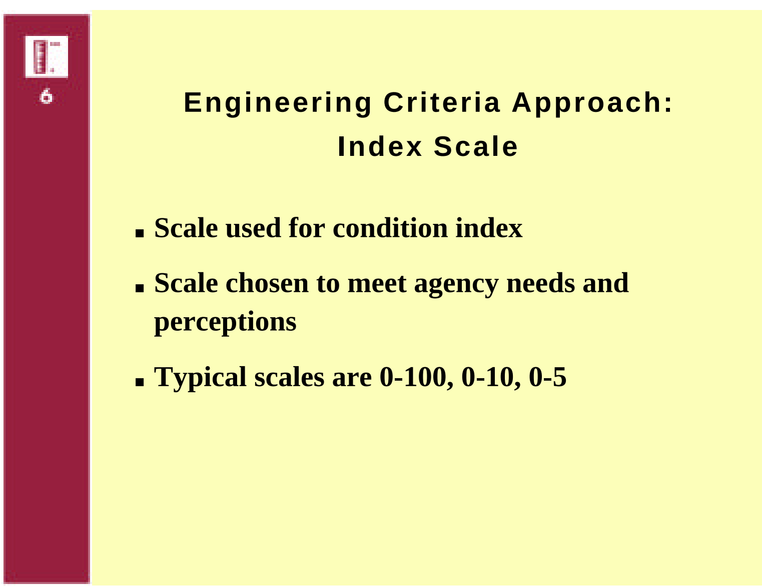
Slide 6-11



Notes:

Ask class to explain diagram.

Slide 6-12



Slide 6-11

Notes:

Plotting the condition index versus age for our example road gives the curve shown in Figure 6.2. The shape of this curve is totally dependent on the deduct values assigned by the experts, and the path through the distress matrix as shown on earlier slides. When one of the deduct values change, a point will move on the curve and it will change its shape. Also, two roads could take two entirely different paths through the matrix. This too would change the shape of the performance curve.

Slide 6-12

Notes:

One of the best introductions to developing individual condition indices is given by Baladi and Snyder in their class workbook for their Highway Pavements NHI class. The following section is paraphrased from their work. The authors introduce three terms which are essential for developing individual condition indices:

- Index scales
- Threshold value
- Engineering criteria

The first step in developing your individual indices will be to decide on a scale. Use 0 (bad) to 100 (good) as an example. Notice the minimum and maximum are only examples, and the fact that the scale decreases with decreasing condition is also only an example. There are other procedures.

Slide 6-13

Engineering Criteria Approach: Threshold Value

- Index value representing unacceptable pavement condition
- Typically taken as middle of an index scale, such as 50 (0-100 scale) or 2.5 (0-5 scale)
- May be set to represent a range such as 40 to 60 (0-100 scale) or 2 to 3 (0-5 scale)

Slide 6-13

Notes:

Engineering Criteria Approach: Threshold Value

§ Index value representing unacceptable pavement condition
§ Typically taken as middle of an index scale, such as 50 (0-100 scale) or 2.5 (0-5 scale)
§ May be set to represent a range such as 40 to 60 (0-100 scale) or 2 to 3 (0-5 scale)

Slide 6-14

Engineering Criteria Approach: Engineering Criteria

- Pavement distress level (severity, extent), considered unacceptable
- Amount of distress for each severity level where action should be taken to correct distress
- May be numerically different for various types of distress

Slide 6-14

Notes:

Engineering Criteria Approach: Engineering Criteria

§ Pavement distress level (severity, extent), considered unacceptable
§ Amount of distress for each severity level where action should be taken to correct distress
§ May be numerically different for various types of distress

Slide 6-15

Engineering Criteria Example

- Use a 100 to 0 Scale
- Set Threshold Condition Value at 50
- Set Engineering Criteria

  90% Low Severity Cracking

  25% Medium Severity Cracking

  15% High Severity Cracking

Slide 6-15

Notes:

Engineering Criteria Example

§ Use a 100 to 0 scale
§ Set Threshold Condition Value at 50
§ Set Engineering Criteria
  90% Low Severity Cracking
  25% Medium Severity Cracking
  15% High Severity Cracking

Slide 6-16

Engineering Criteria Example

- Develop Plot of Deduct Values

  - All three severities start at 0 and pass through the threshold value of 50 at the engineering criteria selected

  - In this example they pass through the threshold value of 50 at 15%, 25%, and 90% for low, medium and high severity cracking

Slide 6-16

Notes:

Engineering Criteria Example

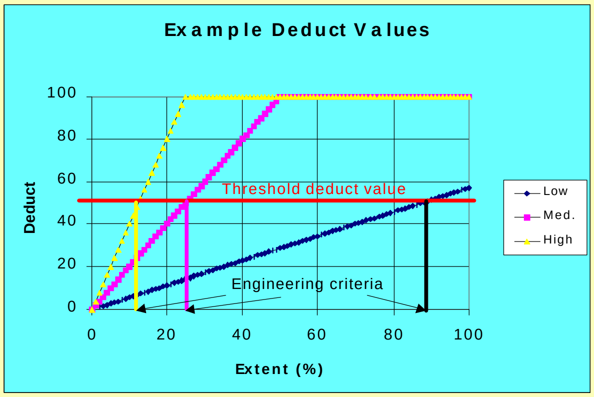
§ Develop Plot of Deduct Values

  - All three severities start at 0 and pass through the threshold value of 50 at the engineering criteria selected

  - In this example they pass through the threshold value of 50 at 15%, 25%, and 90% for low, medium and high severity cracking

Slide 6-17

Development of Deduct Values



Slide 6-17

Notes:

To use this graph (Figure 6.2), enter an extent on the x-axis, go up to the respective severity line, and then across to get the deduct value for the y-axis.

Slide 6-18

Engineering Criteria Example

- **Develop Final Deduct Values from relationships shown on plot**
- **The Deduct Values may be developed as set of continuous functions which may be shown as:**
  - **- a plot on a chart**
  - **- a formula**
  - **- a set of deduct tables**

Slide 6-18

Notes:

Engineering Criteria Example

§ Develop Final Deduct Values from relationships shown on plot

§ The Deduct Values may be developed as set of continuous functions which may be shown as a plot on a chart or as a formula, or as a set of deduct tables

Slide 6-19

Example Deduct Value Table

(Straight Line approach)

Severity	Extent (%)				
	None	1 – 10	10 - 25	25 - 50	> 50
Low	0	3	10	21	43
Medium	0	10	35	75	-
High	0	20	70	-	-

Slide 6-19

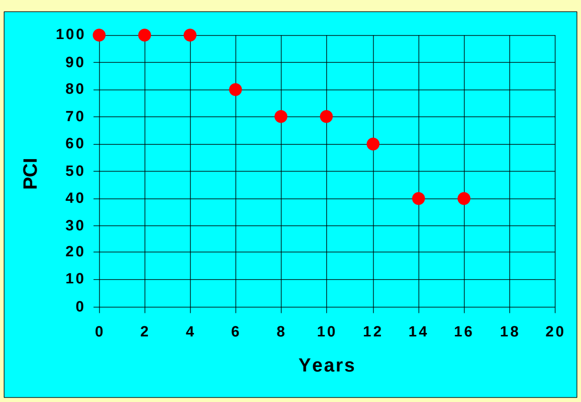
Notes:

Table 6.5 shows a matrix of the deduct values that result from using Equation 6.3 shown above for each severity level in the example. To get these deduct values we assumed the extent for each severity was the midpoint in the range, and found that point on the respective line from the graph. For example, 5 is used for the 1-10 range, and 17.5, 37.5 and 75, respectively for the other ranges.. The threshold value of 60, and the engineering criteria of 70, 20 and 10 were also used.

Slide 6-20

Pavement Performance

Using deducts from Engineering Criteria



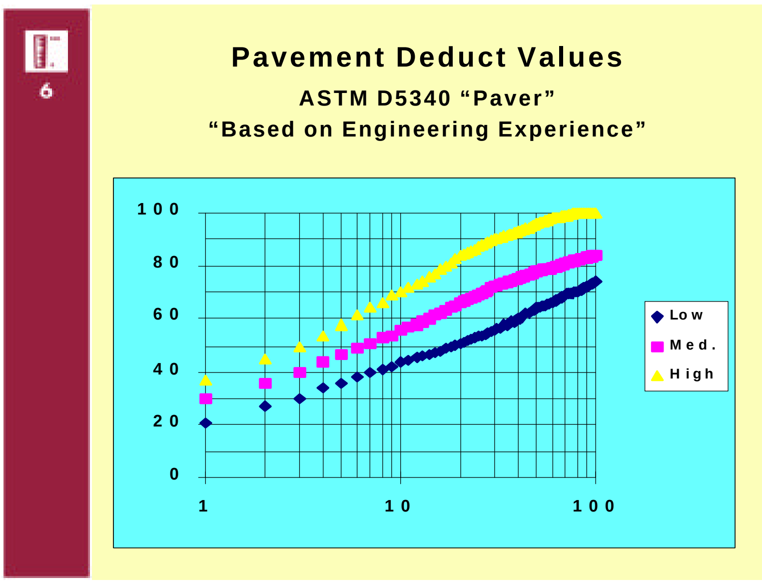
Slide 6-20

Notes:

<u>Pavement Performance</u>

Using deducts from Engineering Criteria

Slide 6-21

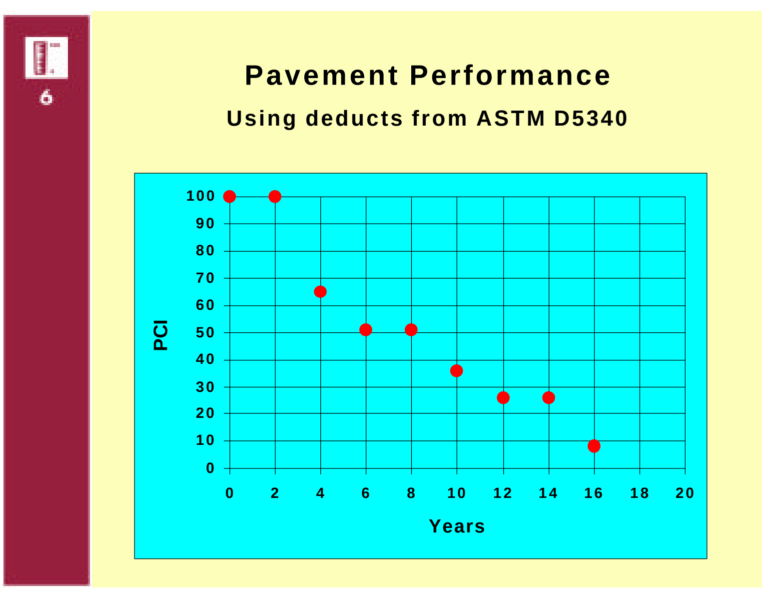


Slide 6-21

Notes:

ASTM D5340 gives a set of deduct value versus extent curves based on work done by Shahin et al. These curves are different from Baladi and Snyder's because they used a curved line on a semi-log graph as opposed to a straight line on a normal graph. Figure 6.4 illustrates the curves given for alligator (fatigue) cracking.

Slide 6-22

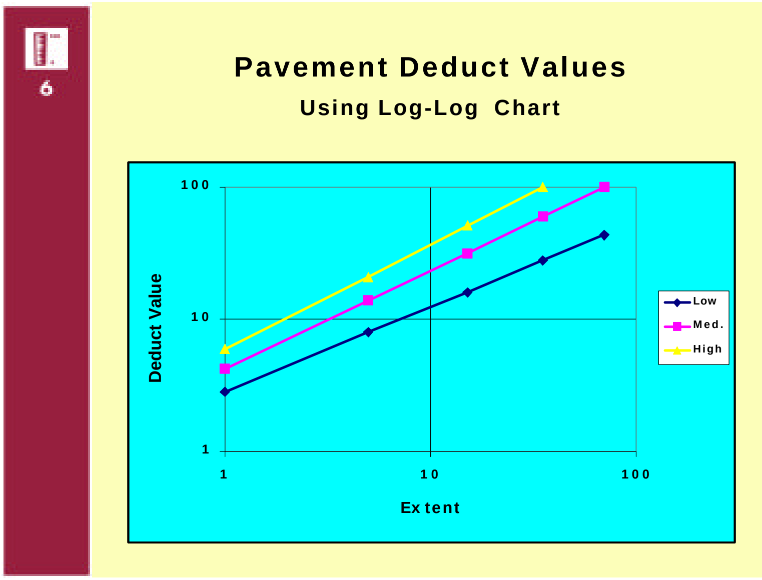


Slide 6-22

Notes:

This graph (Figure 6.5) shows the performance curve which using the new deduct values. This time we see an improvement from age 6 to age 8. The important thing to notice regarding this curve is the fact that it is concave upwards. This happens because of the huge initial deduct values.

Slide 6-23



Slide 6-23

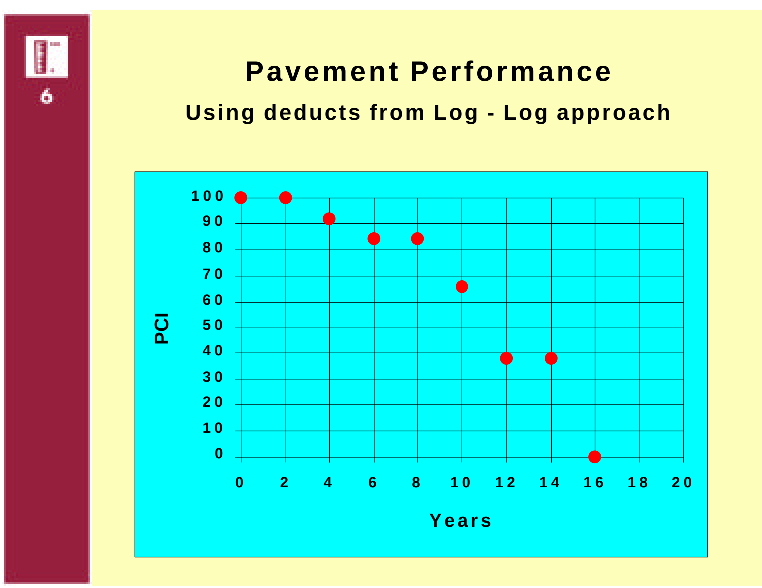
Notes:

A variation of the straight line approach by Baladi was used in the development of pavement distress indices in South Dakota.

These curves are different from both previous examples because they use a straight line on a log-log graph. Figure 6.6 illustrates the curves developed for alligator (fatigue) cracking from South Dakota.

The resulting matrix of these deducts is shown in Table 6.7. Once again, curves at the midpoint of the extent range were used to get these deduct values.

Slide 6-24



Slide 6-24

Notes:

This slide shows the performance curve which results from following the same path through the matrix using the new deduct values. This time we see an improvement from age 12 to age 14. The important thing to notice regarding this curve is the fact that it is concave downwards. (Figure 6.7)

Slide 6-25

Distress Index Development
Basic Criteria

- **Scaled deduct values so resulting condition index threshold value occurs near middle of scale**
- **Transition of deduct values should produce reasonable smooth performance curve matching trends of distress observed in field**

Slide 6-25

Notes:

Distress Index Development
Basic Criteria

§ Scaled deduct values so resulting condition index threshold value occurs near middle of scale
§ Transition of deduct values should produce reasonable smooth performance curve matching trends of distress observed in field

Slide 6-26

Current Practices

- **1994 - NCHRP Synthesis 203 survey**
- **50 states / 9 provinces**
- **Roughness (IRI) use increased sharply**
- **Structural capacity - vary widely**
- **Friction / skid testing - not common at network level**

Slide 6-26

Notes:

Current Practices

§ 1994 – NCHRP Synthesis 203 survey
§ 50 states / 9 provinces
§ Roughness (IRI) use increased sharply
§ Structural capacity – vary widely
§ Friction / skid testing – not common at network level

Slide 6-27

Current Practices

- **Distress info - most variation**
  - field procedure
  - distress definitions
- **Little opportunity to exchange information**
- **Approximately. 80% of agencies use**
  - distress index
  - serviceability index / rating
  - priority rating
- **No evident trends in development**
- **67% use composite indices (roughness)**

Slide 6-27

Notes:

Current Practices

§ Distress info – most variation
- field procedure
- distress definitions

§ Little opportunity to exchange information

§ Approximately 80% of agencies use
- distress index
- serviceability index / rating
- priority rating

§ No evident trends in development

§ 67% use composite indices (roughness)

Slide 6-28

Instructional Objectives

- **Historic development of pavement condition indices**
- **The basic functions of condition indices in PMS**
- **Different types of condition indices**
- **Development of a pavement condition index**

Slide 6-28

Notes:

Review the objectives for this module.

MODULE 7

ESAL FLOW MAPS

Purpose:

The purpose of this module is to decribe the basic concepts of characterizing truck loading by the use the Equivalent Single Axle Loads (ESAL), and how they are determined. They will be able to understand the application of ESAL's rather than basic traffic volumes in PMS. They will also better understand how to produce accurate ESAL estimates considering daily, monthly and seasonal truck flows for use in pavement management systems and in pavement design.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Describe what ESALs are and why they are used in pavement design and in PMS
- Describe how ESALs are determined and what measurements are needed to develop an ESAL flow map
- Describe the basic equipment needed and what sampling plan may be required to collect sufficient truck volumes and classifications to develop reasonably accurate ESAL estimates for PMS and pavmeent design needs
- Understand the benefits of having more complete ESAL estimates in a PMS and how they can be used to improve the analysis and project selection

Reference:

Module 7 of the Course Workbook

Duration:

45 minutes

Equipment:

Laptop computer, multi-media projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

30 Microsoft PowerPoint® Slides

Approach:

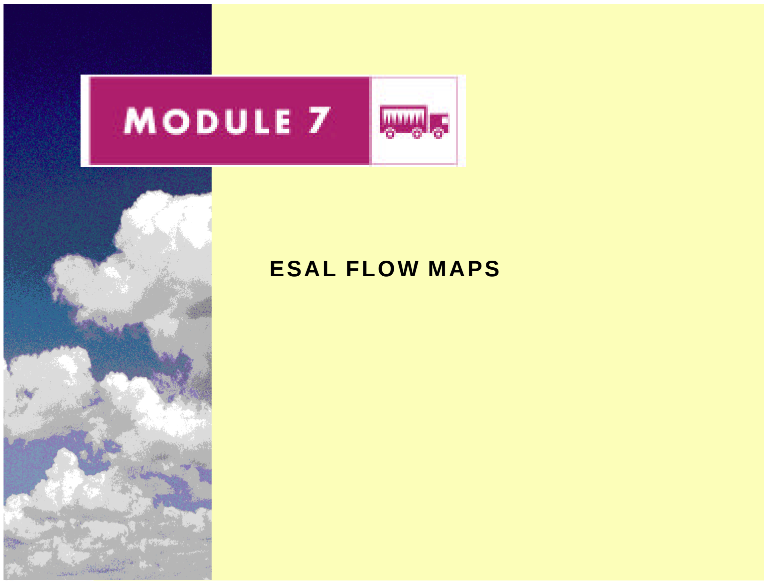
This module is taught through slide presentations and discussion with the participants. As an overall introduction to the principles of ESAL flow maps, it is important that the participants develop an understanding of these principles.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on distance learning for this module. All slides prepared will also be applicable in a distance learning course.

Slide 7-1



Slide 7-1

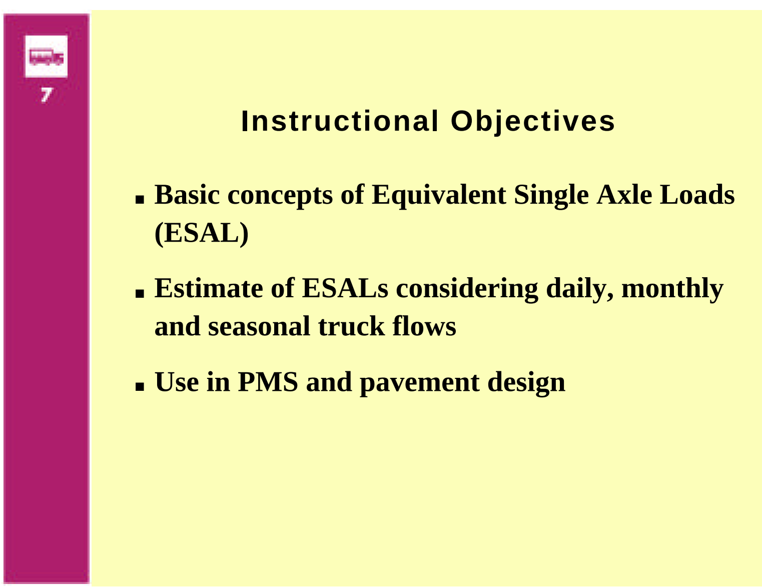
Notes:

Module 7 introduction slide.

This module is targeted towards states.

For an 8000-mile network, costs average approximately $1.00 to $1.50/year to collect data.

Slide 7-2



Slide 7-2

Notes:

<u>Instructional Objectives</u>

§ Basic concepts of Equivalent Single Axle Loads (ESAL)

§ Estimate of ESALs considering daily, monthly and seasonal truck flows

§ Use in PMS and pavement design

Slide 7-3

Load Equivalency

$$\text{LEF} = \frac{\text{No. of 18 kip ESAL to cause loss of serviceability}}{\text{No. of X kip axle loads to cause same loss}}$$

Where:

X = Axle load for which equivalency is calculated.

Slide 7-3

Notes:

The standard axle used by most highway agencies and design procedures is the 18-kip (80 kN) single axle. The basis for the conversion of the mixed traffic loads to the equivalent number of standard axle load applications was developed from data collected at the AASHO Road Test, conducted in Ottawa, Illinois from 1958 to 1960.

At the Road Test, similar pavement designs were loaded with different axle types and loadings so that the direct effect of each axle type and load on pavement damage (expressed in terms of present serviceability loss) could be ascertained. A load equivalency factor was defined as shown on this slide.

Slide 7-4

Load Equivalency

Example:

- 100,000 reps of a 18 kip (SAL)
- 14,347 reps of a 30 kip load (SAL)
- Find LEF 30 kip SAL
- $\text{LEF}_{\text{30-kip single}}$ = 100,000/14,347 = 6.97

Slide 7-4

Notes:

As an example consider two identical pavement structures that are subjected to loadings from two different axle types.

Assume that the first pavement structure sustains 100,000 applications of an 18-kip (80 kN) single axle for a serviceability drop from 4.2 to 2.5, while the second pavement structure sustains 14,347 applications of a 30-kip (133 kN) single axle for the same serviceability loss.

The load equivalency factor for the 30-kip (133 kN) single-axle load is then 6.97.

This means that 14,347 passes of the 30-kip (133 kN) single axle produce as much damage as 100,000 applications of the 18-kip (80 kN) single axle.

Slide 7-5

Estimate of Relative Damage Fourth Power *Law*

Relative Damage = (Ratio between axle loads)^4

Example :

Relative damage 30 kip single axle compared to 18 kip single axle.

LEF = $(30{,}000/18{,}000)^4$ = **7.71**

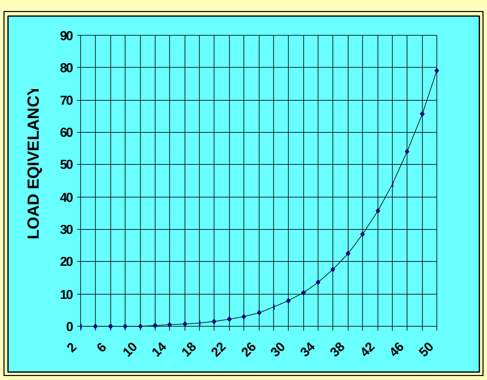
Slide 7-5

Notes:

The traditional relationship between pavement damage and the applied load is that damage increases to the fourth power as the axle load increases. For example, in the above table where the load is doubled (15-kip [67 kN] single axle to 30-kip [133 kN] single axle and 18-kip [80 kN] tandem axle to 36-kip [160 kN] tandem axle), the LEF increases approximately by a factor of 2^4, or 16.

Slide 7-6

Single Axle Load Equivalency



Slide 7-6

Notes:

This concept is illustrated in Figure 7.1, which shows the increase in the damage factor (LEF) as the gross axle load is increased. The benefits of distributing a load over a tandem axle are also apparent, as for the same gross weight the damage factors are much less for the tandem axle than for the single axle.

Kentucky allows coal trucks (40k single axles) on state highways. They actually damaged the steel plates used for W/M.

Slide 7-7

Truck Factor

- Average amount of damage done by one vehicle in terms of ESALs
- May be for all trucks (ie. 1 ESAL / Truck)
- Best if expressed for various vehicle classes

Slide 7-7

Notes:

While the LEFs provide a means of expressing equivalent levels of damage between axles, it is more convenient to express that damage in terms of the average amount of damage inflicted by a particular vehicle. That is, the average damage done by each axle on a vehicle are added together and expressed as the total amount of damage done by the passing of that one vehicle.

Slide 7-8

Example of Increase In Truck Factor

Rural Interstate Flexible Pavement

Year	T F (ESAL /Truck)
1971	0.595
1975	0.691
1979	0.766
1982	0.929
1985	0.992

Slide 7-8

Notes:

The observation of historical increases in the truck factor is illustrated in the following change in the average truck factor (all trucks except panels and pickups) for rural Interstate flexible pavements from 1971 to 1985.

- § Deregulation caused a significant jump in the truck factor.
- § Went from 5 axle trucks in 1971 to 9 axle trucks today.

Slide 7-9

Truck Weight Data Collection

- Permanent weigh stations
- Portable static scales
- Weigh-in-motion (WIM)

Slide 7-9

Notes:

The collection of accurate and representative truck weight data is extremely critical in estimating past or future traffic loadings. Axle type and loading has a large impact on the damage done to a pavement. In fact, axle type and weight are far more critical for pavements than vehicle gross weight. Two different trucks could have the same gross weight but cause greatly different amounts of damage to a pavement, depending upon their axle configuration.

Bypass routes to avoid states.

Slide 7-10

Components of a Monitoring System

- Truck volume by classification
- Volume growth rate for each truck class
- Truck factor for each truck class and growth rate
- Lane distribution for the truck traffic
- Variation in average weight of each truck type
- Percent of ESAL occurring each month

Slide 7-10

Notes:

<u>Components of a Monitoring System</u>

§ Truck volume by classification

§ Volume growth rate for each truck class

§ Truck factor for each truck class and growth rate

§ Lane distribution for the truck traffic

§ Variation in average weight of each truck type

§ Percent of ESAL occurring each month

Slide 7-11

ESAL Flow Maps

- Development of a truck flow map or ESAL traffic load file for PMS
- Florida and Washington data used

Slide 7-11

Notes:

This last section of this module recommends procedures Highway Agencies can use to determine the location and frequency of their truck monitoring activities. The objective of the procedures is to help an agency design a program that cost-effectively meets its needs for truck traffic load data within its overall pavement management structure. The general recommendations are based on a series of analyses performed with WIM data from Florida and WIM and vehicle classification data from Washington. This section has been largely extracted from the Final Report from Research Project T9233, Task 16 “Truck Flows and Loads for Pavement Management” by Mark Hallenbeck and Amy J. O’Brien.

Slide 7-12

ESAL Flow Maps Calculation

- Determine number and distribution of AVC and WIM devices
- Adjust data from short duration AVC and WIM to estimate average annual conditions
- Appropriate length of short duration counts to meet required needs

Slide 7-12

Notes:

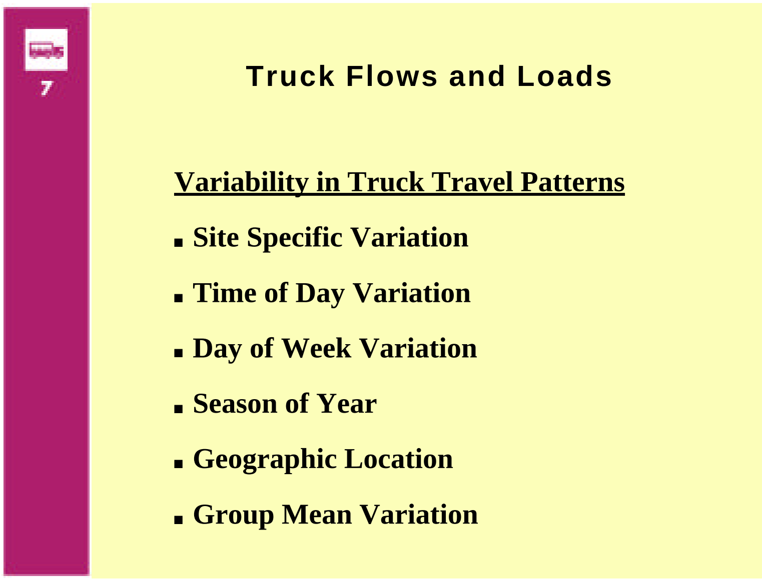
ESAL Flow Maps Calculation

§ Determine number and distribution of AVC and WIM devices

§ Adjust data from short duration AVC and WIM to estimate average annual conditions

§ Appropriate length of short duration counts to meet required needs

Slide 7-13



Slide 7-13

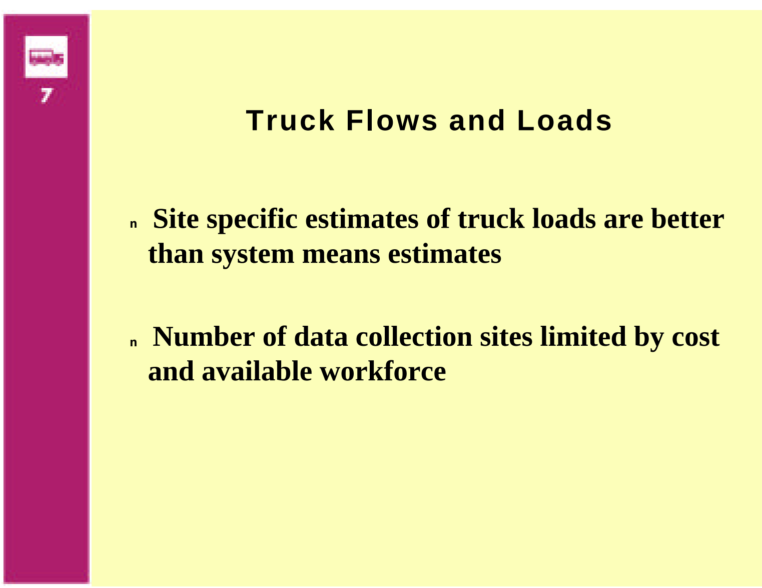
Notes:

Truck Flows and Loads

Variability in Truck Travel Patterns:

- Site Specific Variation
- Time of Day Variation
- Day of Week Variation
- Season of Year
- Geographic Location
- Group Mean Variation

Slide 7-14



Slide 7-14

Notes:

Truck Flows and Loads

- Site specific estimates of truck loads are better than system means estimates
- Number of data collection sites limited by cost and available workforce

Slide 7-15

Design of a Continuous Data Collection Program for Vehicle Classification and Weight

- **Determine number of continuously operating WIM sites needed**
- **Determine number of continuously operating AVC sites needed**
- **Develop truck load (ESAL) file for road network based on annual estimates using data measured on "similar" roads**

Slide 7-15

Notes:

Design of a Continuous Data Collection Program for Vehicle Classification and Weight

§ Determine number of continuously operating WIM sites needed

§ Determine number of continuously operating AVC sites needed

§ Develop truck load (ESAL) file for road network based on annual estimates using data measured on "similar" roads

Slide 7-16

To Determine the Number of WIM Sites Needed

Step 1: Create Groups of Roads
Step 2: Determine homogeneity of groups
Step 3: Determine number of sites needed

Slide 7-16

Notes:

The number of continuously operating WIM sites that are needed within each state will vary from state to state, depending on the variability of truck traffic in the state and the accuracy with which the state wishes to estimate average damage factors and other group statistics. The greater the variability of truck patterns is within an agency (either seasonal or geographic), the greater is the number of sites required. The more homogeneous the truck traffic is, the smaller is the number of continuously operating sites required.

The basic steps listed in this Slide are recommended to establish the optimum number of WIM sites.

Slide 7-17

Create Groups of Roads

- **Divide network into reasonably homogeneous truck populations and patterns**
- **Subdivide to get lower variability**

Slide 7-17

Notes:

Create Groups of Roads

§ Divide network into reasonably homogenous truck populations and patterns

§ Subdivide to get lower variability

Slide 7-18

Determine Homogeneity of Groups

- **Examine similar travel patterns**
- **Plot the daily damage factors over time and compare plots for different sites within each group**

Slide 7-18

Notes:

Determine Homogeneity of Groups

§ Examine similar travel patterns

§ Plot the daily damage factors over time and compare plots for different sites within each group

Slide 7-19

Determine the Number of Sites Needed

$$n = [(Z)(S_o)/d]^2$$

where:

n = number of sites required.

Z = Z-score for the desired level of confidence

S_o= Standard deviation of the group damage factor

d = desired precision or allowable error expressed in damage factor units (ESALs)

Slide 7-19

Notes:

Determine the Number of Sites Needed

Slide 7-20

Determine the Number of AVC Sites Needed

Step 1: **Calculate Seasonal & Day-of-Week Adjustment Patterns**

Step 2: **Create Groups of Roads.**

Step 3: **Determine Homogeneity of Groups.**

Step 4: **Determine number of sites needed.**

Slide 7-20

Notes:

Determine the Number of AVC Sites Needed

Step 1: Calculate Seasonal & Day-of-Week Adjustment Patterns

Step 2: Create Groups of Roads

Step 3: Determine Homogeneity of Groups

Step 4: Determine number of sites needed

Slide 7-21

Calculate Seasonal and Day of Week Adjustment Pattern

- **Calculate seasonal and day-of-week adjustment patterns for all sites**

Slide 7-21

Notes:

The first step is to calculate the seasonal and day-of-week adjustment patterns for all sites within an agency that have the appropriate data. (Sites to be used in this effort must have continuously operating WIM or vehicle classifier equipment functioning for at least one year.) To simplify the factor process, the day-of-week and seasonal adjustment patterns should be combined into one factor.

Slide 7-22

Create Groups of Roads

- **Develop groups with relatively similar truck volume patterns**
- **Road groups may be different from the damage factor groups developed for WIM site development**

Slide 7-22

Notes:

Create Groups of Roads

§ Develop groups with relatively similar truck volume patterns

§ Road groups may be different from the damage factor groups developed for WIM site development

Slide 7-23

Determine Homogeneity of the Groups

- **Determine acceptability of initial road groups by computing mean and standard deviation of seasonal factors**

Slide 7-23

Notes:

Determine Homogeneity of the Groups

§ Determine acceptability of initial road groups by computing mean and standard deviation of seasonal factors

Slide 7-24

Determine the Number of Sites Required

$$n = [(Z)(S_o)/d]^2$$

where:

n = number of sites required

Z = Z-score for desired level of confidence

S_o = Standard deviation of group damage factor

d = Allowable error expressed as fraction of mean seasonal factor for group

Slide 7-24

Notes:

The equation shown on this Slide is used to determine the number of sites required.

The greater the precision or the coefficient of variation of the damage factors that is desired, the greater the number of data collection points required

Slide 7-25

Develop ESAL File

- Develop ESAL file in same processes and same file format as annual daily traffic volume file

Slide 7-25

Notes:

Develop ESAL File

§ Develop ESAL file in same processes and same file format as annual daily traffic volume file.

§ Took 10 years to develop in WA. Very expensive to develop and maintain.

Slide 7-26

Cost Estimate

- Based on WSDOT Highway Network
- Following Guidelines which were first developed by a Data Rationalization Study

Slide 7-26

Notes:

Cost Estimate

§ Based on WSDOT Highway Network

§ Following Guidelines which were first developed by a Data Rationalization Study

Slide 7-27

Cost Estimate

- 21 WIM sites needed for 10,000 kilometer Network across all functional classes
- Initial Cost approximately $1,000,000 for installation of 21 WIM Sites
- Annual Operations cost about $750,000 with staff of 12

Slide 7-27

Notes:

Cost Estimate

§ 21 WIM sites needed for 10,000 kilometer Network across all functional classes

§ Initial Cost approximately $1,000,000 for installation of 21 WIM sites

§ Annual Operations cost about $750,000 with staff of 12

Slide 7-28

Cost Estimate

- Installation costs based on 19 Piezo Cable systems and 3 Bending Plate Systems with two lanes monitored at each site
- Operational costs based on costs to calibrate sites, maintain sites and replace sites as they fail, plus occasional pavement repair to provide smooth approach to weight system

Slide 7-28

Notes:

Cost Estimate

§ Installation costs based on 19 Pizo Cable Systems and 3 Bending Plate Systems with two lanes monitored at each site

§ Operational costs based on costs to calibrate sites, maintain sites and replace sites as they fail, plus occasional pavement repair to provide smooth approach to weight system

Slide 7-29

Cost Estimate

- Approximately 60 permanent AVC Sites also required to be placed on all functional class highways
- Installation and operational costs about same for AVCs as for WIMs; AVC cost less and are more durable but 3 times number required
- AVCs already an integral part of monitoring program for AADT files

Slide 7-29

Notes:

<u>Cost Estimate</u>

§ Approximately 60 permanent AVC Sites also required also placed on all functional class highways

§ Installation and operational costs about the same for AVCs as for WIMs; AVCs cost less and are more durable but 3 times number required

§ AVCs already an integral part of monitoring program for AADT files

Slide 7-30

Summary

- Module focuses on how to obtain accurate traffic data
- Rough costs to develop and maintain WIM System to meet these guidelines
- Input data for use in PMS affect reliability of prediction models and pavement designs

Slide 7-30

Notes:

Examples from Florida and Washington in Instructor’s Guide.

Slide 7-31

7

Instructional Objectives

- **Basic concepts of Equivalent Single Axle Loads (ESAL)**
- **Estimate of ESALs considering daily, monthly and seasonal truck flows**
- **Use in PMS and pavement design**

Slide 7-31

Notes:

Review the objectives for this module.

MODULE 8

PERFORMANCE MODELS

Purpose:

This module introduces the use of pavement performance models to predict future pavement conditions for the highway network as part of the agency's pavement management activities. The types of models normally used at the network and project level are introduced and examples of the principal approaches are provided. Guidelines on determining the reliability of the performance models and update requirements are also provided.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Understand the use of performance models in pavement management.
- Identify the common modeling approaches used to develop models for pavement management.
- Understand methods for evaluating the reliability of the pavement performance models.
- Describe the requirements for updating the models over time.

Reference:

Module 8 of the Participant's Notebook

Duration:

100 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

43 Microsoft PowerPoint® Slides

Approach:

This module is taught through Slide presentations and discussion with the participants. The module provides an overview of the use of models in pavement management and introduces the most common modeling techniques. Examples from Washington State and Illinois are also provided.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

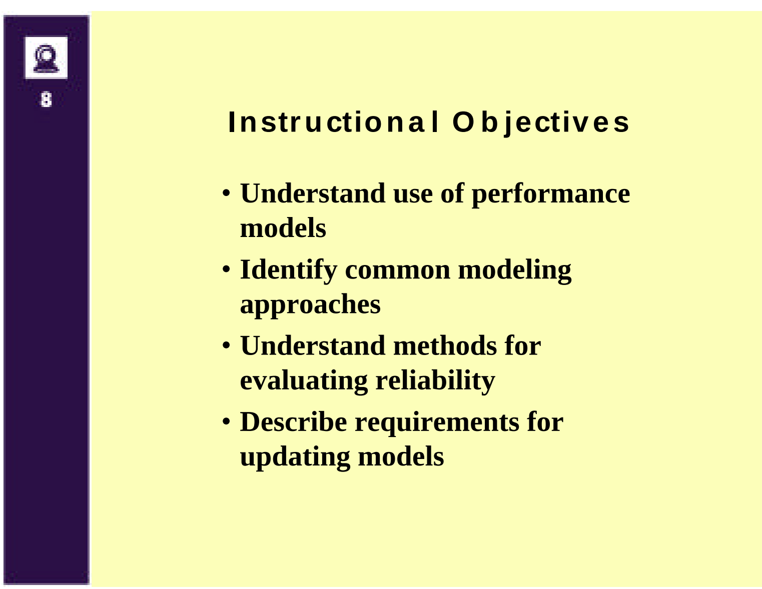
Slide 8-1

Slide 8-1

Notes:

Describe the purpose of this module and the approach that will be used.

Slide 8-2

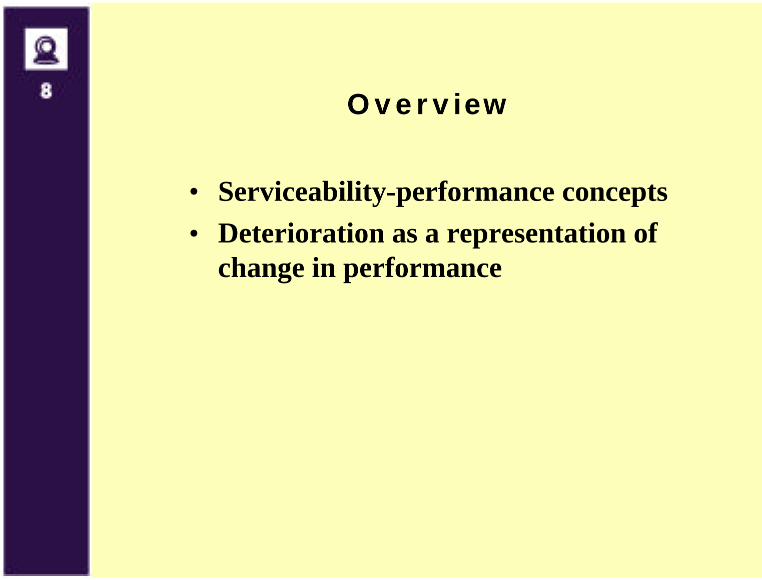


Slide 8-2

Notes:

Describe the objectives for this module. This Slide lists the information the participants will learn.

Slide 8-3



Slide 8-3

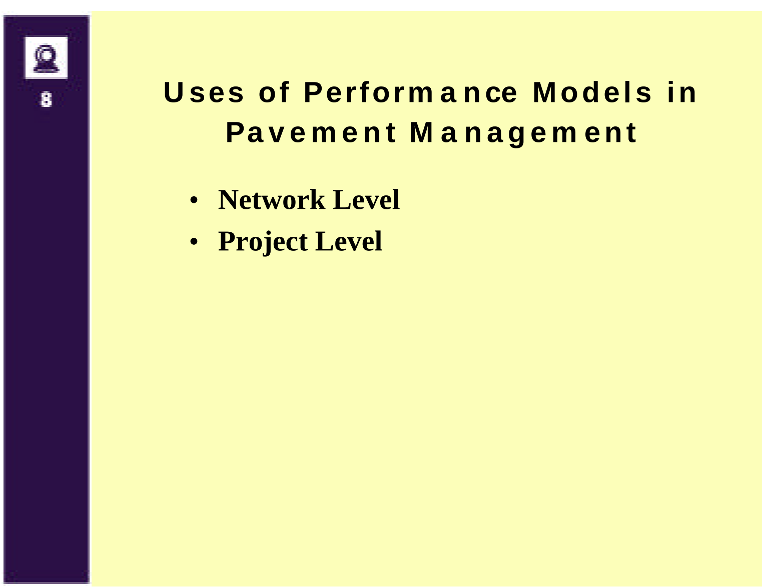
Notes:

Introduce the early work of Carey-Irick to define pavement performance in terms of serviceability-performance concepts.

Today, it is common practice among practitioners and researchers to use terms such as deterioration to represent the change in pavement performance over time.

For this course, performance models represent the pavement deterioration patterns that are modeled.

Slide 8-4



Slide 8-4

Notes:

Pavement performance models are an important component of a multi-year analysis for these types of activities.

Pavement performance models are used differently at the network and project levels. These are the primary activities that performance models are used for at the network level.

Discuss typical network-level modeling approaches

§ Deterministic models

§ Probabilistic models

Have participants read from text Page 8-2.

Slide 8-5

	Types of Performance Models						
	Deterministic				Probabilistic		
	Primary Response	Structural	Functional	Damage	Survivor Curves	Transition Process Models	
	• Deflection • Stress • Strain	• Distress • Pavement Condition	• PSI • Safety	• Load Equiv.		Markov	Semi-Markov
National Level				✔	✔	✔	✔
State or District Level		✔	✔	✔	✔	✔	✔
Project Level	✔	✔	✔	✔			

Slide 8-5

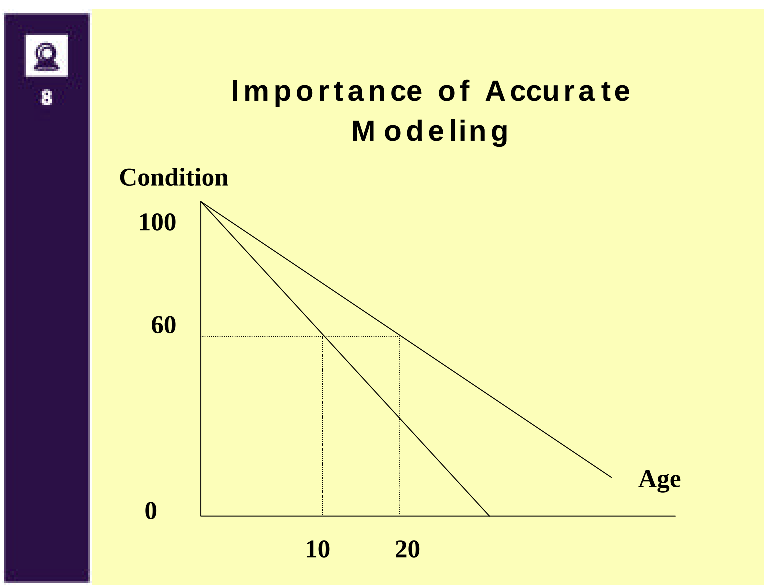
Notes:

This is Table 8.1 on Page 8-3. It shows the principal types of models used at different levels within transportation agencies.

Point out that higher levels of management are more interested in models that predict composite indexes of network condition. At the national level, models are used for policy and economic matters. At the district level, there is less concern about the performance of individual section and more of a focus on the overall condition of the pavement network for the entire state or a subset of the network.

Point out that at the project level, the focus is on the performance of individual sections or design approaches.

Slide 8-6



Slide 8-6

Notes:

This slide illustrates the importance of accurate models to predict future conditions. It is presented in the course materials as Figure 8.1. It illustrates that a pavement condition of 60 could be predicted in 10 years or 20 years, depending on which model is used.

Slide 8-7

Performance Model Development Criteria

- Adequate database
- Inclusion of all significant variables that affect performance
- Adequate functional form of the model
- Satisfaction of the statistical criteria concerning the precision of the model
- Understanding of the principles behind each modeling approach

Slide 8-7

Notes:

In 1980, Darter introduced the basic criteria that should be followed to develop reliable performance models. These criteria are included.

In addition to these points, it is important that the limitations of each model be understood so that they are not used outside of the range of their intended use.

Slide 8-8

Data Requirements

- Requirements vary depending on the type of model being developed
- Inventory Information
- Monitoring Data

Slide 8-8

Notes:

Depending on the type of model being developed, data requirements will vary.

At the most basic level, inventory and monitoring data re used to develop the models.

Examples of inventory information include geographic location or section length.

Examples of monitoring data include pavement condition, cracking quantities, and AADT.

<u>Data Requirements</u>

§ Requirements vary depending on the type of model being developed
§ Inventory information
§ Monitoring data

Slide 8-9

Lack of Historical Data

- **If historical databases are not available due to changes in survey procedures, new rehabilitation techniques, or other factors, other techniques are available:**
  - incorporate input from experienced practitioners
  - update the models as additional data are available

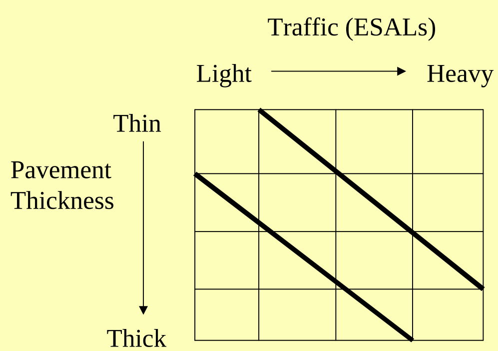
Slide 8-9

Notes:

This slide emphasizes that agencies do not have to wait until historical databases are available in order to develop performance models. Expert models have been used successfully in a number of agencies. They can be supplemented as field data become available.

Slide 8-10

On-the-Diagonal Issue



Slide 8-10

Notes:

This slide is Figure 8.2. It shows that it is difficult to observe differences in pavement performance at the network level due to factors such as traffic, material variances, and climatic conditions because these factors are accounted for in the design of the pavement structure through design programs. As a result, if an agency sought to model the effect of traffic on pavement performance, this is difficult to do without also looking at pavement thickness because the thickness is a related factor that is affected by the anticipated level of traffic. Without considering thickness data in the models, pavements with equal design periods would show little variation in condition with traffic alone.

Slide 8-11

Data Requirements

- **Sufficient amounts of data must be used**
- **Data must be measured accurately and without bias**
- **Data must be representative**
- **Data must be maintained over time**

Slide 8-11

Notes:

Data Requirements

§ Sufficient amounts of data must be used

§ Data must be measured accurately and without bias

§ Data must be representative

§ Data must be maintained over time

Slide 8-12

Model Limitations

- **Models must be used appropriately**
- **Limitations of models must be considered**
- **Boundary conditions should be identified and satisfied**

Slide 8-12

Notes:

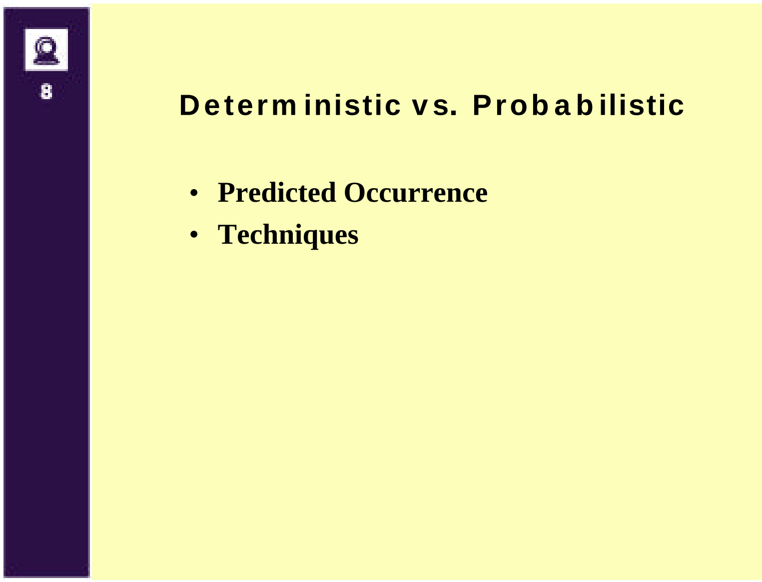
Model Limitations

§ Models must be used appropriately

§ Limitations of models must be considered

§ Boundary conditions should be identified and satisfied

Slide 8-13



Slide 8-13

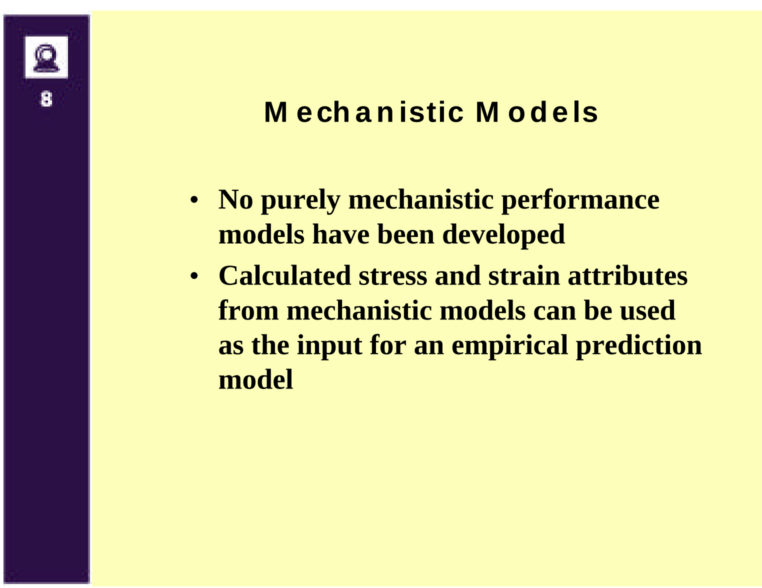
Notes:

A number of different types of deterministic models can be developed. This slide emphasizes the primary approaches used to develop deterministic models.

If deterministic models are not used, the agency probably uses probabilistic models.

To date, no purely mechanistic models have been developed because they are only applicable to calculating pavement response in terms of mechanisms such as stress, strain, or deflection. These factors could be used as the inputs for an empirical prediction model.

Slide 8-14



Slide 8-14

Notes:

<u>Mechanistic Models</u>

§ No purely mechanistic performance models have been developed

§ Calculated stress and strain attributes from mechanistic models can be used as the input for an empirical prediction model

Slide 8-15

8

Mechanistic-Empirical Models

- Models developed using pavement response as the dependent variable
- Use elements of both mechanistic models (fundamental principles of pavement behavior) and empirical models (results from experience or experiments)
- N = A * $(1/e)^B$

Slide 8-15

Notes:

Mechanistic-Empirical Models

§ Models developed using pavement response as the dependent variable

§ Use elements of both mechanistic models (fundamental principles of pavement behavior) and empirical models (results from experience or experiments)

§ N=A * $(1/e)^B$

Slide 8-16

8

Regression Analysis

- A technique used to determine the relationship between variables
- Often used in agencies with historical databases available

Slide 8-16

Notes:

Regression used when historical data are available.

Slide 8-17

Subjective Approaches

- Used in agencies that do not have historical data available
- Can be used to develop either deterministic or probabilistic models

Slide 8-17

Notes:

Subjective models are used when no historical data are available.

Slide 8-18

Development of Deterministic Performance Models

- Very common modeling techniques in pavement management
- Predict a single number based on its relationship with one or more variables
- Can be empirical or mechanistic-empirical correlations calibrated using regression
- Condition is modeled as a function of other variables

Slide 8-18

Notes:

Deterministic models are the most common types of models for pavement management.

With these models, some type of condition (such as an overall condition index or distress quantity) is modeled as a function of variables such as pavement age, traffic, environment, pavement construction characteristics, and maintenance and rehabilitation actions.

Slide 8-19

Regression Analysis

- **Statistical tool used to establish the relationship between two or more variables**
- **Models can be linear or non-linear, depending on the relationship between variables**

Slide 8-19

Notes:

Regression Analysis

- Statistical tool used to establish the relationship between two or more variables.
- Models can be linear or non-linear, depending on the relationship between variables.

Slide 8-20

Regression Model Forms

- **Linear Regression**
  - $Y = a + bX$
- **Multiple Linear Regression**
  - $Y = a_0 + a_1X_1 + a_2X_2 + . . . A_nX_n$
- **Non-Linear Regression**
  - $Y = a_0 + a_1X^1 + a_2X^2 + . . . A_nX^n$
  - Polynomial regression models may be constrained
  - Least squares fit is used to improve the models

Slide 8-20

Notes:

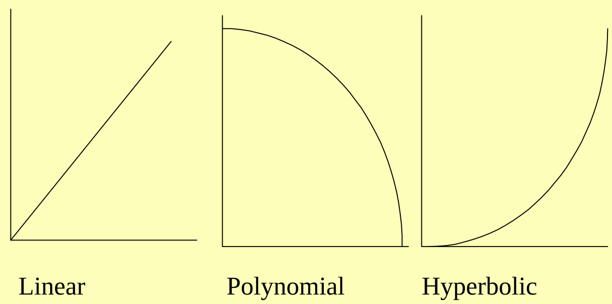
This slide shows the equations for various regression model forms.

In polynomial regression, the number of curves in the regression line is equal to one less than the degree of the polynomial. These curves may be constrained so that the curve can not increase over time.

The term least squares fit comes from the minimization of the squared differences between the actual data points and their corresponding points on the fitted line (or curve). Polynomial least squares models are popular for predicting the change in the dependent variable as a function of the independent variable(s).

Slide 8-21

Deterministic Model Forms



Slide 8-21

Notes:

The functional form of a performance model, or the way in which the variables are arranged, can only be determined through consideration of the actual relationships between the variables and the trends from the data on the plots.

These figures are shown in the notebook as Figure 8.3. It illustrates several types of deterministic model forms.

The individual developing the model must understand the relationships between the variables being considered in order to select the appropriate form.

Slide 8-22

Family Models

- **Reduces number of variables**
- **Group pavement sections by characteristics**
- **Assume similar deterioration patterns**
- **Reflects average deterioration for family**
- **Allows ranges of values to be used for developing families**

Slide 8-22

Notes:

<u>Family Models</u>

§ Reduces number of variables

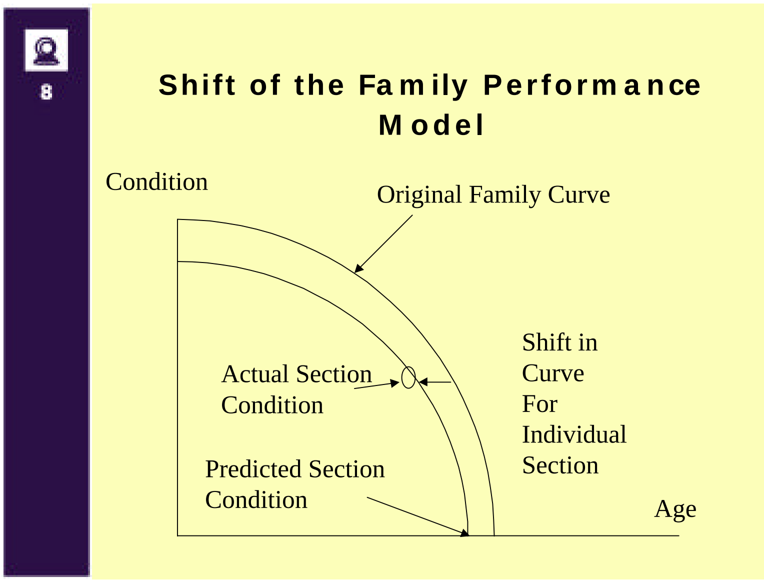
§ Group pavement sections be characteristics

§ Assume similar deterioration patterns

§ Reflects average deterioration for family

Allows ranges of values to be used for developing families

Slide 8-23



Slide 8-23

Notes:

Figure 8.4 discuss diagram.

The performance of each section is found by shifting the family curve to intersect the condition point for the section. The shift is always parallel to the family prediction curve.

Slide 8-24

Advantages/ Disadvantages to Family Models

- **Advantages**
- **Disadvantages**

Slide 8-24

Notes:

<u>Advantages/Disadvantages to Family Models</u>

§ Advantages
- Fairly easy to develop and interpret
- Reduces the number of variables in the model
- Allows ranges of values to be used rather than exact measurements

§ Disadvantages
- Does not explicitly deal with errors in data or model form
- Difficult to measure the effect of independent variables

Slide 8-25

Statistical Evaluation of Models

- Coefficient of determination (R2)
- Root mean square error (RMSE)
- Number of data points (n)
- Hypothesis tests on regression coefficients

Slide 8-25

Notes:

These are some of the statistical tools that are available for evaluating the fit of the performance models to the data from which they were developed.

Before performing a statistical evaluation, the agency must ensure that the form of its models adheres to the boundary conditions or other physical principles that influence the predicted value of the dependent variable.

Slide 8-26

Coefficient of Determination (R^2)

- Provides an indication of how much of the total variation in the data is explained by the regression equation or performance curve
- Network Level normally < 0.9
- Project Level normally > 0.9

Slide 8-26

Notes:

This test provides an indication of how much of the total variation in the data is explained by the regression equation or performance curve.

Slide 8-27

8

RM SE

- **Standard deviation of the predicted dependent variable value for a specific value of the independent variable**
- **Project Level: <=5**
- **Network Level: > 5**

Slide 8-27

Notes:

The RMSE is the standard deviation of the predicted dependent variable value for a specific value of the independent variable.

Root – Mean – Square – Error

This might be drawn graphically on a flipchart.

Slide 8-28

8

Other Tests

- **Number of Data Points**
- **Hypothesis Test of Regression Constants**

Slide 8-28

Notes:

. Other Tests

§ Number of Data Points should be at least 30 to test validity of regression equation.

Statistician should be involved in this process.

§ Hypothesis Test of Regression Constants

Slide 8-29

Limitation of Statistical Evaluations

- **Statistical analyses only evaluate reliability of model for data used in its development**
- **A model can be statistically valid but not representative of actual deterioration patterns of network if poor quality data are used**

Slide 8-29

Notes:

Limitation of Statistical Evaluations

§ Statistical analysis only evaluate reliability of model for data used in its development.

§ A model can be statistically valid but not representative of actual deterioration patterns of network if poor quality data are used.

Slide 8-30

Reliability of Performance Models

- **Network Level**
- **Project Level**

Slide 8-30

Notes:

Reliability of Performance Models

§ Network level
  - Transformations may be required
  - Correlations between independent variables may influence reliability
  - Significance of coefficients must be considered

§ Project level
  - Expect higher coefficients of determination and lower RMSE

Slide 8-31

8

Reliability of Performance Models

Regression Parameter Expectations				
PMS Analysis Level	**R^2**	**RMSE**	**Sample Size**	**# of Independent Variables**
Network	Medium to Low	Medium to Low	Large Sample	>1
Project	High	Low	Small Sample	1

Slide 8-31

Notes:

This is Table 8.3. It summarizes the expectations of regression parameters as a function of the use of the model at the network and project levels.

Slide 8-32

8

Update Requirements

- **Performance models must be updated regularly to continue to reflect deterioration patterns**
- **Feedback loops should be established to link deterioration models with engineering practices.**

Slide 8-32

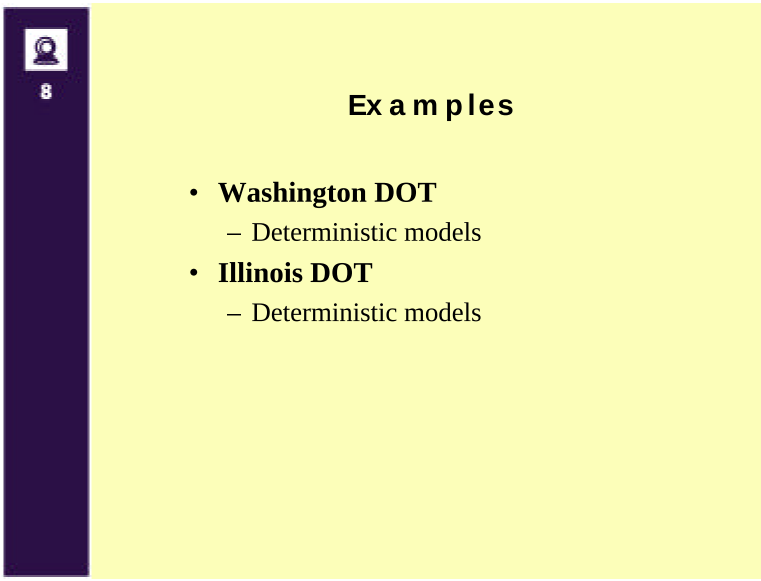
Notes:

Update Requirements

§ Performance models must be updated regularly to continue to reflect deterioration patterns

§ Feedback loops should be established to link deterioration models with engineering practices

Slide 8-33



Slide 8-33

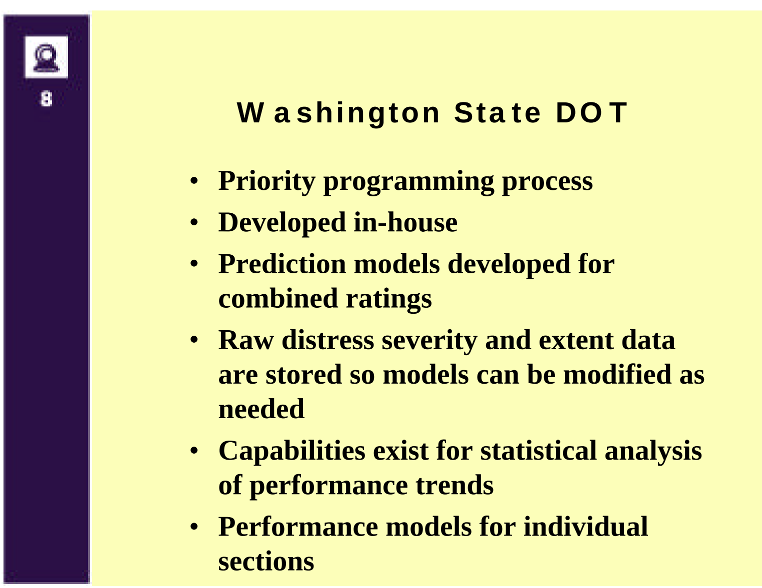
Notes:

<u>Examples</u>

§ Washington Department of Transportation
  - Deterministic models

§ Illinois Department of Transportation
  - Deterministic models

Slide 8-34

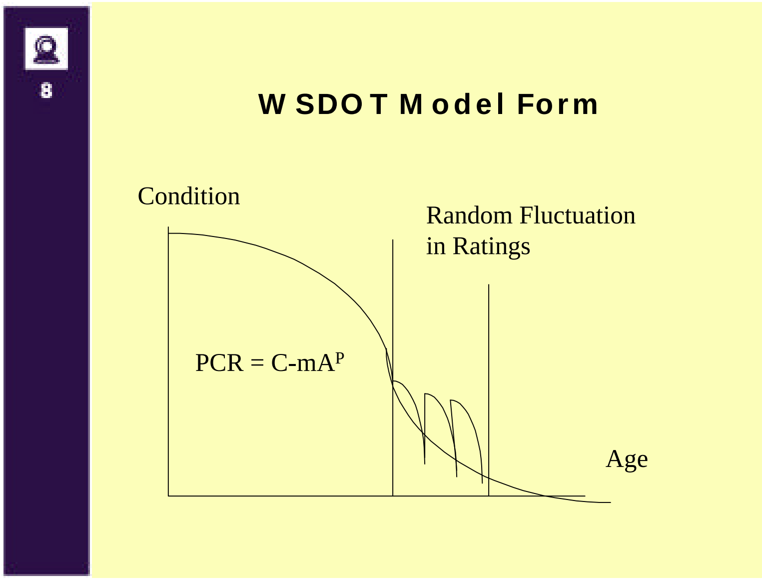


Slide 8-34

Notes:

This slide provides and overview of the modeling activities in WSDOT.

Slide 8-35



Slide 8-35

Notes:

This is Figure 8.8. It shows the general shape of WSPMS performance curves. Define variables for students.

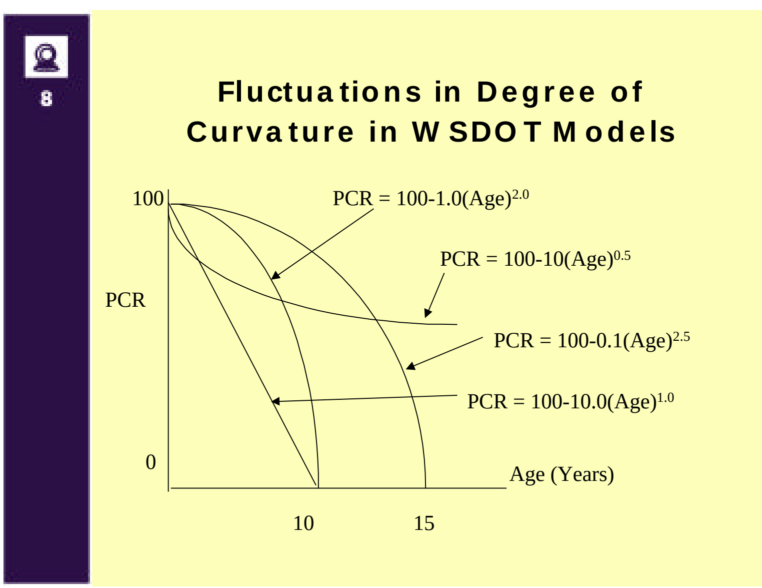
The deceleration rate of deterioration is attributed to the application of temporary fixes to hold the pavement together until a major remedy can be applied. These temporary fixes tend to cause short duration, random fluctuations in the pavement rating – probably best represented by a curve that passes through the mean value in this phase.

<u>WSDOT Limitations to Regression Analysis</u>

§ New surfaces without historical data points
  - Default models used
  - When three points are available, regression is used.

§ Random fluctuation in data (poor data fit).

Slide 8-36



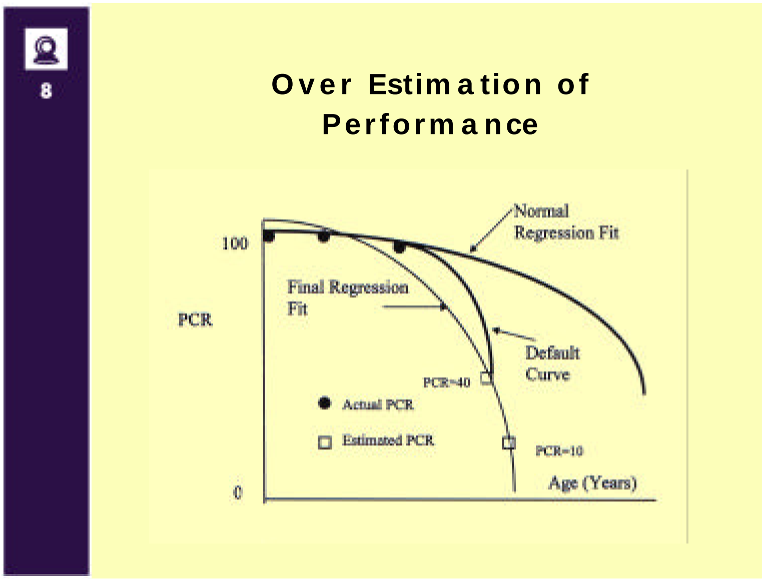
Slide 8-36

Notes:

The degree of curvature in the model is influenced by the constant selected for P, as shown in Figure 8.10.

The P that provides the highest R^2 is selected as the best fit model.

Slide 8-37

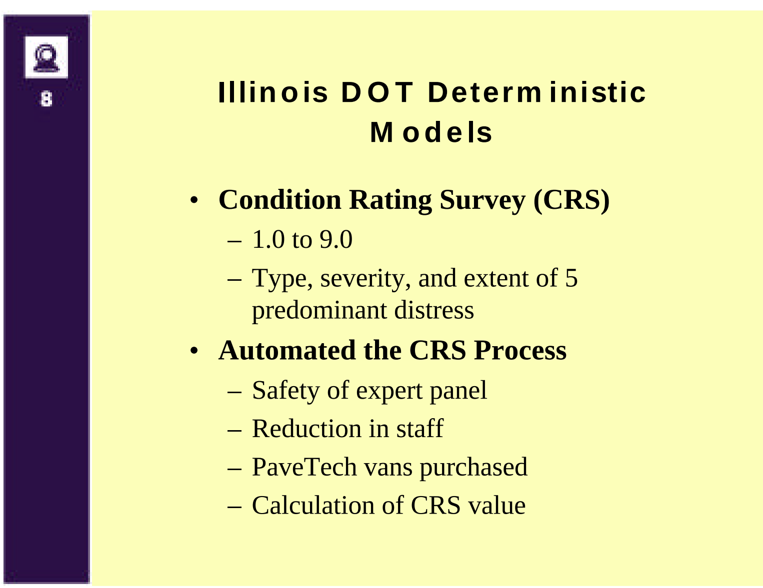


Slide 8-37

Notes:

This is Figure 8.11. Because the WSDOT performance curves overestimate remaining life in early states, a process was established to add the default curve to the last data point. The default curves are used to establish two artificial points that are added to the existing data point, then a regression equation is developed that best fits both actual and artificial data points. This process provides a more realistic estimate of specific project performance by recognizing the past performance trends unique to each project and also incorporating knowledge of the most likely rate of future deterioration from typical pavement performance experience.

Slide 8-38



Slide 8-38

Notes:

In order to understand the performance model development in Illinois, it is important to provide a little background on the CRS and the changes that occurred to the process when they automated the data collection activities.

IDOT Model Objectives

§ Describe the expected conditions at any point in the future

§ Develop alternative rehabilitation strategies

§ Prioritize need pavement improvements

Slide 8-39

IDOT Family Models

System	Surface	District	Total
Interstate	Composite (2)	1-4 5-9	4
	Concrete (2)	1-4 5-9	4
Non-Interstate	Flexible (3)	1-4 5-9 (1-9)ST	3
	Overlays (5)	1-4 5-9 (1-9)CRC	9
	Concrete (4)	1-4 5-9	8
SMART	Flexible & OL (4)	All	4

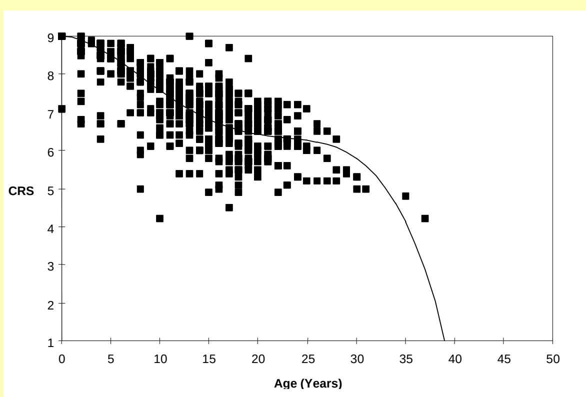
Slide 8-39

Notes:

These are the family groups that were established for model development

Slide 8-40

IDOT Polynomial Approach



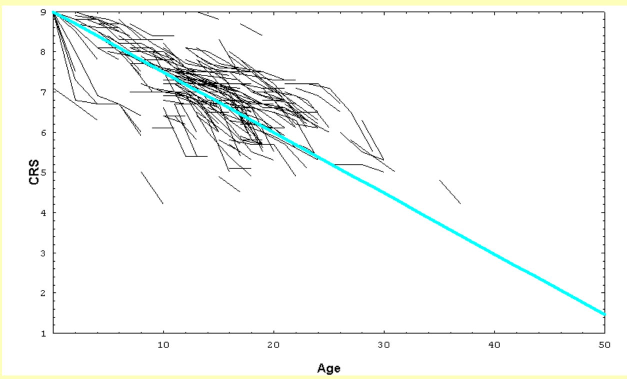
Slide 8-40

Notes:

This is Figure 8.12. This is the first attempt at developing the models. Note the flat spot in the deterioration curves, usually occurring between a condition rating (CRS) of 7.5 to 6.0, the time when IDOT typically schedules pavement sections for rehabilitation. This was not acceptable for programming purposes, so a new approach was developed.

Slide 8-41

IDOT Trajectories



Slide 8-41

Notes:

This is Figure 8.13. It shows the trajectories of CRS for each pavement section in a family. The average deterioration rate of each section is calculated to determine the average deterioration rate associated with the family type. The deterioration rates were then translated into deduct points.

Slide 8-42

D-Crack Adjustments

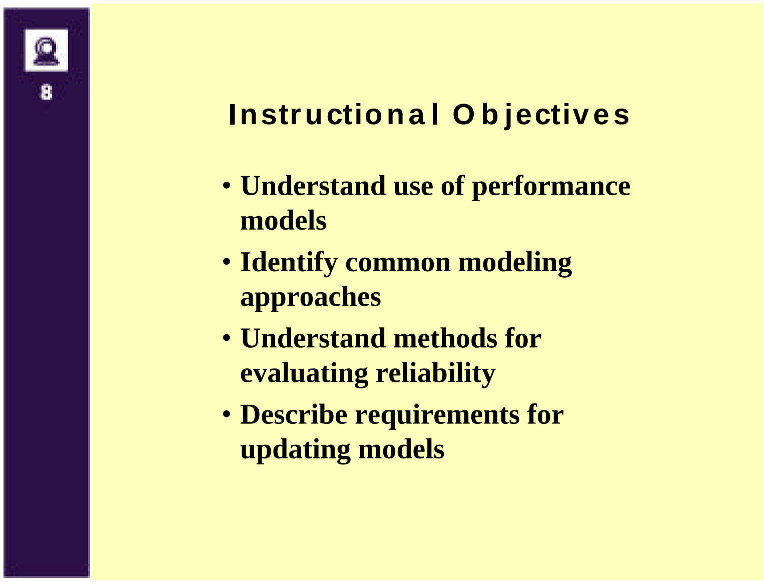
- **Asphalt concrete overlays: deducts increased by 20%**
- **Jointed reinforced concrete: deducts increased by 20%**
- **CRCP: deducts increased by 50%**

Slide 8-42

Notes:

Adjustments were made if the pavements are susceptible to D-cracking, as shown here.

Slide 8-43



Slide 8-43

Notes:

Review the objectives for this module.

MODULE 9

REMAINING SERVICE LIFE

Purpose:

This module defines the concept of Remaining Service Life and illustrates its usefulness through examples.

Objectives:

To expose participants to:

- The concept of remaining service life
- How remaining service life is used and why it is important
- How remaining service life is calculated

Reference:

Module 9 of the Course Workbook

Duration:

45 minutes

Equipment:

Laptop computer, mulit-media projector, screen, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

15 Microsoft PowerPoint® Slides

Approach:

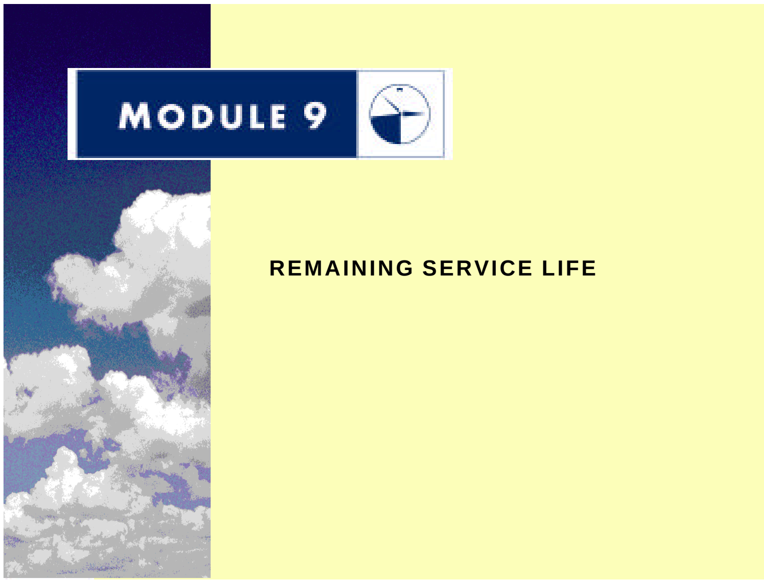
This module is taught through slide presentations and discussion with the participants. As an overall introduction to the principles of remaining service life, it is important that the participants develop an understanding of these principles, as they will be used throughout the course.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. The slides prepared may also be used for distance learning.

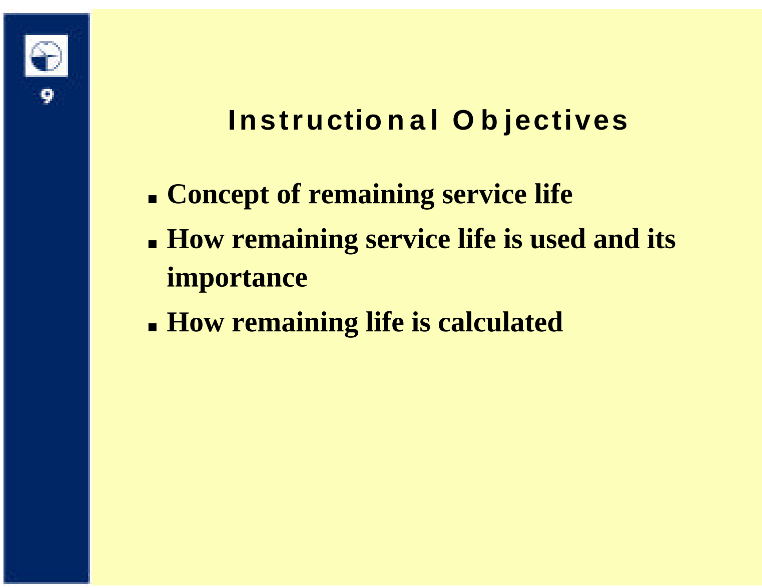
Slide 9-1



Slide 9-1

Notes:

Slide 9-2



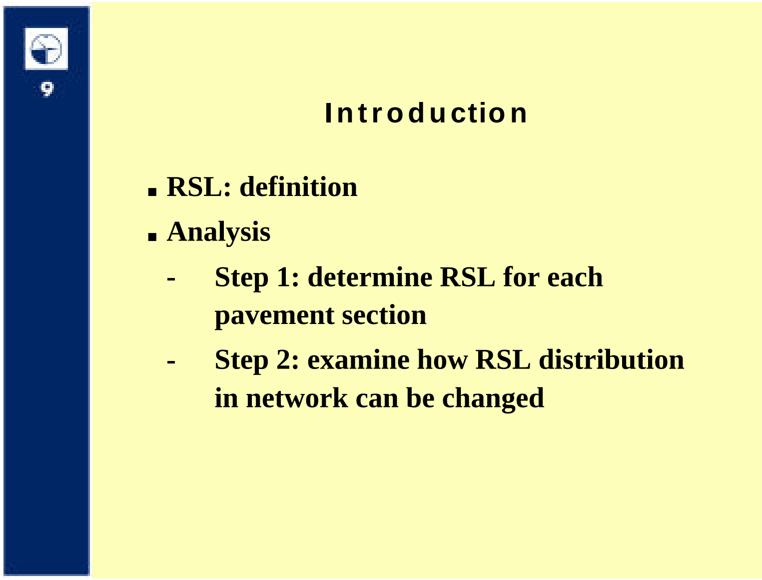
Slide 9-2

Notes:

Describe the purpose and objectives of this module, as listed on the previous pages.

Doctor’s analogy –- cancer vs. T.B.

Slide 9-3



Slide 9-3

Notes:

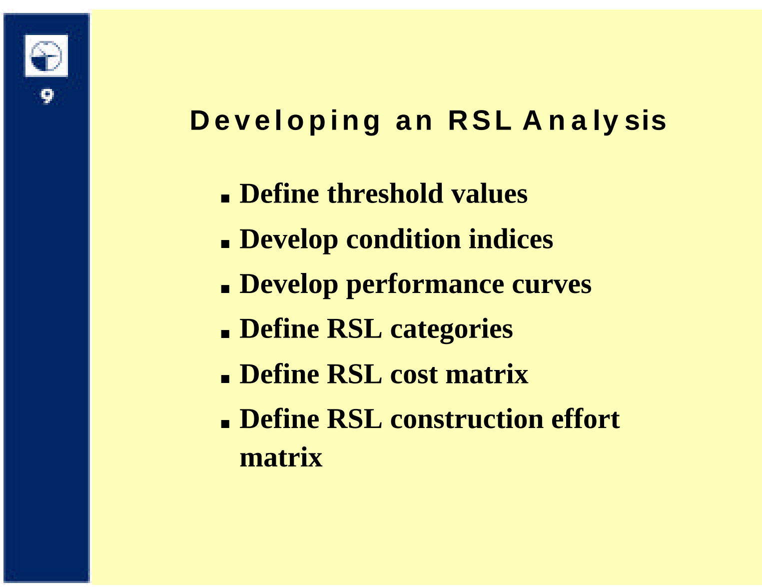
Remaining Service Life (RSL) analysis gets its name because it is concerned with the distribution of Remaining Service Life in a pavement network.

An RSL analysis involves two distinct steps:

Step one requires the agency to calculate the RSL for each pavement section in the network and to examine how the RSL is currently distributed over the entire network.

Step two requires the agency to examine how the distribution can be changed in the future over that network by applying different levels of effort.

Slide 9-4



Slide 9-4

Notes:

To perform a Remaining Service Life analysis, an agency must carefully define certain components in a certain order.

<u>Developing an RSL Analysis</u>

§ Define threshold values

§ Develop condition indexes

§ Develop performance curves

§ Define RSL categories

§ Define RSL cost matrix

Slide 9-5

Defining RSL Categories

- Category **I**: RSL = 0
- Category **II**: 0 < RSL ≤ 5
- Category **III**: 5 < RSL ≤ 10
- Category **IV**: 10 < RSL ≤ 15
- Category **V**: 15 < RSL

Slide 9-5

Notes:

Defining RSL Categories

To show the distribution of RSL over the network it is convenient for the agency to develop a set of RSL categories. These categories assemble the pavement sections into logical groups. For example, Category I could be for pavements with a zero RSL, Category II could be for pavements with 1 to 5 year RSL's, Category III could be for pavements with 6 to 10 year RSL's, Category IV could be for pavements with 11 to 15 year RSL's and, Category V could be for pavements with more than 15 year RSL's. Five year groupings are the most common.

Slide 9-6

Example RSL Cost Matrix

FROM\TO	Category I	Category II	Category III	Category IV	Category V
Category I	MI$	CI-II$	CI-III$	CI-IV$	CI-V$
Category II	n/a	MII$	CII-III$	CII-IV$	CII-V$
Category III	n/a	n/a	MIII$	CIII-IV$	CIII-V$
Category IV	n/a	n/a	n/a	MIV$	CIV-V$
Category V	n/a	n/a	n/a	n/a	MV$

Slide 9-6

Notes:

Example of RSL Cost Matrix

This is Table 9.1 (on Page 9-3). It illustrates what a cost matrix for an RSL analysis looks like. Notice that the rows in the matrix identify the FROM category and the columns identify the TO category. In other words, the cost cell "CII-IV$" represents the average cost (in $/lane-mile) of moving a pavement section form RSL Category II to RSL Category IV. The cells along the diagonal of the matrix are labeled with a prefix of "M." This is used to say that these are the "maintenance" costs for keeping a pavement in that RSL category. The cells below the diagonal are labeled "n/a" because they are not applicable since in theory one cannot move a pavement down an RSL category.

Slide 9-7

Example Construction Effort Matrix

FROM\TO	Category I	Category II	Category III	Category IV	Category V
Category I	n/a	EI-II	EI-III	EI-IV	EI-V
Category II	n/a	n/a	EII-III	EII-IV	EII-V
Category III	n/a	n/a	n/a	EIII-IV	EIII-V
Category IV	n/a	n/a	n/a	n/a	EIV-V
Category V	n/a	n/a	n/a	n/a	n/a

Slide 9-7

Notes:

The Construction Effort Matrix allows the agency to specify what level of effort (in terms of lane-miles of work) they will carry out on the various RSL Categories.

This is Table 9-3 (on Page 9-7). It illustrates what a Construction Effort Matrix looks like. For example, the cell labeled EII-V is where the agency says how many lane-miles will be moved from RSL Category II to RSL Category V in each year. The cost of this work is calculated by multiplying EII-V by CII-V$ from the corresponding cell in the RSL Cost Matrix.

Slide 9-8

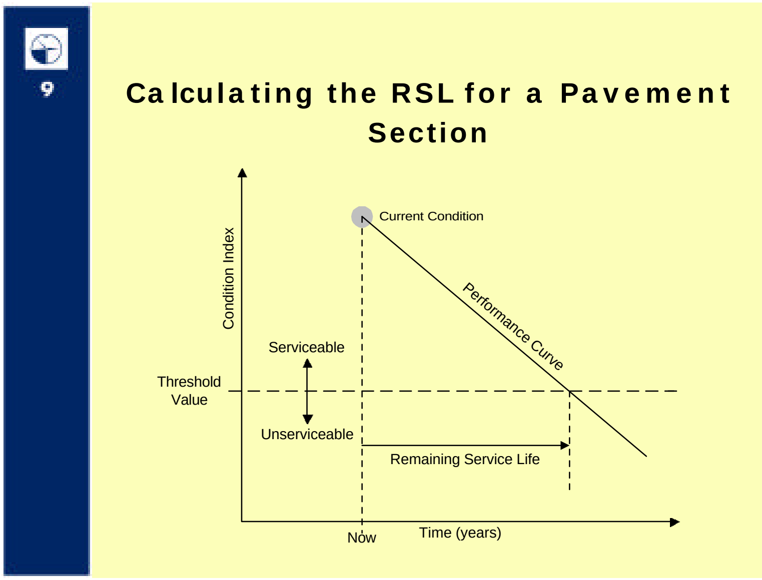
The RSL Analysis

- **Calculate RSL for each section**
- **Show RSL distribution on network**
- **Predict future RSL distribution**
- **Apply different levels of effort and examine effects on future RSL distribution**

Slide 9-8

Notes:

Slide 9-9



Slide 9-9

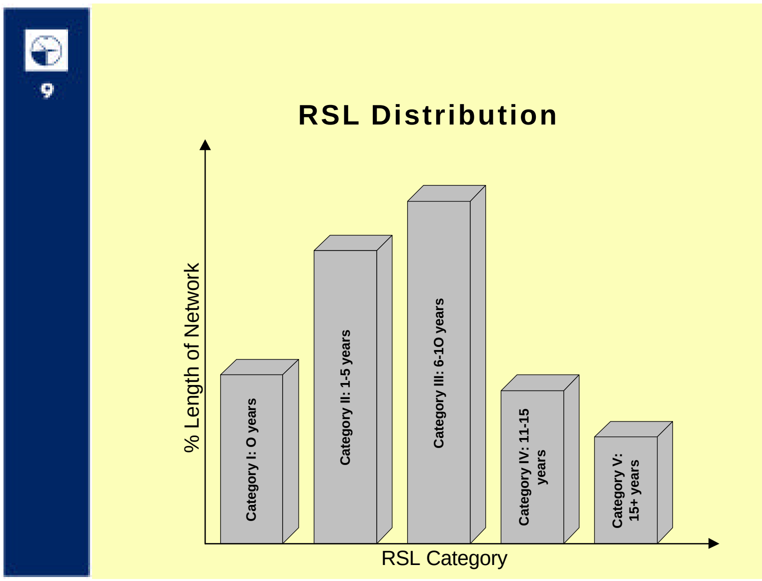
Notes:

<u>Rules for Calculating the RSL</u>

- § Calculate RSL for each Condition Index
- § RSL for the section is smallest of all RSL calculated above
- § Note: If current condition is already less than the Threshold Value, the RSL for the section is zero

This is Figure 9-1 (on Page 9-4). It illustrates the concept of calculating the RSL on a pavement section for an individual condition index. Notice how the performance curve is used to predict when the current condition index will deteriorate to cross the Threshold Value for this condition index. The time it takes for this to happen is the RSL for that condition index on that pavement section.

Slide 9-10



Slide 9-10

Notes:

RSL Distribution

This is Figure 9-2 (on Page 9-5). It is a simple bar chart used to illustrate the current distribution of RSL on the pavement network. A typical bar chart is shown here.

Various conclusions can be drawn from this bar chart. This example network is in trouble; more than three quarters of it will be unserviceable in less than ten years. The more this bar chart is skewed to the right, the better the network is.

The agency can produce this distribution for the entire network, by district, by road class, etc. depending on how sophisticated the aggregations are performed. In the simplest case, only one bar chart is produced for the entire network.

Slide 9-11

9

Calculating the Future RSL

	% of lane-miles in each RSL Category			
	Now	Next Year	After 5 years	After 10 years
Category I	**10**	**15** (= 10 + 25/5)	**35**	**65**
Category II	**25**	**26** (= 25 - 25/5 + 30/5)	**30**	**25**
Category III	**30**	**29** (= 30 - 30/5 + 25/5)	**25**	**10**
Category IV	**25**	**22** (= 25 - 25/5 + 10/5)	**10**	**0**
Category V	**10**	**8** (= 10 - 10/5)	**0**	**0**

Slide 9-11

Notes:

Predicting the Future RSL Distribution

§ Assume the distribution in each RSL Category is even

§ For example, if Category II had 25%, then 5% has an RSL of 1 year and so on

§ Use this assumption to predict the future RSL distribution

Calculating the Future RSL

The simplest thing to do with the bar chart is to predict what will happen if nothing is done to the network after a certain period of time. This is Table 9.2 (on Page 9-6). It shows what the bar chart will look like after one year, five years and ten years if nothing is done on the network.

In general, a 20,000 lane-mile pavement network loses 20,000 lane-mile-years of RSL every year if nothing is done

Slide 9-12

Example Future RSL Distribution

- **Assume the cell 'EII-V' equals 10 in the Construction Effort Matrix**

	% of lane-miles in each RSL Category	
	Now	Next Year
Category I	**10**	**13** (= 10 + **15/5**)
Category II	**25**	**18** (= 25 - **15/5** + 30/5 - **10**)
Category III	**30**	29 (= 30 - 30/5 + 25/5)
Category IV	**25**	22 (= 25 - 25/5 + 10/5)
Category V	**10**	**18** (= 10 - 10/5 **+ 10**)

Slide 9-12

Notes:

Example Future RSL Distribution

Assume that the agency made the cell EII-V = 10 lane-miles and all other cells equal to zero in the Construction Effort Matrix. This is Table 9.4 (on Page 9-7). It illustrates how the next year distribution for RSL would change. The values shown in bold in the Next Year column of this table are the values that are different than the corresponding values from.

Note: -The amount of road deteriorating from Category II to Category I has changed from 25/5 to 15/5 because 10 lane-miles are removed from Category II at the beginning of the year.

-10 lane-miles are removed from Category II and added to Category V representing the roads being moved.

Work through arithmetic with group.

Slide 9-13

Practical Considerations

- RSL reliability is function of reliability of condition survey and performance curves
- Future RSL distributions are network level not project level

Slide 9-13

Notes:

Practical Considerations

§ RSL reliability is function of reliability of condition survey and performance curves

§ Future RSL distributions are network level not project level

Slide 9-14

Future Trends

- Sophisticated PMS “carries along” RSL calculations with life-cycle cost
- RSL distribution a result of PMS analysis

Slide 9-14

Notes:

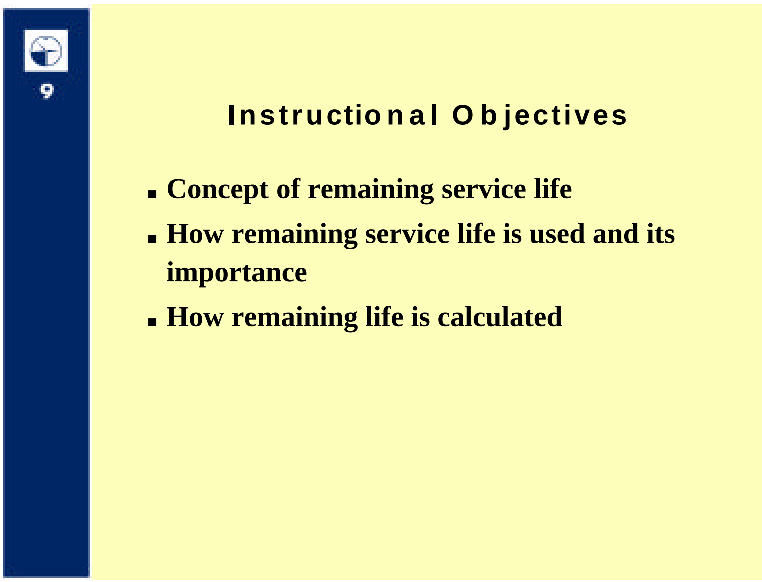
Future Trends

§ Sophisticated PMS “carries along” RSL calculations with life-cycle cost

  - May draw diagram of this.

§ RSL distribution a result of PMS analysis

Slide 9-15



Slide 9-15

Notes:

Review the objectives for this module.

MODULE 10

PRIORITIZATION

Purpose:

This module introduces the principles of a multi-year prioritization analysis as part of an agency's pavement management activities. Each of the components included in a multi-year prioritization analysis are presented and discussed. Examples from highway agencies using multi-year prioritization are also presented

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- § Describe the objectives of a multi-year prioritization analysis.
- § Understand the differences between other multi-year analysis techniques.
- § Describe the components of a multi-year prioritization analysis.
- § Understand the use of a multi-year prioritization analysis as part of an agency's project selection process.

Reference:

Module 10 of the Course Workbook

Duration:

120 minutes

Equipment:

Laptop computer, multi-media projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

83 Microsoft PowerPoint® Slides

Approach:

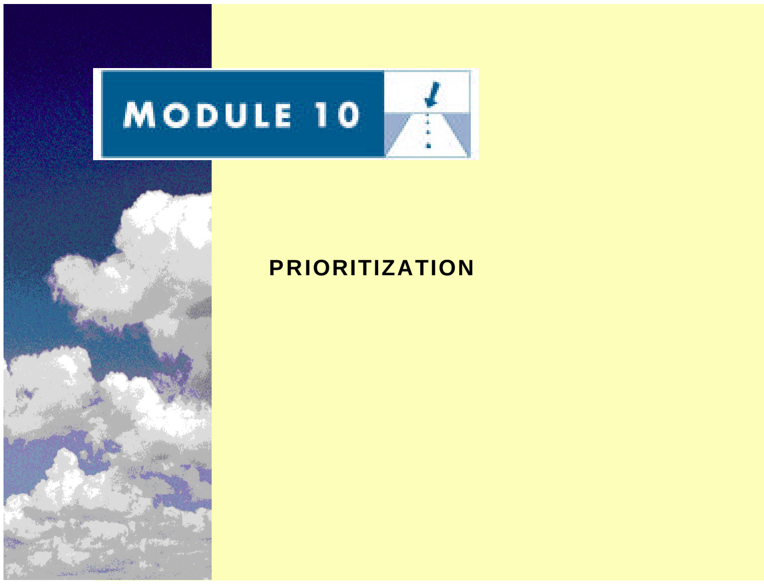
This module is taught through slide presentations and discussion with the participants. As an overall introduction to the principles of prioritization, it is important that the participants develop an understanding of these principles, as they will be used throughout the course.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared will also be applicable in a distance learning format.

Slide 10-1

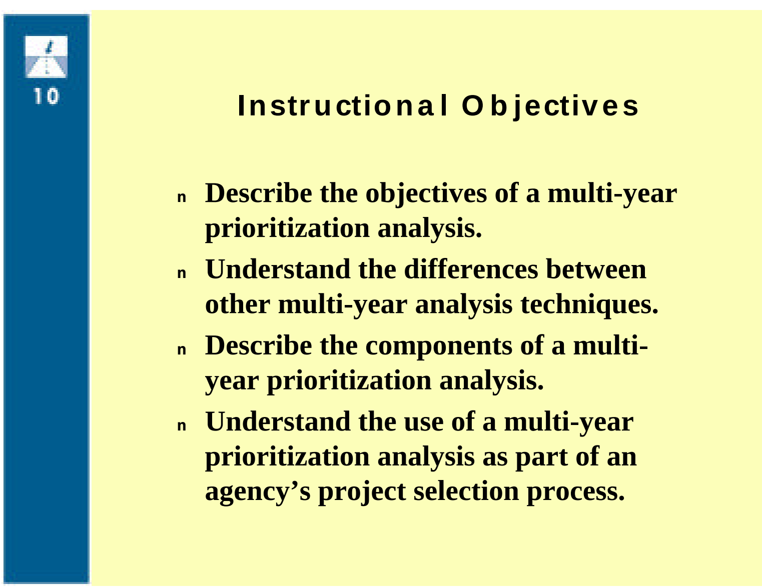


Slide 10-1

Notes:

Introduce the purpose of this module and the format of the material presented in the chapter. Mention that the material for this module is taken from FHWA Demonstration Project 108 A on multi-year prioritization.

Slide 10-2



Slide 10-2

Notes:

Introduce the concepts of MYP as a tool that can be used for a number of different activities, including those shown.

Slide 10-3

What Is Multi-Year Prioritization?

- A method of allocating limited resources in an efficient and cost-effective way over a multi-year period, through an evaluation of long-term impacts

Slide 10-3

Notes:

This slide introduces another way of looking at MYP in terms of an evaluation of long-term impacts by evaluating these factors.

Information extracted from FHWA demo projects (5 states, 2-day course).

Slide 10-4

Benefits Provided By MYP

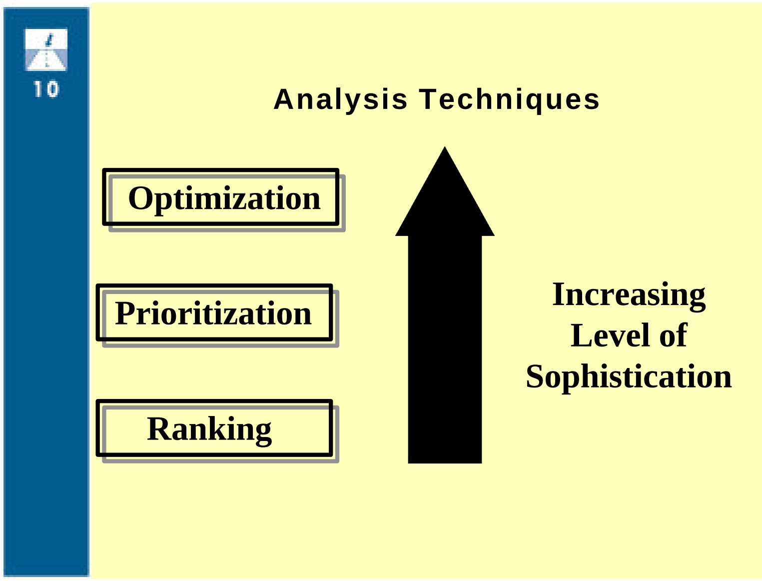
- Forecast future conditions
- Analyze timing options
- Evaluate strategy effectiveness
- Perform economic analyses
- Use of objective measures for prioritizing needs
- Project future needs

Slide 10-4

Notes:

Agencies using MYP have identified a number of benefits not realized through the use of a subjective approach to project selection.

Slide 10-5



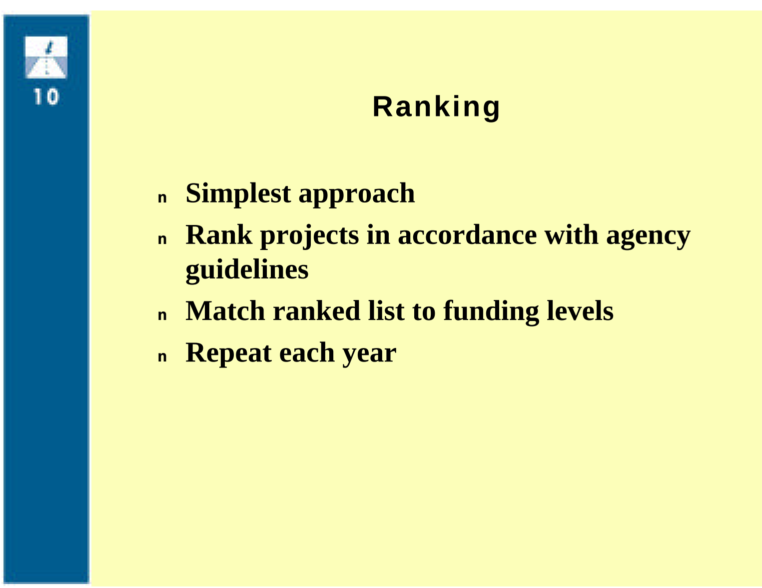
Slide 10-5

Notes:

This slide introduces other techniques that are available. MYP falls in the middle in terms of sophistication.

Ask – how many use one of these techniques?

Slide 10-6



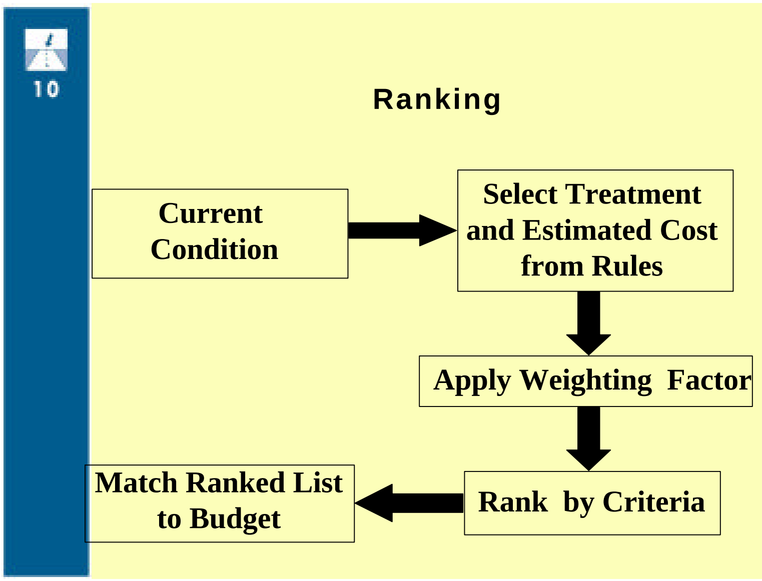
Slide 10-6

Notes:

Introduce ranking as the simplest approach that can be used.

This is the most common approach.

Slide 10-7



Slide 10-7

Notes:

The most common ranking criteria used by highway agencies were reported in NCHRP Synthesis 222. They are:

- Condition
- Initial cost
- Cost & Timing
- Life cycle cost
- Benefit/cost ratio

This slide is Figure 10.2. It presents the ranking process.

Slide 10-8

Ranking Example

Section	Condition Level	Treatment	Cost (mil)
67A	67	Minor	1
67B	82	PM	0.5
67C	52	Major	3
14A	71	Minor	2
14B	74	Minor	1.5
Univ1	85	PM	0.5

Slide 10-8

Notes:

An example is provided to illustrate the simplicity of ranking. This slide (Table 10.1) shows the pavement sections in the example.

Treatments:

Reconstruction:	0–30
Major Rehabilitation:	30-60
Minor Rehabilitation:	60-80
Preventative Maintenance (PM):	80-90

Slide 10-9

Results for $4 Million Budget

Section ID	Ranking	Condition Level	Treatment	Cost ($millions)
67C	1	52	Major	3
67A	2	67	Minor	1
14A	3	71	Minor	2
14B	4	74	Minor	1.5
67B	5	82	Prev. Maint.	0.5
Univ1	6	85	Prev. Maint.	0.5

Slide 10-9

Notes:

For a $4 million budget, the first two projects are funded.

§ Worst-first strategy

§ Washington started with this system in late 1960s.

Slide 10-10

Example With Weighting Factor

Section ID	Ranking	Condition	Traffic	Weight	Cost
14 A	1	71	0.5	36	2
14B	2	74	0.5	37	1.5
67C	3	52	1	52	3
67A	4	67	1	67	1
Univ1	5	85	1	85	0.5
67B	6	82	1.5	123	0.5

Slide 10-10

Notes:

The example is now complicated by using a weighting factor for traffic. Note that the highest factor is used for low traffic, so now low ranking numbers are the highest priority. For the same $4 budget, a different set of projects are selected.

Ranking Based on Weights for Traffic with a $4 million Budget Sections 14A, 14B, and Univ1 are Funded.

Functional class can be a surrogate for traffic.

Slide 10-11

10

Limitations To Ranking

- Long-term impacts on network are not considered
- Rate of deterioration is not considered
- Economic analysis for alternative strategies not considered

Slide 10-11

Notes:

This slide lists the limitations to the use of ranking.

Slide 10-12

10

Ranking = Single-Year Prioritization

- Definition
- Uses
- Limitations

Slide 10-12

Notes:

Definition:

§ Ranking process of current needs
§ Priorities established one year at a time based on existing conditions
§ Often selects projects using a worst first philosophy
§ Updated annually

Uses:

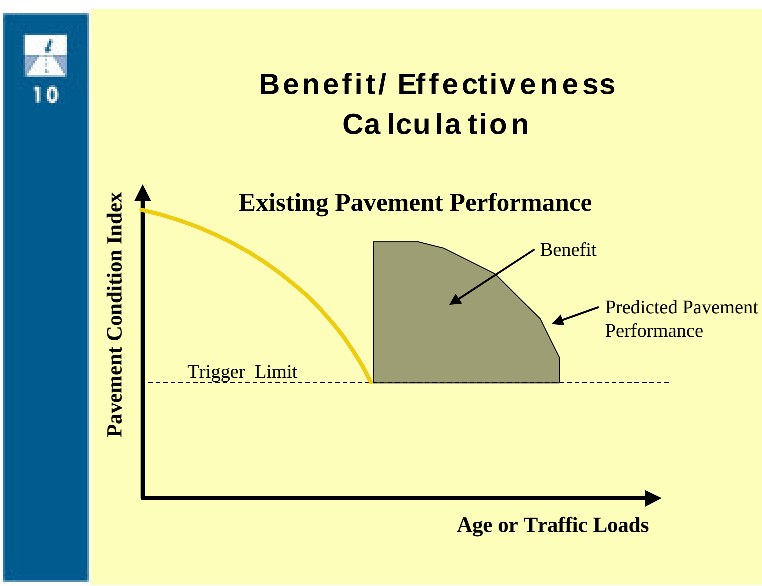
§ Addresses most pressing problems first
§ Provides a somewhat objective process
§ Provides a means of justifying expenditures to managers and legislatures

Limitations:

§ Match those identified for ranking techniques
§ Tends to keep agencies in a “fire fighting” mode

Slide 10-13

Slide 10-14



Slide 10-13

Notes:

This slide introduces MYP and the common approaches used in the analysis.

Slide 10-14

Notes:

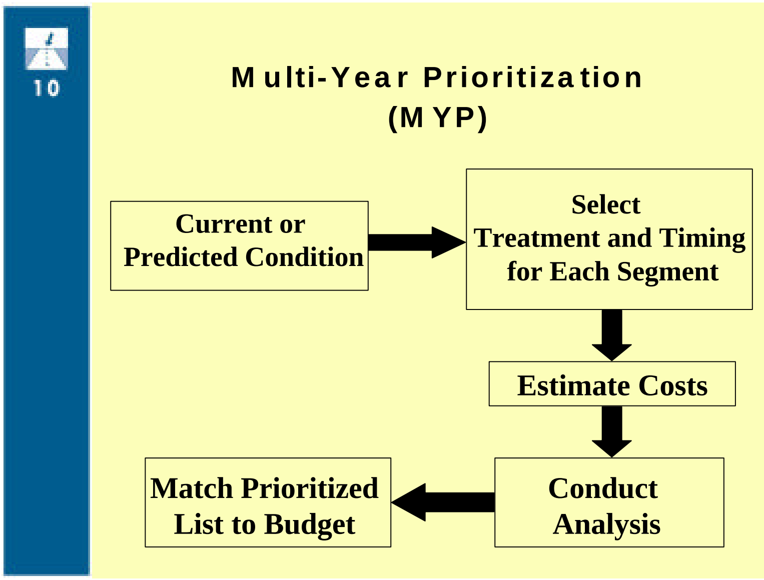
Figure 10.3. This figure illustrates the calculation of benefit as the area under the curve of the treatment performance curve.

Ask participants:

- How are benefits defined in this figure?
- What does it represent?

Very few agencies have sufficient data to build a performance curve. Most use family curve approach.

Slide 10-15

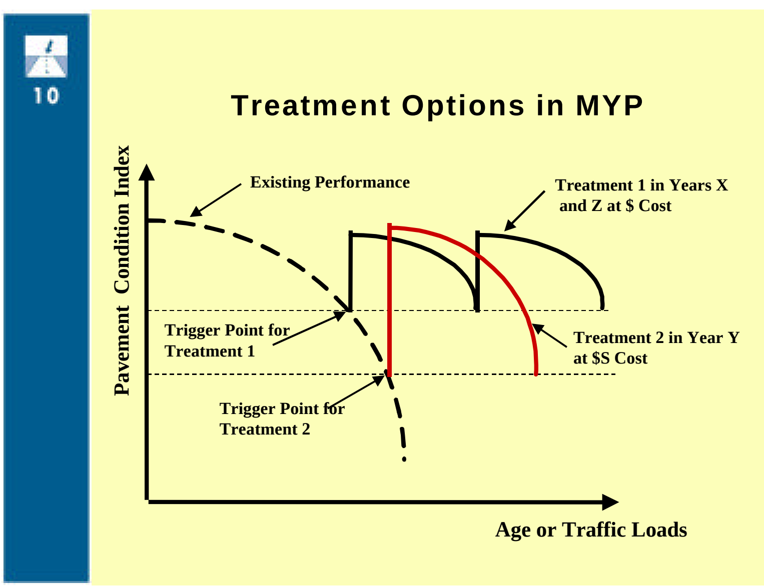


Slide 10-15

Notes:

Figure 10.4. This figure illustrates the MYP process.

Slide 10-16

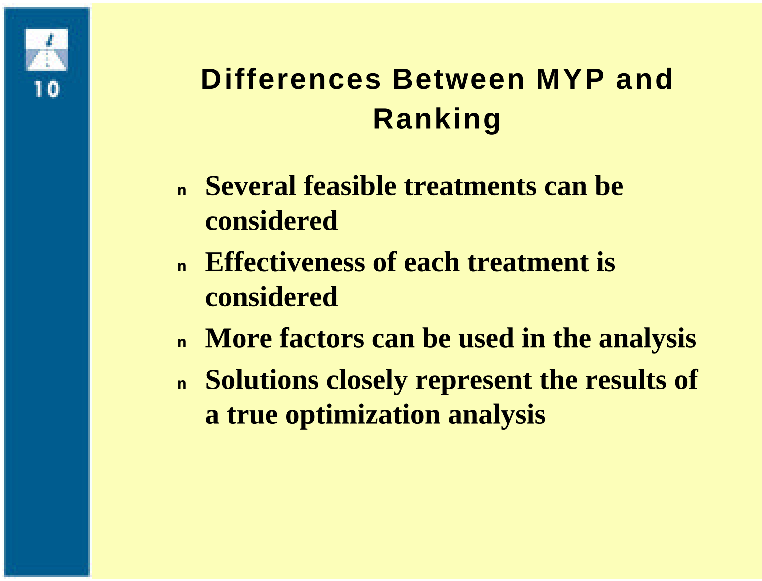


Slide 10-16

Notes:

Figure 10.5. This figure illustrates the importance of using a computer for a MYP analysis because of the number of options that can be considered for each pavement section.

Slide 10-17

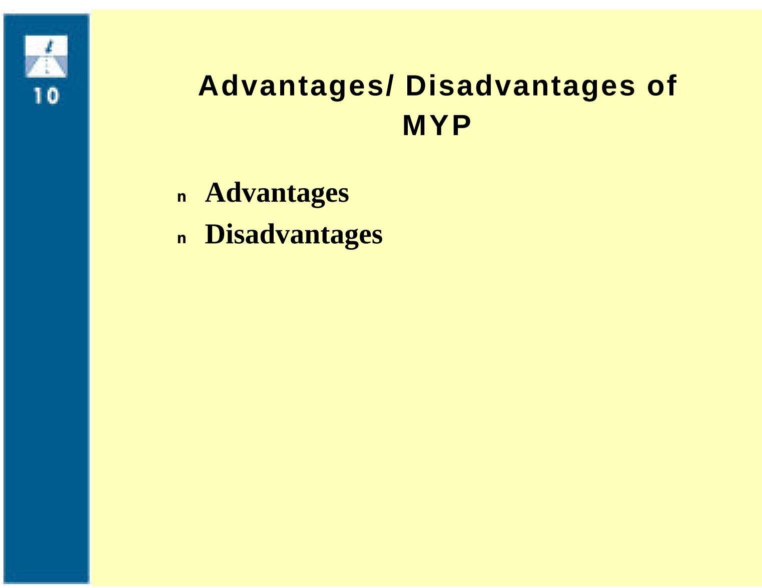


Slide 10-17

Notes:

This slide features some of the differences in MYP (from ranking).

Slide 10-18



Slide 10-18

Notes:

The advantages and disadvantages of MYP are listed here. It is hoped that the advantages outweigh the disadvantages.

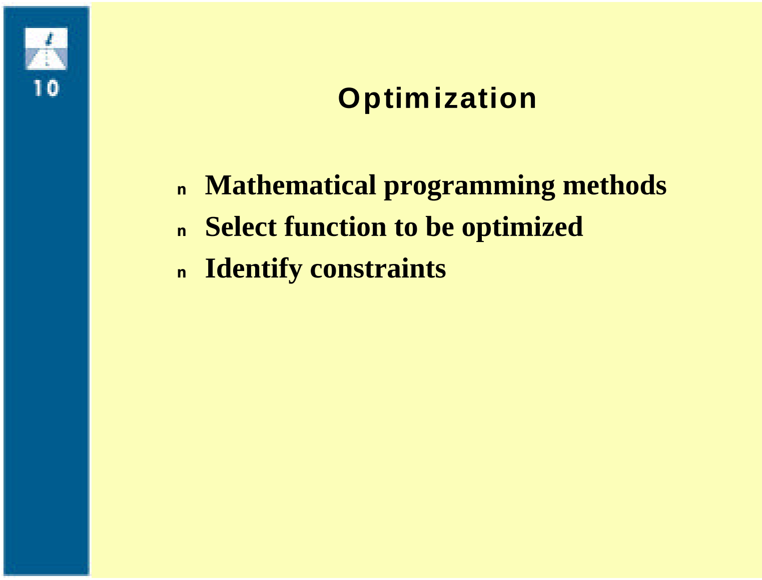
Advantages of MYP:

- Timing options can be considered
- An optimal solution for any budget level can be developed
- Targets can be set for future serviceability levels
- Impacts can be quickly assessed

Disadvantages of MYP:

- More complex than ranking or SYP
- The reliability of the results is based on the quality of the performance models

Slide 10-19



Slide 10-19

Notes:

The most sophisticated approach is true optimization, which makes use of mathematical programming techniques such as those listed here. The agency is responsible for setting the goals for the analysis and any constraints affecting the analysis.

Mathematical programming methods:

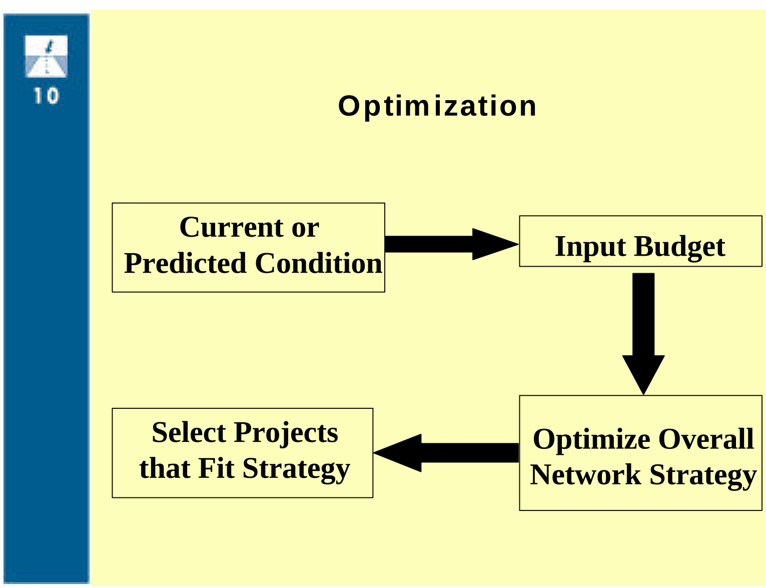
- Linear
- Non-linear
- Integer Programming
- Dynamic Programming

Select function to be optimized:

- Total Benefit to the Agency
- Lowest Initial Cost

Identify constraints

Slide 10-20

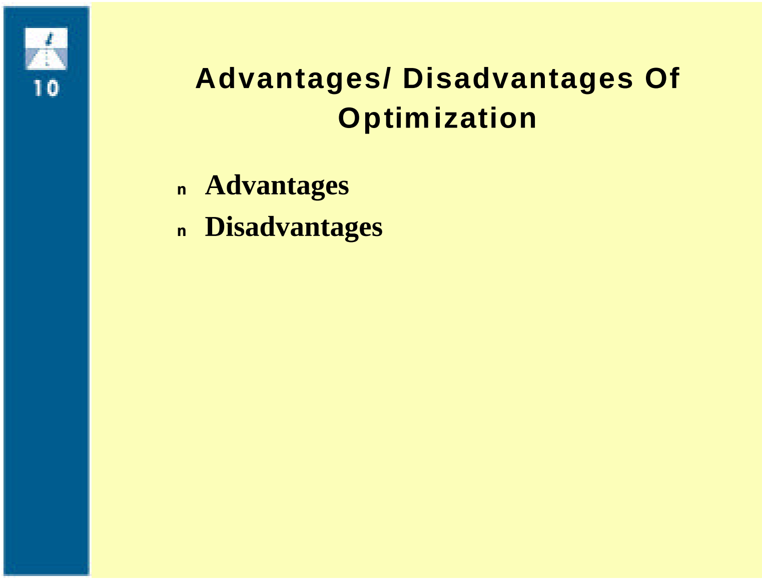


Slide 10-20

Notes:

Figure 10.6. This is the optimization process.

Slide 10-21



Slide 10-21

Notes:

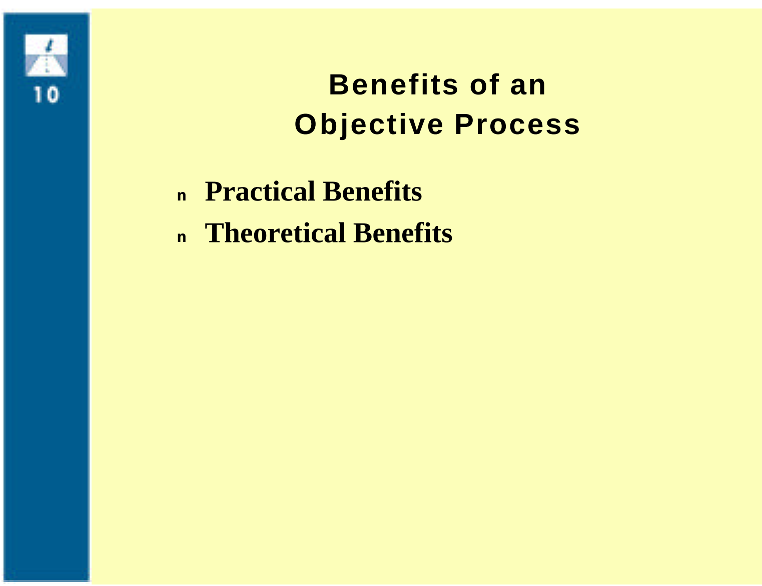
Advantages of Optimization:

- Inter-project trade-offs are evaluated to select strategies
- Strategies will definitely adhere to budget limits
- Moves the system towards a defined level of performance

Disadvantages of Optimization:

- Not well understood
- Difficult to justify selection of projects
- Perception of loss of control in programming and scheduling
- Highly qualified individuals are needed to implement and operate the system

Slide 10-22



Slide 10-22

Notes:

There are a number of overall benefits that can be realized through the use of structured processes such as optimization and prioritization. Some of these benefits are listed here. Lytton has demonstrated the benefits available to an agency using these types of analysis. He has shown that heuristic approaches approximate true optimal solutions.

Benefits of an Objective Process:

- Improved decision-making capabilities
- Solutions generally more cost-effective
- Pavement conditions improved
- Better service to pavement users
- Near optimal solutions can be achieved through the use of heuristic methods
- 20 to 40 percent more benefit with heuristic
- 10 to 20 percent more with optimization

Slide 10-23

Why MYP Does Not Succeed

- Management philosophy supports worst-first
- Outside influences affect project selection
- Large backlog of projects

Slide 10-23

Notes:

Some agencies have MYP software in place, but are not using it to the full potential. These are some of the reasons why.

Slide 10-24

Factors to Ensure the Success of MYP

- Management must support and understand philosophy
- Recommendations represent normal conditions and are not guaranteed
- Different strategies match different goals
- It should be considered a tool

Slide 10-24

Notes:

There are actors to ensure the success of MYP.

Slide 10-25

MYP Analysis Requirements

- Condition/ inventory information
- Performance models
- Treatment strategies/ conditions
- Analysis tools

Slide 10-25

Notes:

MYP Analysis Requirements:

- § Condition/ inventory information
- § Performance models
- § Treatment strategies/ conditions
- § Analysis tools

Slide 10-26

Treatment Strategies

- One or more maintenance or rehabilitation techniques
- Designed to improve or maintain conditions
- Tailored to consider constraints
- Evaluated in terms of cost-effectiveness

Slide 10-26

Notes:

Treatment Strategies:

- § One or more maintenance or rehabilitation techniques
- § Designed to improve or maintain conditions
- § Tailored to consider constraints
- § Evaluated in terms of cost-effectiveness

Slide 10-27

Requirements for Developing a Strategy

- List of strategy guidelines and treatment options
- Costs
- Pavement performance models

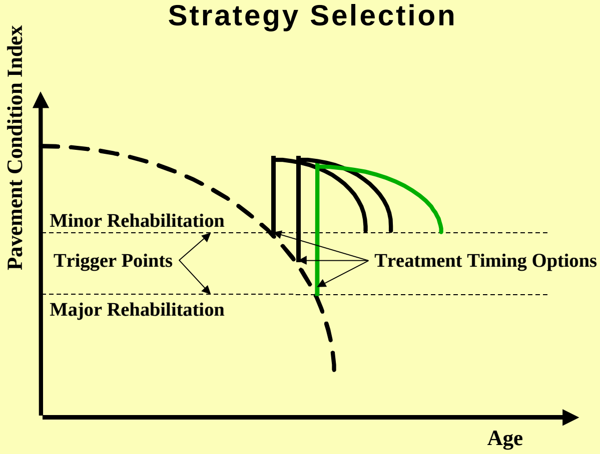
Slide 10-27

Notes:

In order to develop a strategy, these keys must be identified.

Slide 10-28

Sample Timing Options for Strategy Selection



Slide 10-28

Notes:

Figure 10.7. This slide is intended to show that each section could have a number of different timings considered for each treatment.

Slide 10-29

10

Options in Strategy Development

- Project Selection/ Treatment Selection- simultaneous or not
- Single treatments or multiple treatments

Slide 10-29

Notes:

Options in Strategy Development:

- The selection process can be a simultaneous activity or as a separate activity.
- Treatments can be identified as a single or as multiple treatments.

Slide 10-30

10

Single Treatment Strategy

- Most common approach
- Several feasible alternatives may be identified for each section
- Each treatment considered independently
- Most cost-effective treatment generally selected

Slide 10-30

Notes:

Most agencies identify and analyze each treatment separately for a section.

Slide 10-31

Multiple Treatment Strategy

- Combination of treatments considered for each section
- Effectiveness of all treatments is representative of effectiveness of entire strategy
- Subsequent treatments affect selection of strategy

Slide 10-31

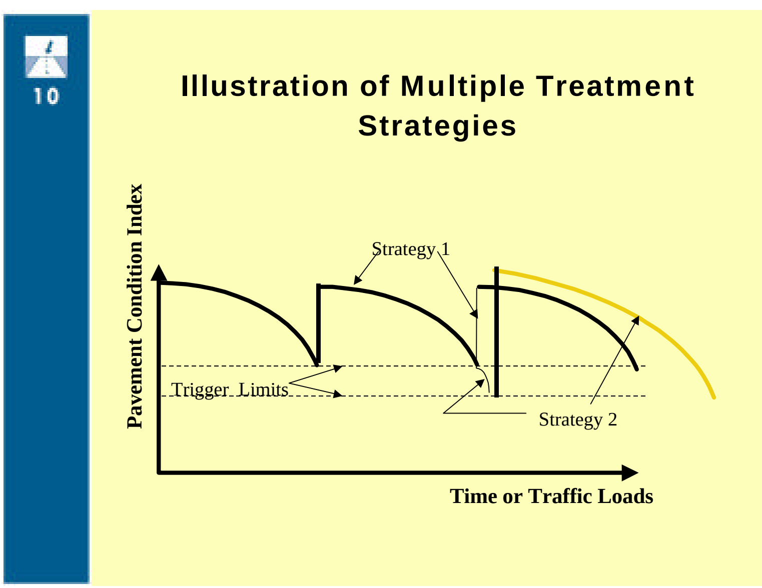
Notes:

Some agencies consider a multiple treatment strategy. With this approach, at least 2 treatments are considered as one strategy. The effectiveness of both treatments is considered as the benefit associated with that strategy.

Multiple Treatment Strategy:

§ Combination of treatments considered for each section
§ Effectiveness of all treatments is representative of effectiveness of entire strategy
§ Subsequent treatments affect selection of strategy

Slide 10-32



Slide 10-32

Notes:

Final list for the project selection process.

Figure 10.8. This figure illustrates 2 separate multiple treatment strategies.

Slide 10-33

Requirements For Strategy Development

- List of all treatments to be considered in analysis
- Set of rules that determine when treatments should be considered feasible

Slide 10-33

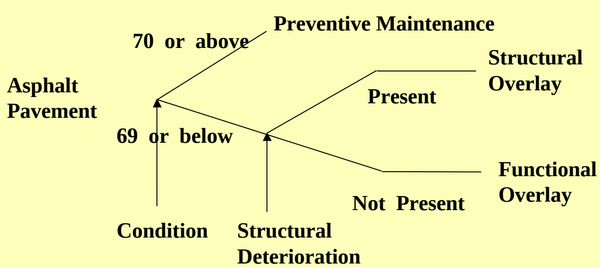
Notes:

Requirements for Strategy Development:

- A list of all treatments to be considered in the analysis
- The set of rules that determine when treatments should be considered feasible
  - decision trees
  - decision matrices
  - programmed rules

Slide 10-34

Decision Trees



Slide 10-34

Notes:

This illustrates a simple decision tree. These are the typical components of a decision tree.

Decision Tree Requirements:

- Surface type and/or construction history
- Functional classification and/or traffic condition indices
- Type of deterioration present
- Geometrics

- Advantages
  - Similar to decision process
  - Flexibility
  - Easily automated

- Disadvantages
  - Alternate options not considered
  - All elements in tree must be forecasted

Slide 10-35

Decision Matrix

Treatment Type	Surface Type	Condition Level	Structural Deterioration
Preventive Maintenance	Asphalt Concrete	70-100	N/A
Functional Overlay	Asphalt Concrete	0-69	Not Present
Structural Overlay	Asphalt Concrete	0-69	Present

Slide 10-35

Notes:

This is Table 10.5. It presents the same information in terms of a decision matrix.

Slide 10-36

Considerations in Developing Decision Trees/ Matrices

- **Decision factors**
- **Availability of data**
- **Ability to predict conditions**
- **Flexibility**

Slide 10-36

Notes:

Considerations in Developing Decision Trees/ Matrices:

- Decision factors
- Availability of data
- Ability to predict conditions
- Flexibility

Slide 10-37

Programmed Rules

- Outline criteria for selection of preferred treatment
- Set treatment for condition range
- Could be transferred into decision matrices or decision trees

Slide 10-37

Notes:

Programmed Rules are a set of rules that define when a treatment is supplied.

- Disadvantages – usually only looking at one alternative.
- Outline criteria for selection of preferred treatment.
- Set treatment for condition range.
- Could be transferred into decision matrices or decision trees.

Slide 10-38

Types of Treatments Considered

- Rehabilitation category
- Specific treatment

Slide 10-38

Notes:

Types of Treatments Considered:

- Rehabilitation category
- Specific treatment

Slide 10-39

Rehabilitation Categories

- **Preventive Maintenance**
- **Minor Rehabilitation**
- **Major Rehabilitation**
- **Reconstruction**

Slide 10-39

Notes:

These are the common treatment categories used.

Advantages

§ Specific treatments not applied.
§ Project specific information is used to select treatment.

Disadvantages

§ General cost data is needed.
§ Several determinate rates may be used.

Slide 10-40

Specific Treatments

- **Asphalt**
  - Routine Maintenance
  - Surface Seal Coats
  - Milling and Inlays
  - Thin Overlay
  - Thick Overlay
  - Mill and Overlay
  - Reconstruction
- **Concrete**
  - Slab Grinding
  - Full- and Partial-Depth Repairs
  - Crack and Seat
  - Thin-Bonded Overlay
  - Unbonded Overlay
  - Slab Replacement
  - Reconstruction

Slide 10-40

Notes:

These are the most commonly listed specific treatments included in a PMS. These were listed in NCHRP Synthesis 222.

Slide 10-41

10

Factors to Consider in Developing Treatments

- **Accuracy of cost estimates needed**
- **Ability to differentiate performance characteristics**
- **Level of detail required**
- **Need for selection criteria**

Slide 10-41

Notes:

These are some of the factors to be considered when developing a treatment.

Slide 10-42

10

Prioritization Analysis Components

- **Benefit or effectiveness**
- **Life cycle costs**
- **Benefit/cost ratio or effectiveness ratio**

Slide 10-42

Notes:

Prioritization Analysis Components:

§ Benefit or effectiveness
§ Life cycle costs
§ Benefit/cost ratio or effectiveness ratio

Slide 10-43

Benefits or Effectiveness

- **Effectiveness**
  - Non-Monetary
  - Area under the curve for some traffic value
- **Benefits**
  - Monetary or Non-Monetary
  - Area under the curve for some traffic value

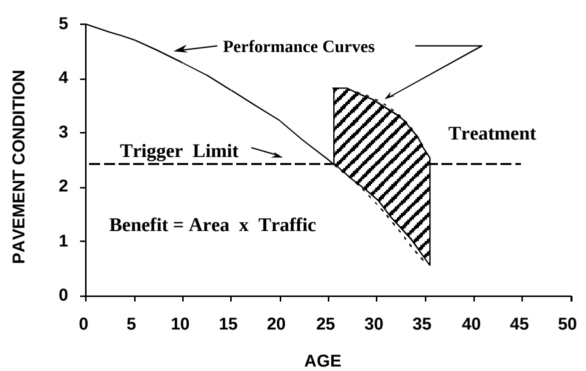
Slide 10-43

Notes:

The additional life obtained by the application of a treatment is defined in terms of effectiveness or benefit. Effectiveness is always defined in non-monetary terms, but benefit could be either monetary or non-monetary.

Slide 10-44

Benefit Calculation



Slide 10-44

Notes:

Figure 10.10. This again shows the calculation of benefit. In many cases, benefit is multiplied by traffic to give more weight to sections with heavier traffic levels.

Slide 10-45

Costs

- **Agency cost**
- **User cost**
- **Salvage value**
- **Maintenance cost**
- **Other relevant costs over the life of the pavement**

Slide 10-45

Notes:

Costs:

- Agency cost
- User cost
- Salvage value (cost when salvage value is negative)
- Maintenance cost
- Other relevant costs over the life of the pavement

Slide 10-46

Prioritization Analysis Techniques

- **Marginal cost-effectiveness analysis**
- **Incremental benefit/cost analysis**
- **Ratio calculation**
  - positive ratio= viable strategy
  - negative ratio= costly strategy

Slide 10-46

Notes:

Most agencies use an effectiveness analysis or a benefit/cost analysis. Ratios greater than 1 are considered.

Slide 10-47

Marginal Cost-Effectiveness

- Identify feasible treatments for each analysis period based on projected condition and established trigger levels
- Calculate effectiveness (E) of each combination of strategies (area traffic)
- Calculate cost (C) of each combination in net present value terms

Slide 10-47

Notes:

The next three slides list the steps involved in an effectiveness analysis. This example was provided by Minnesota.

Example is in text on Page 10-28.

Slide 10-48

Marginal Cost-Effectiveness (cont.)

- Calculate cost-effectiveness (CE) of each combination as ratio of E/C, where highest value is best
- Select treatment and timing for each section with best CE
- Calculate marginal cost-effectiveness (MCE) of all other strategies as follows:

$$MCE = (E_r - E_s)/(C_r - C_s)$$

Slide 10-48

Notes:

The second set of steps.

Slide 10-49

Marginal Cost-Effectiveness (cont.)

- If MCE is negative, or if E_f is less than E_s, comparative strategy is eliminated from future consideration; if not, it replaces strategy selected in previous step
- Process is repeated until no further selections can be made in any year of analysis period

Slide 10-49

Notes:

The final set of steps.

Slide 10-50

Marginal Cost-Effectiveness (MCE) Example

SEG	ALT	Treatment	Eff.	Cost	CE	MCEs
A	1	Seal Coat	1	1	(1/1)=1.0	[redacted]
	2	1"Overlay	5	2	(5/2)=2.5	
	3	2"Overlay	8	4	(8/4)=2.0	
	4	4"Overlay	11	8	(11/8)=1.4	
B	1	2"Overlay	8	4	(8/4)=2.0	
	2	3"Overlay	10	6	(10/6)=1.7	
	3	4"Overlay	11	8	(11/8)=1.4	
C	1	Joint Seal	3	1	(3/1)=3	
	2	Joint Repair	5	4	(5/4)=1.2	
	3	3"Overlay	10	6	(10/6)=1.7	
			Total Budget		12	

Slide 10-50

Notes:

This slide illustrates an example from the course notebook. It is for a sample network with 3 segments and a budget of 12. The steps are defined in the course notebook.

Identify the strategy with the highest CE and determine the MCE increase provided by other strategies for that section.

Slide 10-51

MCE Example (cont.)

SEG	ALT	Treatment	Eff.	Cost	CE		MCEs
A	1	Seal Coat	1	1	(1/1)=1.0	1	[redacted]
	2	1"Overlay	5	2	(5/2)=2.5	2.5	
	3	2"Overlay	8	4	(8/4)=2.0	2	
	4	4"Overlay	11	8	(11/8)=1.4	1.4	
B	1	2"Overlay	8	4	(8/4)=2.0	2	
	2	3"Overlay	10	6	(10/6)=1.7	1.7	
	3	4"Overlay	11	8	(11/8)=1.4	1.4	
C	1	Joint Seal	3	1	(3/1)=3	Use	
	2	Joint Repair	5	4	(5/4)=1.2	0.7	
	3	3"Overlay	10	6	(10/6)=1.7	1.4	
			Total Budget		12	11	

Slide 10-51

Notes:

Update the Effectiveness Table using the MCE for Alts. C2 and C3.

Slide 10-52

MCE Example (cont.)

SEG	ALT	Treatment	Eff.	Cost	CE		MCEs	
A	1	Seal Coat	1	1	(1/1)=1.0	1	***	[redacted]
	2	1"Overlay	5	2	(5/2)=2.5	2.5	Use	
	3	2"Overlay	8	4	(8/4)=2.0	2	1.5	
	4	4"Overlay	11	8	(11/8)=1.4	1.4	1	
B	1	2"Overlay	8	4	(8/4)=2.0	2	2	
	2	3"Overlay	10	6	(10/6)=1.7	1.7	1.7	
	3	4"Overlay	11	8	(11/8)=1.4	1.4	1.4	
C	1	Joint Seal	3	1	(3/1)=3	Use	Use	
	2	Joint	5	4	(5/4)=1.2	0.7	0.7	
	3	Repair	10	6	(10/6)=1.7	1.4	1.4	
		3"Overlay						
			Total Budget		12	11	9	

Slide 10-52

Notes:

Repeat the selection of the highest CE or MCE, and calculate MCEs for any other treatments from the selected segment.

Slide 10-53

M CE Ex a m p le (cont.)

SEG	ALT	Treatment	Eff.	Cost	CE	MCEs		
A	1	Seal Coat	1	1	(1/1)=1.0	1	***	***
	2	1”Overlay	5	2	(5/2)=2.5	2.5	Use	Use
	3	2”Overlay	8	4	(8/4)=2.0	2	1.5	1.5
	4	4”Overlay	11	8	(11/8)=1.4	1.4	1	1
B	1	2”Overlay	8	4	(8/4)=2.0	2	2	Use
	2	3”Overlay	10	6	(10/6)=1.7	1.7	1.7	1
	3	4”Overlay	11	8	(11/8)=1.4	1.4	1.4	0.8
C	1	Joint Seal	3	1	(3/1)=3	Use	Use	Use
	2	Joint Repair	5	4	(5/4)=1.2	0.7	0.7	0.7
	3	3”Overlay	10	6	(10/6)=1.7	1.4	1.4	1.4
			Total Budget		12	11	9	5

[redacted]

Slide 10-53

Notes:

Slide 10-54

M CE Ex a m p le (cont.)

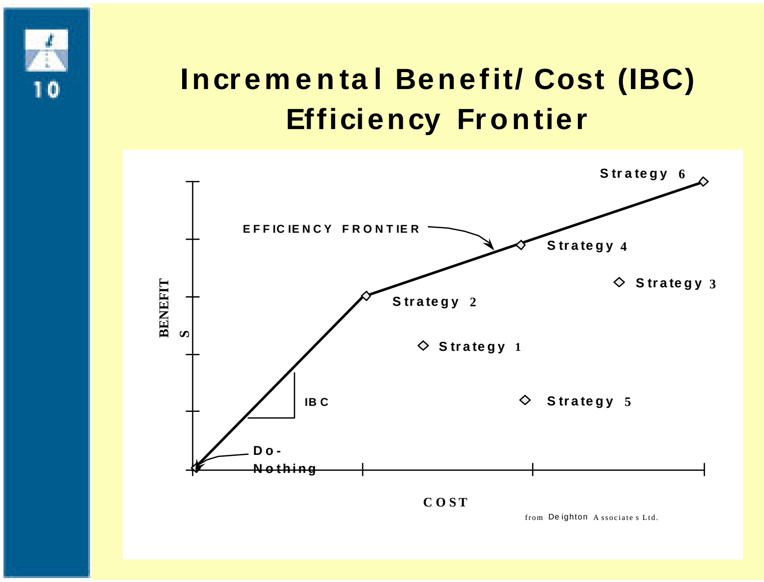
SEG	ALT	Treatment	Eff.	Cost	CE	MCEs				
A	1	Seal Coat	1	1	(1/1)=1.0	1	***	***	***	***
	2	1”Overlay	5	2	(5/2)=2.5	2.5	Use	Use	***	***
	3	2”Overlay	8	4	(8/4)=2.0	2	1.5	1.5	Use	Use
	4	4”Overlay	11	8	(11/8)=1.4	1.4	1	1	0.8	0.8
B	1	2”Overlay	8	4	(8/4)=2.0	2	2	Use	Use	***
	2	3”Overlay	10	6	(10/6)=1.7	1.7	1.7	1	1	Use
	3	4”Overlay	11	8	(11/8)=1.4	1.4	1.4	0.8	0.8	0.8
C	1	Joint Seal	3	1	(3/1)=3	Use	Use	Use	Use	Use
	2	Joint	5	4	(5/4)=1.2	0.7	0.7	0.7	0.7	0.7
	3	Repair 3”Overlay	10	6	(10/6)=1.7	1.4	1.4	1.4	1.4	***
			Total Budget		12	11	9	5	3	1

Slide 10-54

Notes:

Remind participants that there is no one correct answer.

Slide 10-55



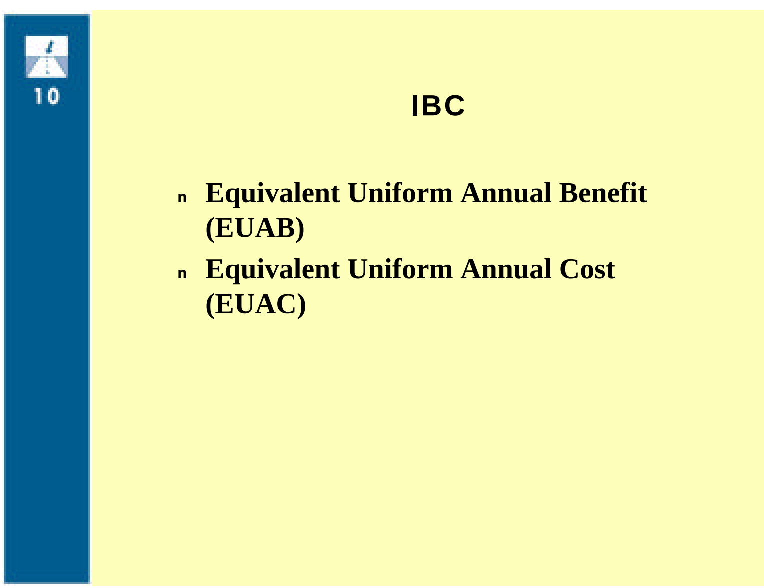
Slide 10-55

Notes:

An incremental benefit/cost analysis can be illustrated through the use of an efficiency frontier (Figure 10.11). The frontier is established so no strategy points exist above the line, and no line segment has a bigger slope than the previous line segment.

Life-cycle costs are recommended for a network level analysis. Recognize that this is not as detailed as project-level analysis.

Slide 10-56



Slide 10-56

Notes:

An incremental benefit cost analysis often uses EUAB and EUAC as the economic calculations for the analysis.

Slide 10- 57

EU A B

Calculate the Equivalent Uniform Annual Benefit

$$\textbf{EUAB} = \textbf{PVB} \; \frac{[r\,(1+r)^n]}{[(1+r)^n - 1]}$$

Slide 10-57

Notes:

This shows the calculation of EUAB. Equation is in text.

PVB = Present Value Benefit
= Area x Traffic

r = Discount Rate

n = Useful Life of Longest-Lived Treatment

Slide 10- 58

EU A C

Calculate Equivalent Uniform Annual Cost

$$\textbf{EUAC} = \textbf{PVC} \; \frac{[r\,(1+r)^n\,]}{[(1+r)^n - 1]}$$

Slide 10- 58

Notes:

This shows the calculation of EUAC.

PVC = Present Value Cost (Present Worth)

r = Discount Rate

n = Useful Life of Longest-Lived Treatment

Slide 10- 59

IBC

Calculate Incremental Benefit/Cost

$$IBC_j = \frac{(EUAB_j - EUAB_{j-1})}{(EUAC_j - EUAC_{j-1})}$$

Treatment for each section are sorted by increasing EUAC
Negative IBC’s are eliminated

Slide 10- 59

Notes:

This shows the calculation of the incremental benefit cost ratio.

Slide 10- 60

Integration of MYP Into Project Selection

- **List of candidate projects**
- **Foundation for scoping review**
- **Evaluation of trade-offs**
- **Impact analysis**
- **Budget needs**

Slide 10- 60

Notes:

Integration of MYP into Project Selection:

- List of candidate projects
- Foundation for scoping review
- Evaluation of trade-offs
- Impact analysis
- Budget needs

Slide 10- 61

Examples of Coordinated Project Selection Efforts

- Evaluation of various treatments
- Identification of sites for scoping visits
- Improved efficiency of pre-construction process
- Fewer scope changes

Slide 10- 61

Notes:

The course notebook lists several efforts by state agencies to improve the coordination of the project selection process. These examples should be explained here.

Slide 10- 62

Case Study -Indiana DOT (InDOT)

- MYP for interstate system
- One complete programming cycle developed using new software

Slide 10- 62

Notes:

Indiana provides an excellent example of an agency using a MYP process. To date, it is just used on the interstates and has been used for one rehabilitation cycle.

Slide 10- 63

InDOT Overview

- Mainframe database
- Data extracted into dROAD database on personal computer
- Incremental benefit/cost analysis
- 5-year analysis, 2 years out
- PMS recommendations used as first cut list for scoping visits

Slide 10- 63

Notes:

These are some of the overview points from INDOT. They use Deighton's software to prepare a 5-year plan, 2 years in advance.

Slide 10- 64

InDOT PMS Process

- Collect condition data
- Load and analyze data using the PMS software
- Identify proposed new projects
- Conduct scoping visits to define limits and reset priorities
- Set project scope
- Re-analyze projects
- Match projects to budget
- Make necessary revisions

Slide 10- 64

Notes:

This is a summary of the PMS process in Indiana. The scoping visits are an excellent example of a coordinated agency effort to better define the project scopes.

Slide 10- 65

InDOT Software Tools

- **dROAD**
  - database
  - extracted data from mainframe computer
- **dTIMS**
  - analysis tools

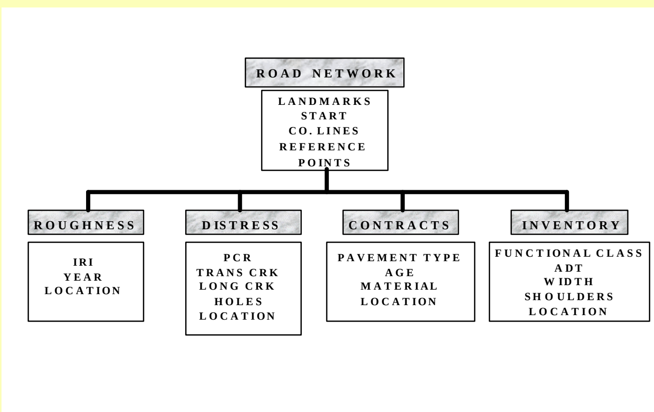
Slide 10- 65

Notes:

INDOT uses dROAD as its database and dTIMS as its analysis tool.

Slide 10- 66

Required Data



Slide 10- 66

Notes:

This is Figure 10.13. It lists the data required to support the system.

Slide 10- 67

Analysis Groups

- **Groups of pavements with like characteristics**
  - functional class
  - traffic volumes
  - pavement type
- **Used for performance models and for setting analysis conditions**

Slide 10- 67

Notes:

Pavements are grouped into categories with like characteristics. These characteristics are used to identify families.

Instructor may wish to give equivalent local taxonomy.

Slide 10- 68

Performance Measures

- **Individual condition indices**
  - ride (PSI)
  - rutting (RUT)
  - distress (PCR)
- **Composite index**
  - pavement quality index (PQI)
  - PQI = 0.55PCR + 8.8PSI - 0.25RUT

Slide 10- 68

Notes:

These are the methods used to assess pavement conditions. Individual indices are calculated for ride, distress, and rutting. The predicted values are then used to calculate a Pavement Quality Index (PQI). The sample equation shown is for interstate composite pavements.

Slide 10- 69

10

Deterioration Models

- Regression analysis for PSI, PCR, and RUT performance models
- Forecasted indices used to calculate future PQI values

Slide 10- 69

Notes:

A regression analysis was used to develop performance models for each individual index.

Slide 10- 70

10

Performance Models

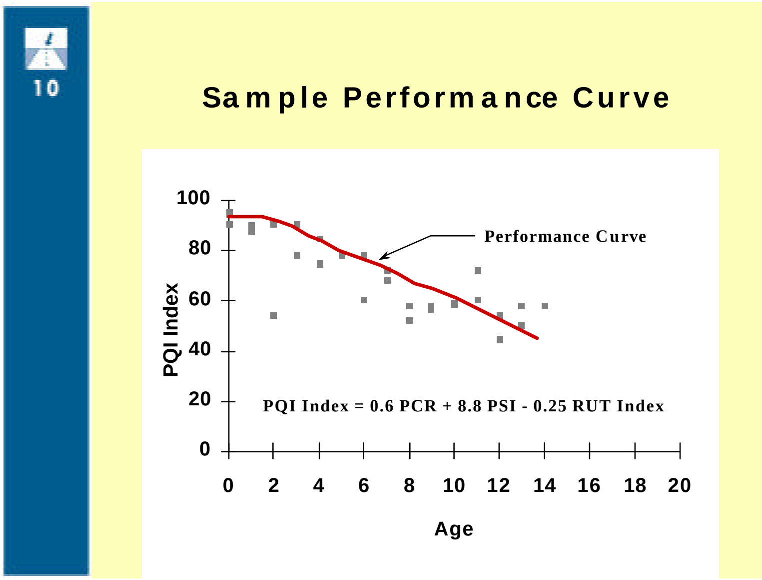
Functional Class/Surface Type	PSI	PCR	RUT	PQI
Interstate Composite	✔	✔	✔	✔
Interstate Flexible	✔	✔	✔	✷
Interstate Crack and Seat	✔	✔	✔	✷
Interstate Jointed Concrete	✔	✔		✷
Interstate Continuously Reinforced Concrete	✔	✔		✷
State Route Composite	✷	✷	✷	✷
State Route Asphalt	✷	✷	✷	✷
State Route Composite - Low Traffic	✷	✷	✷	✷
State Route Asphalt - Low Traffic	✷	✷	✷	✷
Other Jointed Concrete	✷	✷		✷
Other Continuously Reinforced Concrete	✷	✷		✷

Slide 10- 70

Notes:

Table 10.10 (on Page 10-39) lists the performance curves that are completed (a check mark) and those that will be completed soon (an asterisk).

Slide 10- 71



Notes:

Figure 10.14. This illustrates a composite pavements.

Slide 10- 72

10

Treatment Type

– Mill and thin resurface

Structural overlay

–

– Patch

Replace

- **Reset Values**
- **Trigger Values**

Notes:

These are the variables that are defined

Slide 10- 73

Treatment Costs

Interstate Treatments and Cost	
Treatment Type	**Cost per sq yd**
Mill and Resurface	$6.00
Structural Overlay Rural	$50.00
Structural Overlay Urban	$60.00
Crack and Seat Rural	$50.00
Crack and Seat Urban	$60.00
Patch	$5.00
Replace Rural	$66.00
Replace Urban	$77.00

Notes:

Table 10.11. This lists the costs for

Slide 10- 74

Treatment Trigger Values

PVMT	COMPOSITE					
PSI	GOOD 5-3.5		FAIR 3.5-2.8		POOR < 2.8	
RUT	GOOD <0.45	BAD >0.45	GOOD <0.45	BAD >0.45	GOOD <0.45	BAD >0.45
PCR						
100-90	NO	R/S	NO	R/S	R/S	4R
90-80	NO	R/S	NO	R/S	R/S	4R
80-70	NO	R/S	R/S	4R	4R	4R
70-60	4R	4R	4R	4R	4R	4R
60-50	4R	4R	4R	4R	RPL	RPL
<50	4R	4R	RPL	RPL	RPL	RPL

Slide 10- 74

Figure 10.15. Shows the decision matrix for interstate composite

Slide 10- 75

Financial Parameters

- Budget levels for each year of the analysis
- Economic factors impacting life cycle costs

Slide 10- 75

Notes:

Financial Parameters:

§ Define parameters

Slide 10- 76

Analysis Procedures

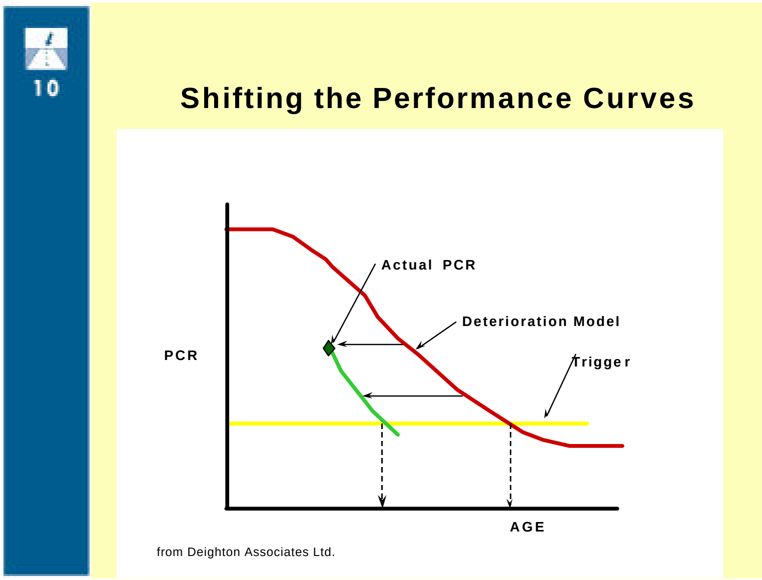
- Shifting performance curves
- Trigger initial treatments
- Calculate reset values
- Calculate subsequent condition indices
- Trigger subsequent treatments
- Calculate costs
- Calculate benefits
- Calculate IBC
- Optimize strategy selection

Slide 10- 76

Notes:

After all the parameters are defined, the analysis can be run. These are the steps dTIMS goes through to run the analysis.

Slide 10- 77



Slide 10- 77

Notes:

The performance curve is shifted to better represent the deterioration pattern of an individual section using a family model. Figure 10.16.

Slide 10- 78

Slide 10- 78

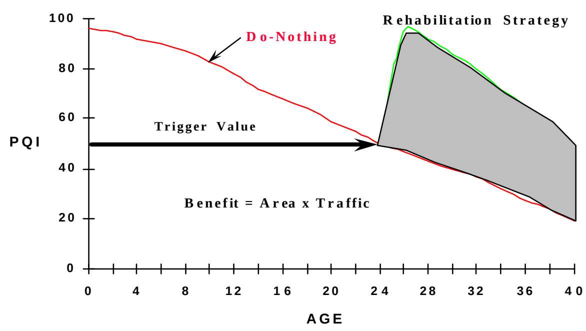
Notes:

These are some of the other steps that must be performed:

- Triggering initial treatments
  - Identify all sections falling in trigger zone
- Calculating reset values
  - Forecast future conditions for remaining years
- Calculating subsequent condition indices
  - Forecast future conditions for remaining years
- Reset indices after feasible treatments are identified
- Triggering subsequent treatments
  - Similar to triggering initial treatments
  - Only subsequent treatment remaining
- Calculating life cycle costs
  - Determine end strategy
  - 20-year analysis period
  - Discount rate of 6%
- Calculating benefits
- Forecast future conditions for remaining years

Slide 10- 79

Benefit Calculation



Slide 10- 79

Notes:

This is how they calculate the benefit of a treatment. It is the area times the traffic level. Figure 10.17.

Slide 10- 80

Other Steps (cont.)

- **Calculating IBC**
  - EUAB
  - EUAC
  - EUAB/EUAC
  - IBC = incremental change in benefits and costs
  - Sorted by increasing IBC

Slide 10- 80

Notes:

The incremental benefit/cost is then determined.

Slide 10- 81

Program Development Process

- Tentative program list
- Field evaluation packets
- Site visits
- Revised scopes
- Re-analyze results

Slide 10- 81

Notes:

This slide documents the scoping process used by InDOT. Field committees go to each feasible site to evaluate the project scope. Based on the information reported by the team, revised scopes and costs are developed and reprioritized.

Program Development Process:

- Tentative program list
- Field evaluation packets
  - Functional characteristics
  - Proposed rehabilitation and costs
  - Condition information
  - Design/construction information
- Site visits
- Revised scopes
- Re-analyze results

Slide 10- 82

Instructional Objectives

- Describe the objectives of a multi-year prioritization analysis.
- Understand the differences between other multi-year analysis techniques.
- Describe the components of a multi-year prioritization analysis.
- Understand the use of a multi-year prioritization analysis as part of an agency's project selection process.

Slide 10- 82

Notes:

Review the objectives for this module.

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MODULE 11

OPTIMIZATION

Purpose:

This module introduces the participants to the use of optimization for the development of multi-year programs. The overall objectives of an optimization analysis are presented and the types of models most commonly used are discussed. Case studies from agencies using optimization are also provided.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Understand the philosophy of optimization.
- Identify the concepts involved in an optimization analysis.
- Identify the types of models used in an optimization analysis.

Reference:

Module 11 of the Course Notebook

Duration:

60 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

41 Microsoft PowerPoint® Slides

Approach:

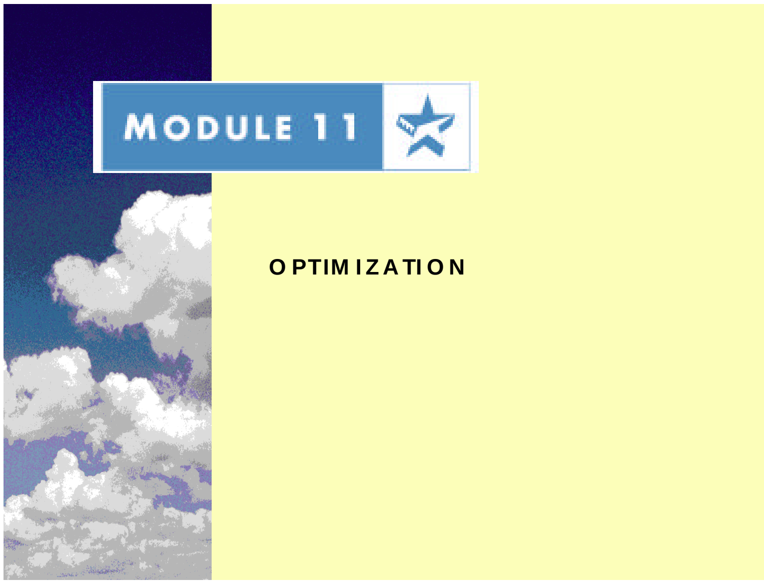
This module is taught through slide presentations and disucssion with the participants.

Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Leraning for this module. The slides prepared may also be used for distance learning.

Slide11-1

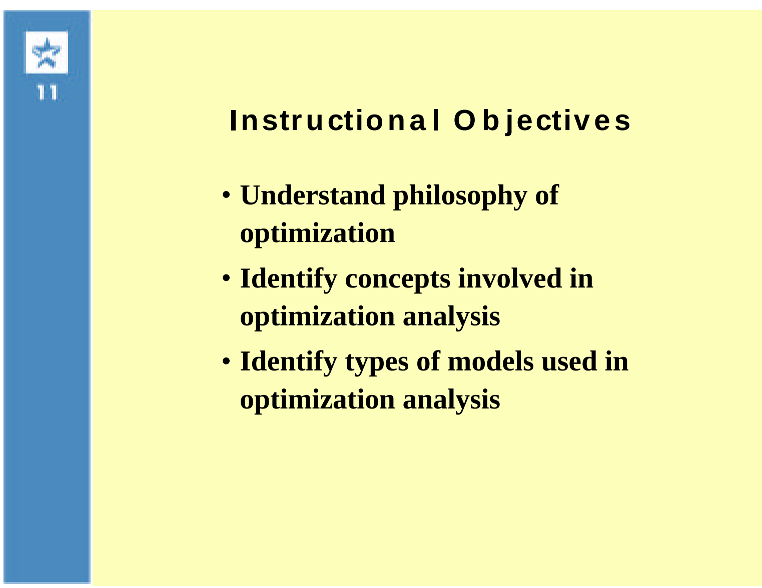


Slide11-1

Notes:

Introduce the purpose of this module. Provide an overview of the layout of the module and mention the case study from the Kansas DOT.

Slide11-2



Slide11-2

Notes:

Introduce the objectives of this module.

Slide11-3

Optimization

- Uses sophisticated mathematical modeling techniques for the analysis
- Multi-step process
- Provides improved benefit to agencies

Slide11-3

Notes:

Introduce the concept of optimization as a multi-step process to develop strategies to meet agency goals and then identify projects to match the strategies.

Discuss the benefits realized by an agency that adopts an optimization analysis rather than ad-hoc approaches. Discuss the additional benefits over heuristic approaches.

Slide11-4

Optimization Analysis Steps

- Determine agency goals
- Establish network-level strategies that achieve the goals
- Select projects that match the selected strategies

Slide11-4

Notes:

Discuss the three activities normally involved in optimization. Mention that an agency can analyze tradeoffs between various projects. It can also be used to focus the recommendations towards the achievement of an overall level of network performance.

Slide11-5

Optimization Considerations

- **Other techniques are easier to understand**
- **Loss of control perceived**
- **Requires individuals with backgrounds in mathematics, statistics, and operations research**
- **Consistency in data is more important**
- **Requires sophisticated computers**

Slide11-5

Notes:

Because of the sophistication of this type of analysis, an agency should consider several factors before deciding whether to use this approach.

Slide 11-6

Is Optimization Appropriate?

- **Select prioritization if:**
  - Management wants to exercise significant control over the planning and programming exercises.
- **Select optimization if:**
  - Management wants to take a global view and is willing to put substantial faith in a system.

Slide 11-6

Notes:

From a simplistic point of view, this slide summarizes when prioritization should be selected and when optimization is more appropriate.

Few agencies in North America use true optimization techniques,
e.g. Kansas.

Slide 11-7

Objective Function

- Used to express an agency goal in mathematical terms
- Typical objective functions:
- Identify/define constraints
  - minimize cost
  - maximize benefits

Slide 11-7

Notes:

In order to use optimization, the agency must define a goal in mathematical terms called an objective function. Objective functions fall into one of two categories, as listed here.
After the objective function is defined, constraints or limitations must be defined.

Slide 11-8

Markov Transition Probability Matrix

Current State	Future State			
	1	2	3	4
1	0.2	0.4	0.3	0.1
2		0.2	0.6	0.2
3		0.1	0.3	0.6
4			0.1	0.9

Slide 11-8

Notes:

Table 11.1. This illustrates a Markov transition probability matrix to model the likelihood of a pavement transitioning from one condition state to another.

Explain table and how it works.

Slide 11-9

11

Markov Assumptions

- **Future condition is independent of past condition**

Slide 11-9

Notes:

It is critical to understand that with this approach, there is a basic assumption that the next year’s condition is independent of how the pavement acquired the current year’s condition state.

This limitation can be overcome by including factors such as age and design life of the last rehabilitation action into the definition of the condition state.

Slide 11-10

11

Other Parameters

- **Transition costs must be defined**
  - Life-cycle costs
  - Present worth analysis typically more common
- **Heuristic approaches reach near optimal solutions**
  - ICB Ratio

Slide 11-10

Notes:

In addition, the costs associated with the transitions must be defined using life cycle costs.

Also emphasize that there are several approaches that can be used for optimization, including Markov and semi-Markov decision processes. Heuristic (trial and error) approaches give near optimal solutions.

Other decision processes include:

- Monte Carlo simulation
- Fuzzy set methods

Slide 11-11

Example of a Markov Decision Process

- **Assumptions**
  - 100 km network
  - Two condition states: good (1) or bad (2)
  - 80% of the network is in good condition
  - 20% of the network is in poor condition
  - Two maintenance activities are considered: Do Nothing (DoNo) and Overlay (Over)

Slide 11-11

Notes:

A Markov decision process is illustrated through the use of a small example. The example illustrates the use of transition probabilities, costs, and the selection of the optimal long-term policy.

Discuss the parameters of the example.

Slide 11-12

Transition Probability Matrix

	To Condition States			
From Condition States	Do Nothing		Overlay	
	1	2	1	2
1	0.6	0.4	0.95	0.05
2	0.01	0.99	0.8	0.2

Slide 11-12

Notes:

This shows the transition probability matrices for the example. It is included in the course materials as Table 11.2.

These have been determined by expert personnel.

Slide 11-13

Network Conditions - Year 1
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	80%*0.6 = 48	80%*0.4 = 32
2	20%*0.8 =16	20%*0.2 = 4
Total	64%	36%

Slide 11-13

Notes:

This figure replicates the first year from Table 11.3. It shows the calculation of the probability that a randomly-selected segment in the network will be in condition state 1 and 2, using the transition probability matrix shown in the previous slide.

Slide 11-14

Network Conditions - Year 2
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	64%*0.6 = 38.4	64%*0.4 =25.6
2	36%*0.8 =28.8	36%*0.2 = 7.2
Total	67.2%	32.8%

Slide 11-14

Notes:

This is the calculation of the second year in the analysis. Note the change in percentage of pavements in condition states 1 and 2.

Slide 11-15

Network Conditions - Year 3
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	67%*0.6= 40.2	67%*0.4= 26.8
2	33%*0.8= 26.4	33%*0.2 = 6.6
Total	66.6%	33.4%

Slide 11-15

Notes:

This shows year three of the example. At this point, the network begins to reach a steady state condition in which the probability of being in each condition state remains constant. In this example, the steady state is reached in year 3.

Slide 11-16

Example Cost Data

Condition State	Action	Initial Cost	Annual Maintenance Cost	Total Cost
1	Do Nothing	$ -	$ 2,000	$ 2,000
2	Overlay	$ 10,000	$ 100	$ 10,100

Slide 11-16

Notes:

For this portion of the analysis, the costs associated with each condition state and rehabilitation alternative must be considered. This table, Table 11.4 in the manual, summarizes the initial costs and annual costs associated with each alternative. No user costs or salvage values are considered.

Slide 11-17

Policy Costs - Year 1
For Repair Strategy

Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	80	Do Nothing	$160	$362
2	20	Overlay	$202	

Slide 11-17

Notes:

This slide shows the first year in Table 11.5. Using the cost information, this slide illustrates the cost of implementing the policy in the first year.

Slide 11-18

Policy Costs - Year 2
For Repair Strategy

Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	64	Do Nothing	$128	$492
2	36	Overlay	$364	

Slide 11-18

Notes:

Similarly, this shows the cost of the second year of the policy.

Slide 11-19

Policy Costs - Year 3
For Repair Strategy

Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	67	Do Nothing	$134	$467
2	33	Overlay	$333	

Slide 11-19

Notes:

This is the third year of the analysis and the costs associated with it. This is the cost associated with the steady state conditions.

Optimal policy is the policy with the minimum expected cost after system reaches steady state conditions.

Slide 11-20

Simulation Objectives

- **Identify the policy with the minimum expected cost after the system reaches steady state.**
- **Establish desired long-term performance standards and minimum budgets to achieve standards or short-term objectives to reach steady state within a specified period at a minimum cost.**

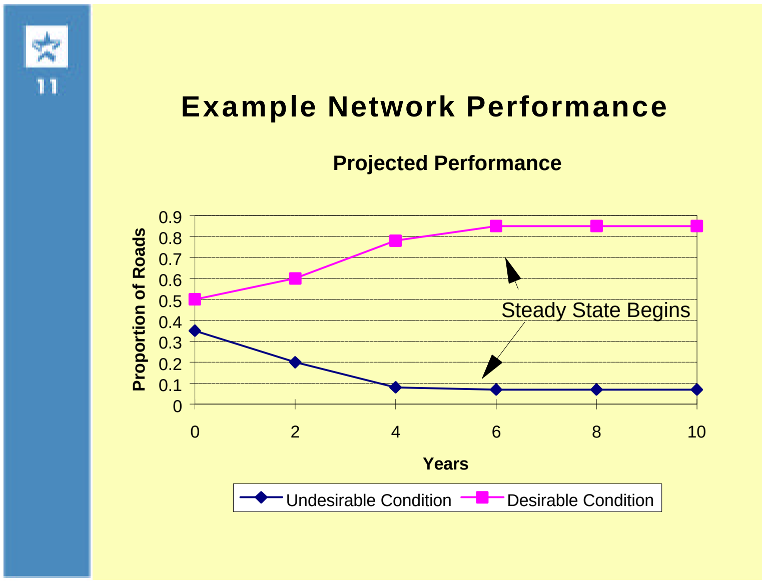
Slide 11-20

Notes:

Summarize the objectives of this type of analysis and the difference between short-and long-term goals.

Short term = 5-10 years, but may not be able to reach steady state due to budget or policy changes.

Slide 11-21

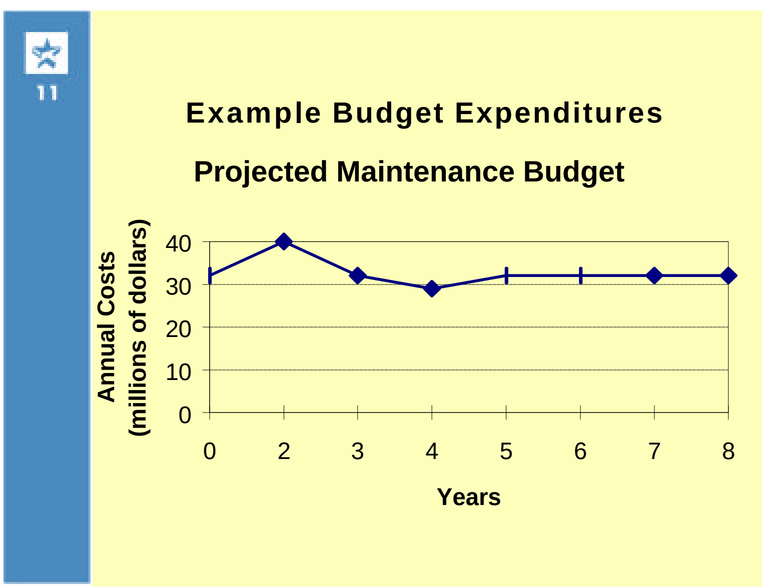


Slide 11-21

Notes:

This slide is Figure 11.1. It shows the behavior of the network as a steady state condition is achieved.

Slide 11-22



Slide 11-22

Notes:

This slide shows that when steady state conditions are reached, budgets begin to flatten out and reach a constant level.

Slide 11-23

Markov Approach

- **Advantages**
- **Disadvantages**

Slide 11-23

Notes:

Discuss the advantages and disadvantages associated with an optimization analysis.

Slide 11-24

Mathematical Programming Methods

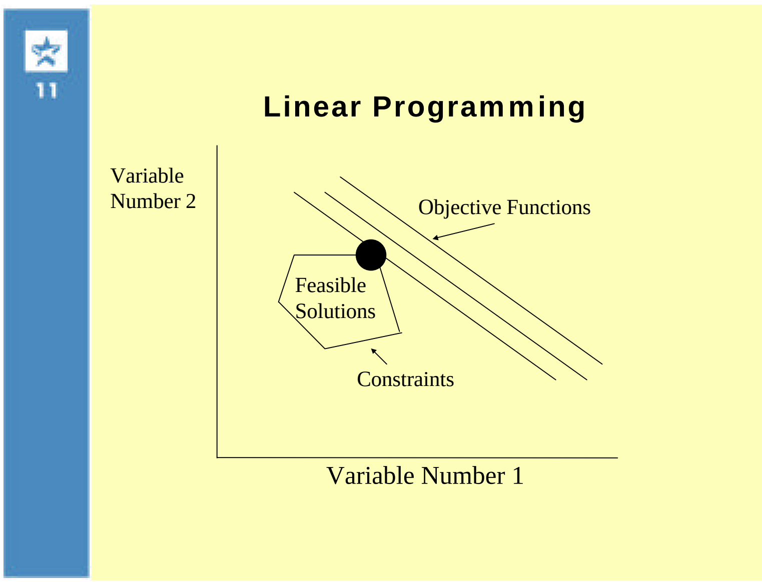
- **Linear programming**
- **Non-linear programming**
- **Integer programming**
- **Dynamic programming**

Slide 11-24

Notes:

There are a number of different approaches used to solve the objective function of the equation subject to the given constraints. These are the four most common mathematical programming approaches used in pavement management.

Slide 11-25



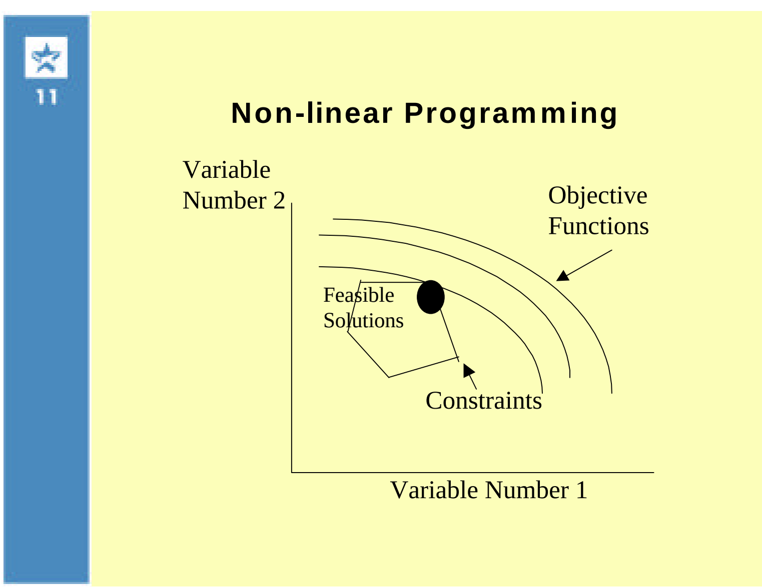
Slide 11-25

Notes:

Linear programming involves an analysis in which both the objective function and the constraints are linear functions of the variables. The variables are continuous, meaning that they can take on all values on the graph.

As shown in this figure, Figure 11.3, the constraints define the boundaries of feasible conditions within which all acceptable solutions will fall. The objective function is represented as a straight line, which is moved toward the feasible region while keeping its slope. The first vertex it encounters is the optimum solution.

Slide 11-26



Slide 11-26

Notes:

Non-linear programming is very similar to linear programming because the best solution comes from an infinite number of solutions of continuous variables. The main difference is that the objective function and some of the constraints may be curvilinear or time dependent.

Figure 11.4. The mathematical manipulations for this approach are more detailed, but the principle remains to identify the point at which the objective function first intersects the feasible region.

Slide 11-27

Integer Programming

Projects	Do Nothing	Seal	Overlay
1	0	1	0
2	1	0	0
3	0	0	1
4	0	1	0

Slide 11-27

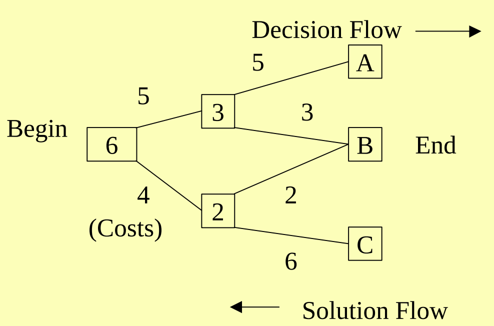
Notes:

Integer programming uses variables that are no longer continuous. The variables only take on the values of 0 or 1 (to do something or not do something). The programming problem results in a decision matrix that is composed of a series of 0s and 1s, as shown in the next slide.

This is Table 11.6. It shows the results of an integer programming analysis in the form of a decision matrix. It uses an objective function and its constraints as do the previous modeling techniques. The objective function seeks to select the projects and alternatives that maximize a benefit or minimize an overall cost.

Slide 11-28

Dynamic Programming



Slide 11-28

Notes:

Dynamic programming methods are used when a number of decisions must be made in sequence and an earlier decision dictates what the subsequent decision will be.

This figure illustrates the sequential nature of the decisions in this type of analysis from Figure 11.5. Each node is a decision point and the lines represent the costs associated with making each choice. The least cost path is identified. Usually the analysis starts at the final condition and works its way backward.

Slide 11-29

Selecting the Appropriate Programming Method

- **Function of:**
  - Type of variables in analysis
  - Form of objective function
  - Sequential nature of decisions
- **Typical approaches:**
  - Linear programming most common
  - Dynamic programming second most common approach
  - Non-linear third most common approach
  - No agency is using integer programming

Slide 11-29

Notes:

The variables being used in the analysis, the form of the objective function, and the sequential nature of the decisions influence the appropriate mathematical programming method.

The most common approach is linear programming. Dynamic programming is the next most common and then non-linear programming. No agencies are currently using integer programming.

Slide 11-30

Markov Implementation Steps

- **Define road categories**
- **Develop condition states**
- **Identify treatment alternatives**
- **Estimate transition probabilities for categories and alternatives**

Slide 11-30

Notes:

To implement a Markov decision process, a step-by-step process can be followed. This shows steps 1 through 3. Steps 1 and 2 are similar to any other approach. Step three establishes the condition states for the transition probability matrices.

Steps 4 and 5. Step 5 involves estimating the probabilities associated with transitions from one condition state to another. These can be estimated from historical data or in-house expertise.

Slide 11-31

Markov Implementation Steps (cont.)

- **Estimate costs of alternatives**
- **Calibrate model**
- **Generate scenarios**
- **Document models**
- **Update models**

Slide 11-31

Notes:

Steps 6 and 7. In step 6, cost information is used to determine a present worth. Step 7 involves setting the objective function and constraints for the short- and long-term optimization models. First, the long-term model is solved to determine the optimal stationary policy for steady state conditions. The short-term goal is solved next to bring the network to the target performance goals defined with the long-term goals.

Steps 8, 9, and 10. Develop the computer software to conduct the analysis and be sure the system is documented and staff is trained in its use. The models should be reviewed at least annually and updated as necessary.

Slide 11-32

Case Study - Kansas DOT

- **System Components**
  - Network optimization system (NOS)
  - Project optimization system (POS) (was not fully operational in 1995)
  - Pavement management information system (PMIS)

Slide 11-32

Notes:

The Kansas DOT system is presented to illustrate an optimization analysis. There are 3 components to the system. The NOS is a network optimization system, the POS is a project optimization system, and the PMIS is the pavement management information system. The PMIS provides the information necessary to run the NOS and POS. The NOS has been operational since 1986; the POS was not fully operational in 1995.

Slide 11-33

Overview of KDOT Data Collection Activities

- **Collect pavement distress information**
- **Monitor rutting**
- **Collect roughness data**

Slide 11-33

Notes:

Overview of KDOT Data Collection Activities

- § Collects pavement distress information annually (type, severity, extent) and reports it in terms of 1 of 27 distress states
- § Monitors rutting, but used primarily in safety evaluations
- § Collects roughness data

Slide 11-34

KDOT M&R Programs

- **Major Modification Program**
- **Substantial Maintenance Program**

Slide 11-34

Notes:

Pavement actions are considered at two levels. The major modification program is intended to improve the safety and service of the existing highway system. It includes lane widening, adding shoulders, and eliminating sharp curves. The substantial maintenance program is used to conserve the condition of the network as long as possible. It includes resurfacing. The substantial maintenance program is developed through optimization goals established in the NOS. Project sections are then investigated further as part of the POS to determine site-specific fixes.

Slide 11-35

KDOT Databases

- CANSYS
- PMIS

Slide 11-35

Notes:

Kansas has 2 databases. CANSYS operates on the mainframe and supports the major modification program for safety improvements. The PMIS is on a minicomputer and has the information for the NOS and POS to run. It is a relational database. Information is uploaded and downloaded between the two databases.

Slide 11-36

KDOT NOS Analysis

- **216 possible condition states**
- **Primary influence variables:**
  - Indices to appearance of first distress
  - Rate of change in distress
- **Rehabilitation actions based on one of 27 distress states**
- **Linear programming used to develop programs to maintain acceptable conditions for lowest possible cost**

Slide 11-36

Notes:

The NOS is sued to define the 216 condition states based on the appearance to first crack and the rate of change in the distress.

27 distress states are used to simplify the assignment of feasible actions, costs, and performance models.

Linear programming is used to develop optimal policies to maintain an acceptable performance level at a minimum cost.

The outputs include the minimum rehabilitation budgets, locations of candidate projects, maximum performance achievable for a fixed budget, and optimal rehabilitation policies.

Acceptable is defined mathematically.

Slide 11-37

KDOT POS Analysis

- Projects from NOS are investigated in more detail using POS
- Identify initial designs to maximize user benefits

Slide 11-37

Notes:

At the POS level, a more detailed analysis is conducted for site specific design. The result is an optimization strategy that maximizes system mileage in a high-performance level over time, or minimizes the maintenance levels required by the state's forces.

Slide 11-38

KDOT System Development

- Issue paper
- PMS Steering Committee
- Pavement Management Task Force
- Consultant

Slide 11-38

Notes:

The development began in 1979 with an Issue paper. A committee was formed to provide the overall direction for the PMS implementation. A task force was organized to supervise and assist the consultant in PMS development. Representatives from several bureaus were included in the task force.

The program is located in the Division of Operations. It has been very successful within the state.

Slide 11-39

11

Instructional Objectives

- **Understand philosophy of optimization**
- **Identify concepts involved in optimization analysis**
- **Identify types of models used in optimization analysis**

Slide 11-39

Notes:

Review the objectives for this module.

MODULE 12

PMS FEEDBACK PROCESS

Purpose:

The purpose of this module is to emphasize the importance of a PMS feedback process. This module will stress the need for an active feedback process to be included as part of the planned PMS implementation effort. The feedback loop also provides an effective process for the agency to evaluate the effectiveness of its pavement design and construction practices through an ongoing analysis of its pavement performance models.

Objectives:

Upon completion of this module, the participant will be able to:

- Explain why a feedback loop is important to the operation of a PMS.
- Describe the various processes in a PMS that need to have a feedback loop established, and the types of feedback that is required
- Describe how to establish a feedback loop
- Describe the possible benefits of a feedback loop to other agency

Reference:

Module 12 of the Participant's Notebook

Duration:

30 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transpar3ncies, transpar3ncy pens

Teaching Aids:

18 Microsoft PowerPoint® Slides

Approach:

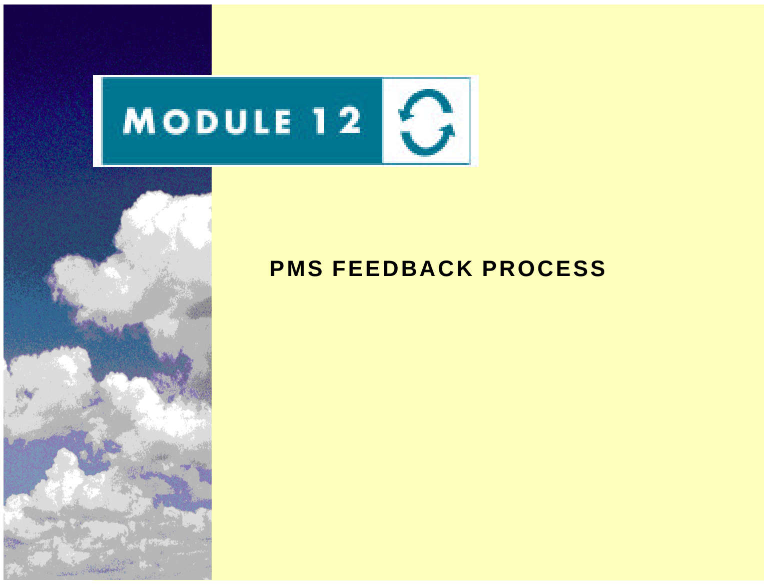
This module is taught through slide presentations and discussion with the participants.

Encourage questions from and promote discussion with the participants.

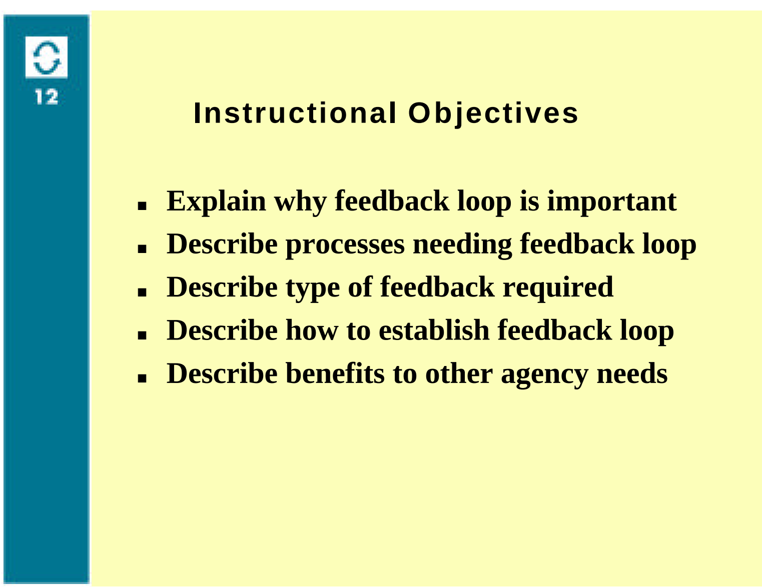
Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

Slide 12-1



Slide 12-2



Slide 12-1

Notes:

Module 12 Introduction Slide

Slide 12-2

Notes:

Instructional Objectives

- Explain why feedback loop is important
- Describe processes needing feedback loop
- Describe type of feedback required
- Describe how to establish feedback loop
- Describe benefits to other agencies

Slide 12-3

Introduction

- **From the 1990 AASHTO Guide:**

"Pavement management systems, similar to any other engineering tool must be reliable in order to be credible. The feedback process is crucial to verify and improve the reliability of a PMS."

Slide 12-3

Notes:

This Module will emphasize the importance of a PMS feedback process. This module will stress the need for an active feedback process to be included as part of the planned PMS implementation effort. The feedback loop also provides an effective process for the agency to evaluate the effectiveness of its pavement design and construction practices through an ongoing analysis of its pavement performance models.

Slide 12-4

Feedback Plan

- **Pavement Performance Models**
- **Treatments**
- **Treatment Trigger levels**
- **Treatment Costs**
- **User Cost Models**
- **Data Quality Use Cost**

Slide 12-4

Notes:

The following sections shown on this slide indicate some of the basic areas of a PMS that should be considered in establishing follow up procedures.

Ask—who has a feedback plan?

Slide 12-5

12

Pavement Performance Models

- **First developed by expert opinion or from limited data**
- **Must be re-calibrated with more extensive field data**

Slide 12-5

Notes:

During the development of a PMS, the service life or performance trends of each pavement type and rehabilitation treatment is estimated from limited agency data, or from the collective opinion of pavement experts within the agency.

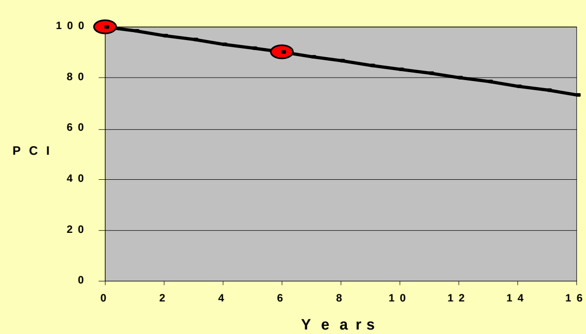
These performance models must be recalibrated with actual field data and operating processes to insure confidence in the system.

Ask—who has this?
And—who based it on actual data?

Slide 12-6

12

Typical pavement performance after 2 surveys



Slide 12-6

Notes:

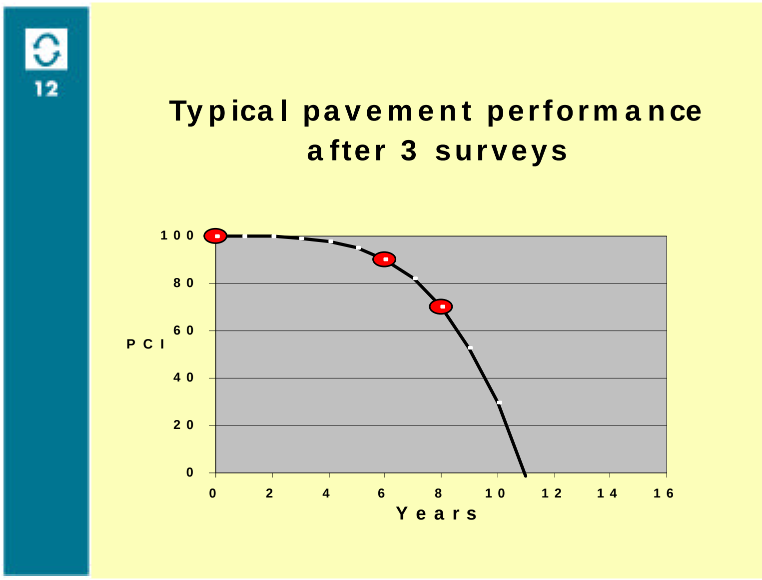
To provide a visual picture of the effect on what increased observation has on pavement performance, the following five slides show a typical deterioration trend for fatigue cracking with time.

The example contains some variation in the distress index with time that represents some minor measurement error that would be expected from the best of condition surveys.

This slide shows only minor deterioration, which would be expected, in relatively new pavement.

Regression analysis at this stage usually predicts very long service lives.

Slide 12-7



Slide 12-7

Notes:

This slide shows a little more deterioration that could be real or from measurement error.

Note the large change in predicted service life from the first slide.

The prediction provided by the curve that fits through all three points is easy to compute mathematically, but it still may not provide a prediction that is better than that provided by expert opinion. It is still a large improvement over the two-point prediction.

Slide 12-8

Slide 12-8

Notes:

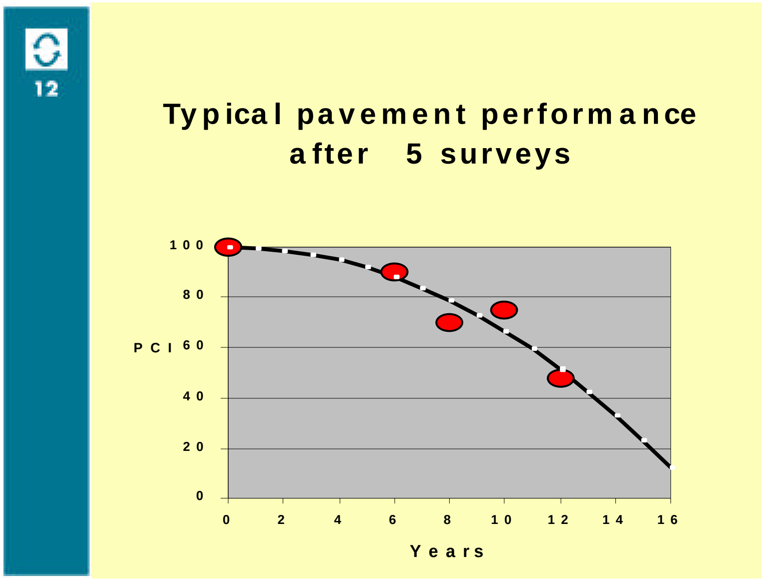
This slide now shows four survey points with the last survey showing a little somewhat less distress than the third survey.

Though there is a large difference in the predicted service life from the last two surveys, these differences are not unusual in real PMS data.

Four points are usually the minimum number of points necessary to conduct a reasonable regression analysis and produce an actual error of estimate and a measure of best-fit (R^2).

The total of four points and subsequent regression curve which best fits those points provides a reasonable prediction of the final performance life of the pavement section as can be seen in this slide.

Slide 12-9



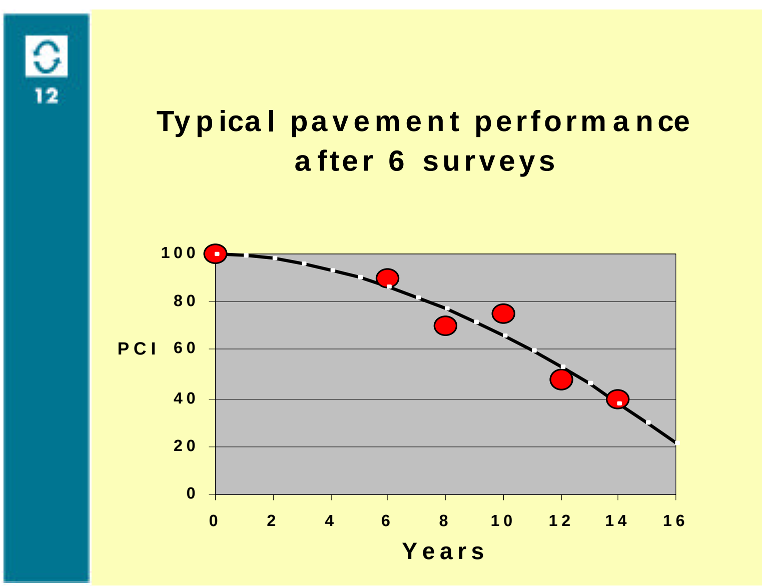
Slide 12-9

Notes:

This slide shows the result of the fifth survey on the service life prediction.

A performance curve developed at this stage of a pavements service life comes very close to the final performance curve.

Slide 12-10



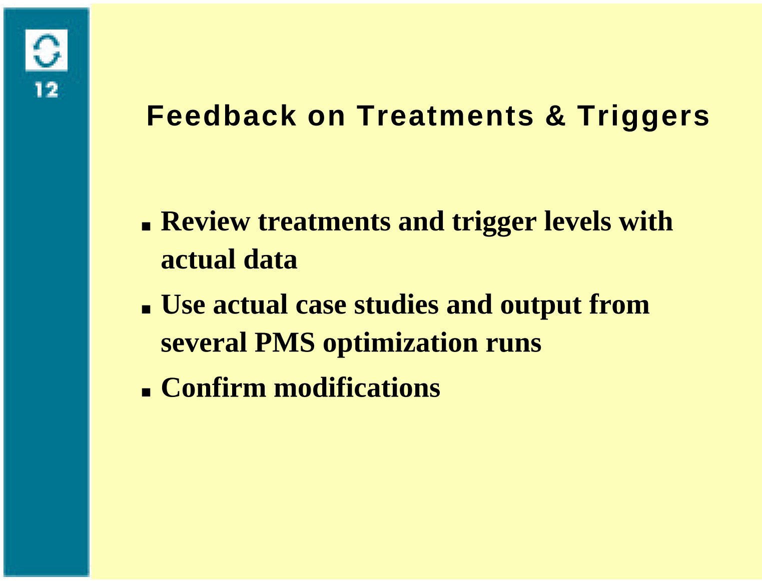
Slide 12-10

Notes:

This is the last performance curve in this series. The final form of the performance curve is fully defined at this stage.

The typical performance curves used in this example are representative of fairly good (accurate) pavement conditions surveys. In real world practice, the actual PCI values could be more variable and the resulting predicted pavement condition trends; thus, more variable.

Slide 12-11



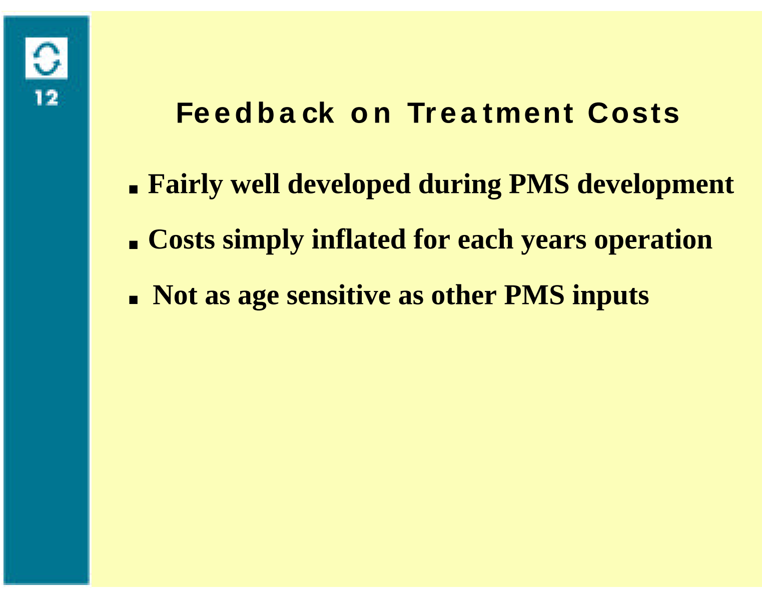
Slide 12-11

Notes:

During the development of a PMS, basic rehabilitation treatments are established that will be used in the PMS network optimizing program. These treatments are established based on limited agency data or from the collective opinion of pavement experts within the agency. In many cases the development of a PMS causes the agency to establish, for the first time, a basic policy on what rehabilitation treatments are used by the agency and under what condition (trigger) each specific treatment is used.

The treatments first established during the development of the PMS should be reviewed with real PMS network data and actual case studies using the output from several PMS network optimization runs. This follow up review should test the actual output from the treatment selection process for reasonableness.

Slide 12-12



Slide 12-12

Notes:

Treatment costs may be reviewed at somewhat longer time intervals than the performance models, treatments, and triggers covered earlier. Since treatment costs are compared together, the relative cost differential between treatments are more important to the network analysis that total costs. Thus, if there is no major change in relative costs between treatments from year to year then treatment costs may be inflated each year for five or more years without having much effect on the network analysis results. To confirm that there has not been a significant relative change between treatments they should be reviewed every five years. Obviously if there is a change in treatments used in the network analysis in less than five years then the relative treatment costs should be checked at the same time. A detailed recompilation of all treatment costs should be considered at six to eight years.

Slide 12-13

12

Feedback on Data Quality Use Cost

- **Quality control of inventory/condition data essential**
- **Feedback loop on data quality regular part of PMS process**
- **Periodically raise and answer questions of cost, quantity, and use of data**

Slide 12-13

Notes:

Good quality control of inventory and condition data is essential to the success of a pavement management system. The data must be accurate, repeatable, and consistent from location to location and from year to year, and representative of what actually exists in the field.

Training of personnel and/or calibration of each is necessary to assure long term confidence in the system and its results or output. This is one of the continuing processes that clearly should be in place in a functional PMS, but certain aspects also fall in the follow up category.

Slide 12-14

12

Other Feedback Areas

- **Pavement related research**
- **Pavement construction on performance**
- **Pavement design**

Slide 12-14

Notes:

In the 1990 AASHTO Guidelines for Pavement Management Systems it was noted that “feedback information can also be useful: (1) for agency research programs, (2) to evaluate the influence of construction on performance, and (3) as a measure of the effectiveness for methods used for designing of new and rehabilitated pavements.

The following are a few case examples where PMS information has been used through a specific feedback process to provide information in areas outside of the PMS operations.

Ask—who’s done this before?

Slide 12-15

12

Pavement Research

- Pavement management data used in research of pavement performance
- Can confirm cost effectiveness of efforts like Superpave

Slide 12-15

Notes:

General comments about use in pavement research.

Slide 12-16

12

Pavement Construction

How construction variability influences pavement performance

Air Voids Content (%)	Loss in Service Life (yrs)
7	0
8	2
9	6
10	17
12	36

Slide 12-16

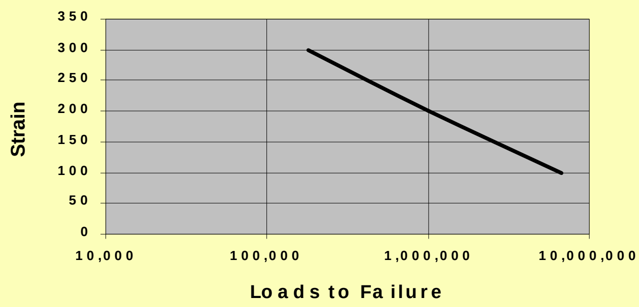
Notes:

In 1987, a special study to look at the effects of air voids on the performance of hot mixed asphalt concrete pavement was conducted. The study consisted of conducting a literature review and a survey of state highway agencies through the use a questionnaire. At the same time Washington State was participating in a small FHWA study to develop pavement performance relationships based on accumulated years and accumulated ESALs. A small set of data (70 projects) from this study with construction air void data , from the PMS data base was also analyzed for the effect of air void content on service life. The findings of this combined study are given on the table shown on this slide. Here the use of PMS data clearly contributed to the findings of the study.

Slide 12-17

Pavement Design

Fatigue Damage Model



Ask participants, "What feedback processes in your work are you using (what kinds/examples)?"

Slide 12-17

Notes:

An in-house study was conducted by WSDOT, which looked at the fatigue damage experienced from PMS data, for reconfirmation of the damage relation developed in their M-E design procedure. In the study, 31 sites were selected from the PMS data base as well as recent project design files. The study found the same general range in damage versus strain found in the original study. However, the average fatigue damage was found to be a little greater at the various strain levels.

Slide 12-18

Summary

From the 1990 AASHTO Guide:

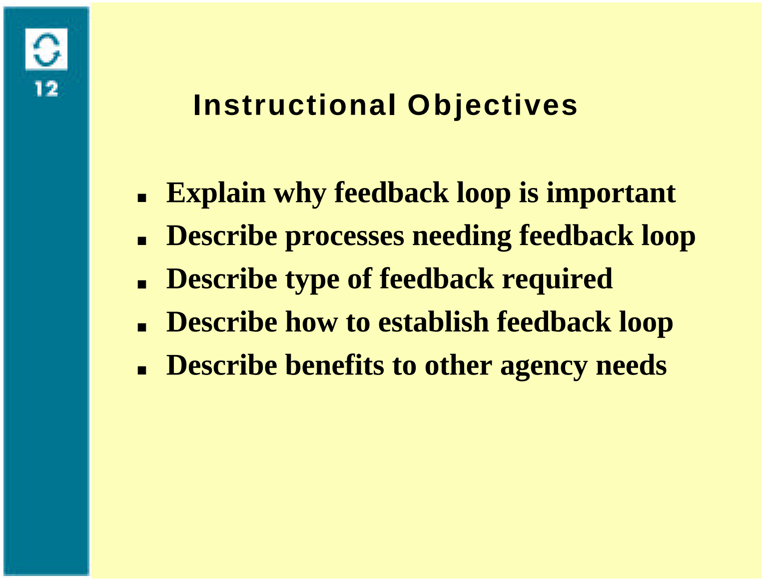
- "The PMS should be reviewed periodically to make certain that it is achieving the original objectives.
- Follow up provides the opportunity to identify and make improvements in the system.
- Feedback is essential to the long-term success of a PMS and to maximize its ultimate benefit to the agency."

Slide 12-18

Notes:

General summary of this section using quote from the 1990 AASHTO Guidelines.

Slide 12-19



Slide 12-19

Notes:

Review the objectives for this module.

MODULE 13

INSTITUTIONAL AND IMPLEMENTATION ISSUES

Purpose:

The purpose of this module is to introduce and understand the institutional isssues and barriers that develop when planning and implementing a pavement management system for an agency. In addition, it will discuss implementation concepts and guidelines that may be followed to provide for a successful implementation and maintenance of a pavement management system in an agency.

A short discussion period should be included.

Objectives:

Upon completion of this module, the participant will be able to understand the following:

- Historical perspective of institutional and implementation issues
- Understand institutional issues and their importance to a successful PMS implementation
- Be introduced to guidelines addressing institutional issues

Reference:

Module 13 of the Course Workbook

Duration:

60 minutes

Equipment:

Laptop computer, mulitmedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

17 Microsoft PowerPoint® Slides

Approach:

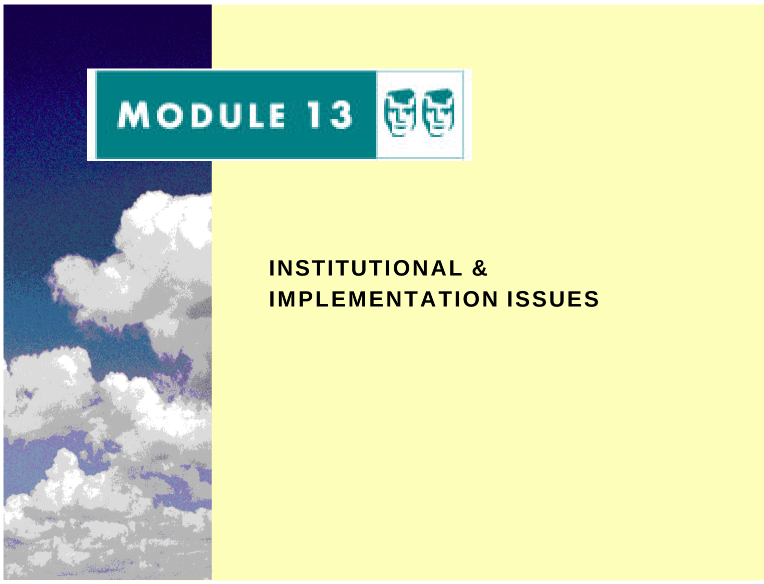
This module is taught through slide presentations and discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

Encourage questions from and promote discussion with the participants.

Slide 13-1



Slide 13-1

Notes:

Module 13 introduction slide.

Slide 13-2

Slide 13-2

Notes:

Provide a historical perspective beginning with initial development in the 1970's and growing disenchantment with the "black box" in the early 1980's. Institutional issues become more of a concern at 2nd International Conference.

Understand what institutional issues are.

Provide some guidelines for implementation.

Slide 13-3

13

Historical Perspective

- PMS emerged in mid-1970's
- Early emphasis on optimization of multi-year
- "Black box"
- 1980's - institutional issues become important

Slide 13-3

Notes:

- Pavement management emerged in the mid 70's predominantly as computerized systems.
- Many states including Arizona and Washington began the development and implementation of PMS for use in their highway departments.
- Earliest emphasis was on optimization of multi-year programs resulting in very sophisticated systems.
- A pragmatic tool soon became a high-level technical exercise. The end result was the reliance on a PMS as a "black box" which automatically selected and scheduled projects with little understanding by the user. Users became disenchanted.
- Institutional issues given importance. During 1980's, several activities served to advance PMS.

Slide 13-4

13

Institutional Issues & Barriers

- People
- Organization
- PMS design, development, and selection

Slide 13-4

Notes:

Over the last several years, the microcomputer revolution has provided greater access to computers and created a more friendly computational environment. The state-of-the-art in PMS concept was not well-developed and the analysis techniques have advanced to such a level that many of the technical problems have been addressed, or the approaches to solving them have been identified.

The institutional issues and barriers can loosely be grouped into three classes;

People

Organization

Development and Implementation

Slide 13-5

Slide 13-5

Notes:

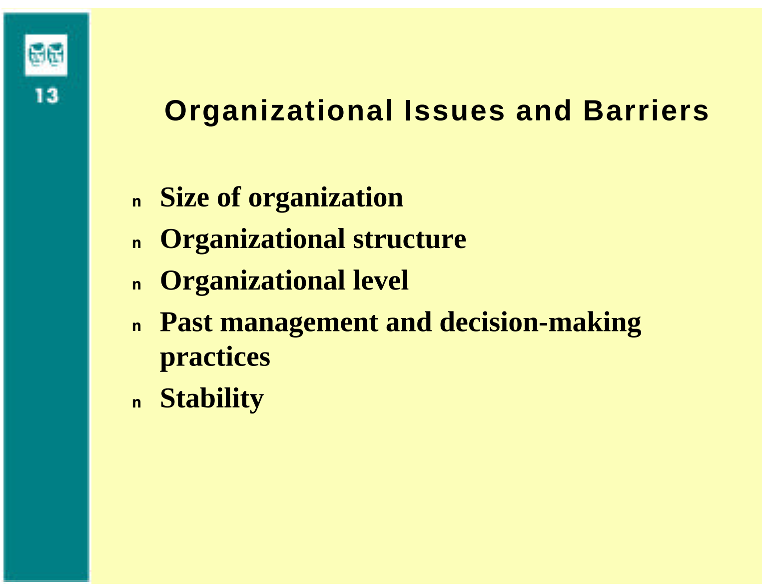
This is related to the personalities and interpersonal relationships of individuals in an organization. Barriers result from personnel conflict, inappropriate competition, and communication problems.

People Issues and Barriers

- Turf protection
- Fear of exposure
- Place of development
- Resistance to change

Ask participants for examples.

Slide 13-6



Slide 13-6

Notes:

A number of conditions and situations in any organization can make change difficult or at times nearly impossible. Many are issues that must be addressed during implementation to keep then from developing into barriers to effective use. The following are some of the most common situations.

Organizational Issues and Barriers

- Size of organization
- Organizational structure
- Organizational level
- Past management and decision-making practices
- Stability

Slide 13-7

13

Organizational Issues and Barriers

- Planning horizons
- Constraints on selection of projects
- Fixed facilities and processes
- Resources
- One-person show
- Competing fund needs

Slide 13-7

Notes:

§ Planning horizons
§ Constraints on selection of projects
§ Fixed facilities and processes
§ Resources
§ One-person show
§ Competing fund needs

Slide 13-8

13

PMS Design Development & Selection

- Matched to agency needs
- Complexity
- “Black box”

Slide 13-8

Notes:

Although many of the hardware and management support issues should have been resolved in development, there are many options available. The following describe some of the problems that can occur from selection of an inappropriate system.

§ Matched to agency needs
§ Complexity
§ "Black box"

INSTRUCTORS:

§ Pause presentation, leave and let participants discuss institutional problem/solutions within their agencies. Break them up into groups of 4-5 in the same area (i.e. not same group as in workshops).

§ Ask participants to discuss for 10-15 minutes and then elect one speaker per group to stand up and summarize two issues and solutions each.

§ For next group, ask speaker to bring up issues not previously mentioned.

§ Finally, ask if there are any issues not discussed.

§ Recap by instructor, and continue with next slides.

Slide 13-9

13

Implementation Concepts & Guidelines

- Decide if PMS is needed
- Obtain agency support
- Select PMS
- Implement PMS
- Effective PMS operations

Slide 13-9

Notes:

Most implementation guidelines are prepared under the assumption that the decision to implement pavement management has been made. They generally do not address the problems of an individual in an organization who must convince the management structure that pavement management is something that should be adopted and implemented. In addition, many guidelines stop after the pavement management system has been adopted, pavements have been inspected, and information is in the computerized system.

Five phases of pavement management adoption and implementation that covers the full range of implementation. These five phases are as follows.

Slide 13-10

Step 1 - Decide if PMS is Needed

- **Recognize need**
- **Obtaining PMS knowledge**
- **Decide to implement PMS**
- **Develop alliances**
- **Getting PMS on the Agenda**

Slide 13-10

Notes:

This phase is directed at the potential pavement management "champion" in an agency. The champion must first be convinced that pavement management concepts should be adopted, and then the champion must convince the agency to adopt pavement management.

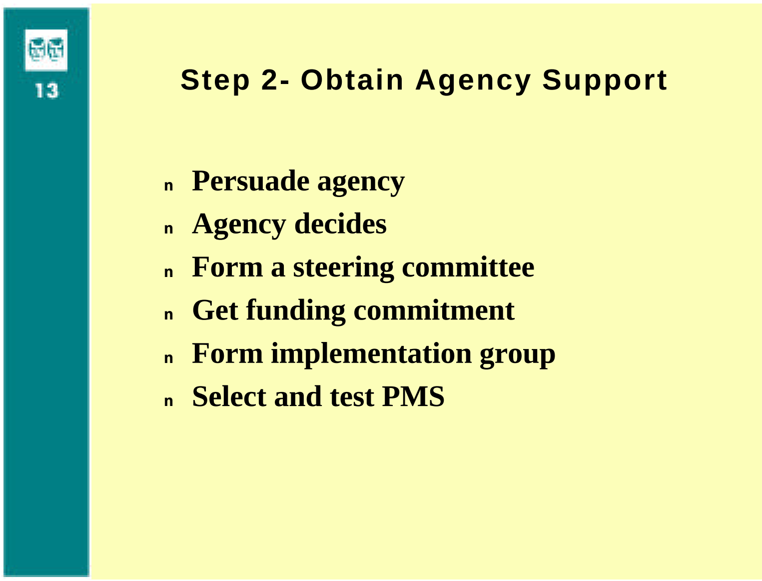
Recognize Need: The champion in the agency recognizes a need to change or enhance the manner in which pavement design, maintenance and rehabilitation planning and programming are conducted.

Obtaining PMS Knowledge: The champion must have the knowledge necessary to decide if pavement management will be good for the agency.

Decide to implement PMS: The agency champion decides to actively pursue adoption of pavement management in the organization or to reject it.

Develop Alliances: A very important step needed in adopting innovations within an agency is the development of an alliance of key individuals in each affected department that would like to see pavement management adopted.

Slide 13-11



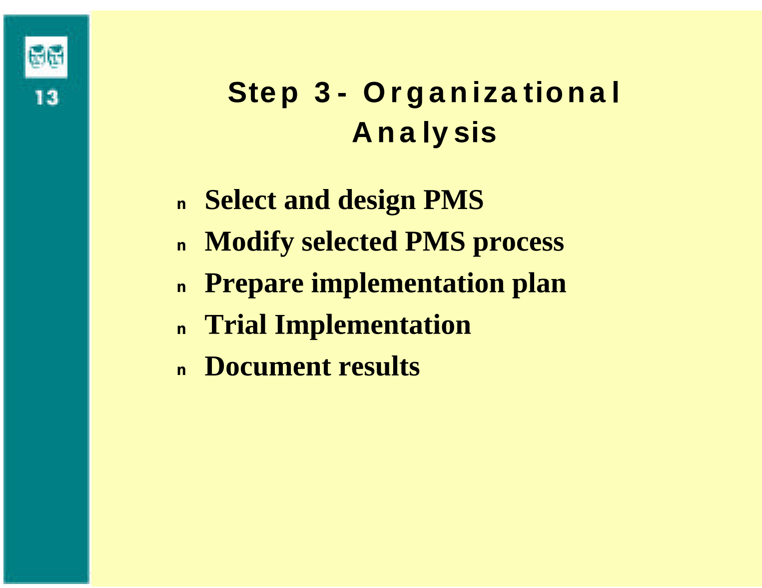
Slide 13-11

Notes:

Step 2 - Obtain agency support

- Persuade agency
- Agency decides
- Forma steering committee
- Get funding commitment
- Form a steering committee
- Get funding commitment
- Form implementation group
- Select and test PMS

Slide 13-12



Slide 13-12

Notes:

Organizational Analysis: The implementation group must review existing organization, methods and procedures to determine how the pavement management process will support decision-making within the agency. A pavement management system matching methods and procedures currently used by the agency has a better chance of being fully adopted than one that requires major changes in the organization lines of communication, chain of authority, data collection procedures, and data storage processes.

Slide 13-13

13

Step 4- Select PMS

- Review goals
- Review implementation plan
- Commit to implementation

Slide 13-13

Notes:

The agency decision makers commit to continue with full implementation, to revise pavement management concepts or to reject pavement management at this time.

Review the Goals: The original goals developed by the steering committee should be thoroughly reviewed and goals should be revised to match the agency needs and constraints, especially the available resources needed for full implementation and use.

Review the Implementation Plan: The pavement management implementation group should review the work plans, resource and time requirements. The implementation group should work from the revised goals using the information learned during the pilot implementation to revise the implementation plan.

Slide 13-14

Step 5- Implement PMS

- Remainder of network
- Complete all modifications
- Collect Data
- Train Staff

Slide 13-14

Notes:

After the pilot implementation, the pavement management process must be implemented for the remainder of the network. At this same time, needed modifications must be completed. This may require that the agency go back and collect new data, or the same data in different ways, for the pilot network.

Collect Data: The data collection and inclusion of various elements of the network will often be staged even after pilot implementation. A method to assure the quality of the data collected must be established and in place.

Train Staff: As the scope of pavement management increases and the implementation steps are completed, the users and operators involved in pavement management must be trained on pavement management concepts and system usage.

Slide 13-15

13

Step 6- Operate PMS Effectively

- **Institutionalize PM process**
- **Match output to management styles & needs**

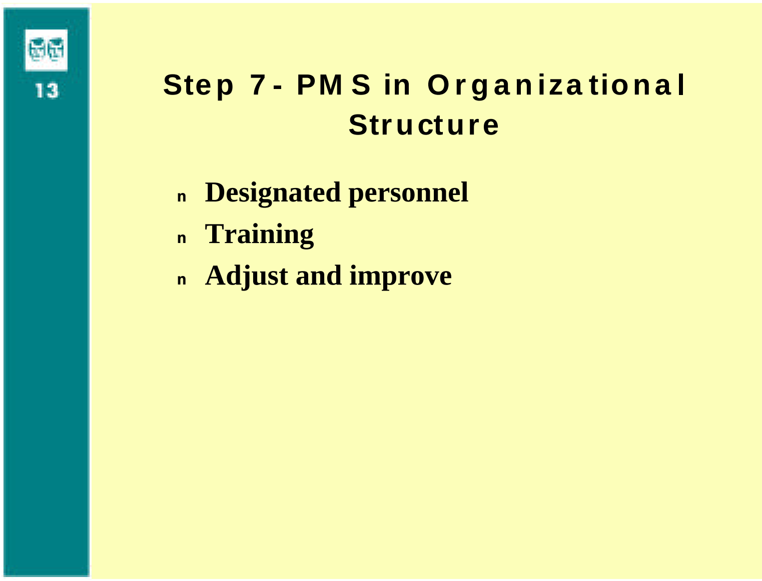
Slide 13-15

Notes:

The purpose of this phase is to institutionalize the pavement management process within the managing organization.

Matching Output to Management Styles and Needs: No matter how good the earlier investigations are, some of the reports generated by the software may not meet the needs of the upper level managers. Pilot implementation will identify some changes, but many needed changes in reports and formats will only be found when the system starts working in earnest. These changes will be needed at this point in part because the users will not completely know what they want until they see some of the reports from the system. As they learn to use the information, they will see other ways to use the same information.

Slide 13-16



Slide 13-16

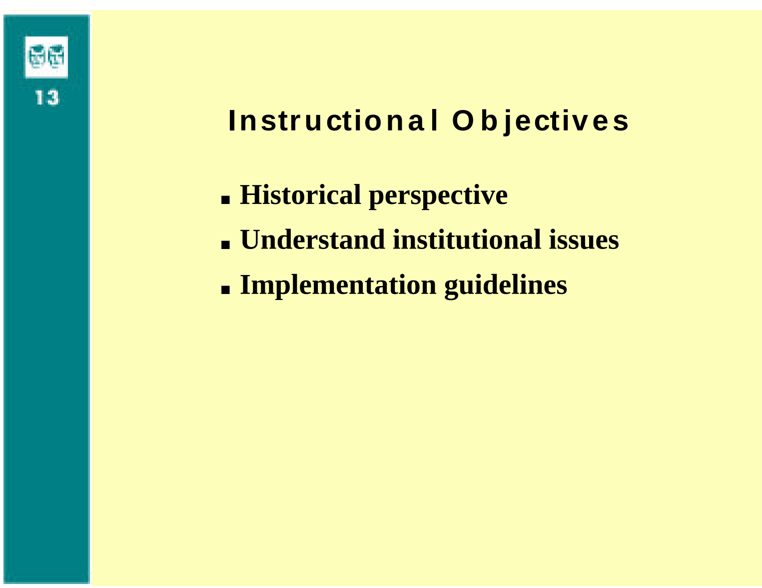
Notes:

PMS in the Organizational Structure: In order to ensure continuity of PMS development, provision must be mead to formalize pavement management into the organizational structure. Although a single champion may have led the development and implementation, pavement management responsibilities must be formally designated to survive inevitable management and personnel changes.

Training: Training is needed when changes are made to the systems; cyclic training is always needed.

Adjust and Improve: Pavement management and data collection procedures continue to evolve as technologies advance. The software system should be modular in form and flexible enough to allow improvements and modifications over time.

Slide 13-17



Slide 13-17

Notes:

Review the objectives for this module.

MODULE 14

Quality Management

Purpose:

This module introduces the fundamental principles of Total Quality and the application of the principles to Pavement Management Systems.

Objectives:

Upon completion of this module, the participant will be able to accomplish the following:

- Identify the fundamental principles of Total Quality
- Become familiar with the application of Quality Management in PMS as applied in Massachusetts.

Reference:

Module 14 of the Participant's Workbook

Duration:

30 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

16 Microsoft PowerPoint® Slides

Approach:

This module is taught through Slide presentations and discussion with the participants.

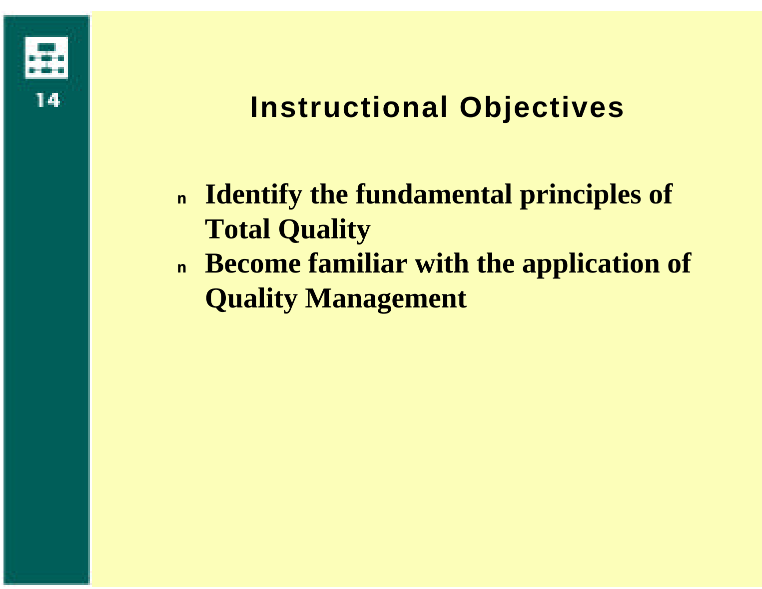
Encourage questions from and promote discussion with the participants.

Distance Learning:

There are no special instructions on Distance Learning for this module. All slides prepared can also be used for distance learning.

Slide 14-1

Slide 14-2



Slide 14-1

Notes:

Module 14 introduction slide.

Slide 14-2

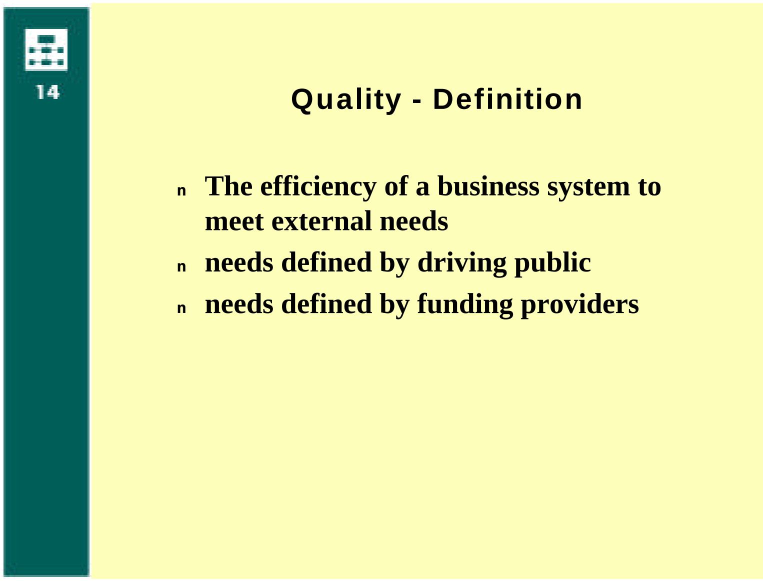
Notes:

Instructional Objectives

§ Identify the fundamental principles of Total Quality

§ Become familiar with the application of Quality Management

Slide 14-3

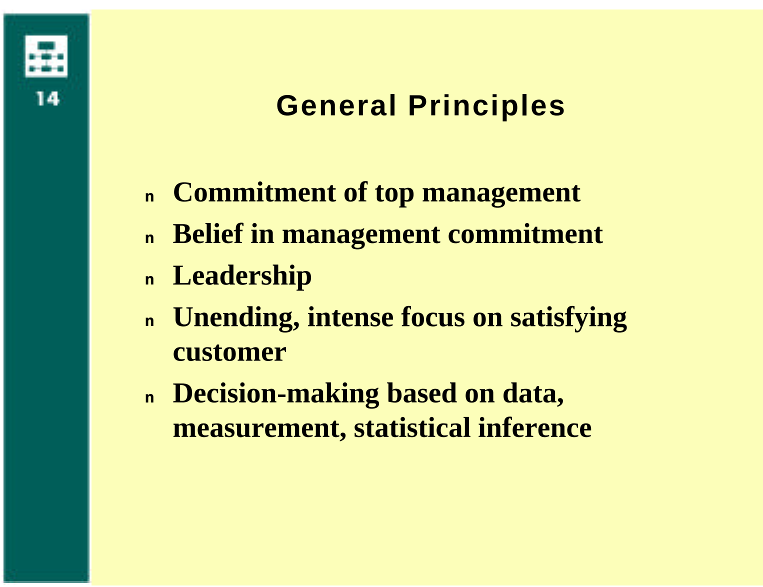


Slide 14-3

Notes:

Quality is the efficiency of a business system to meet external needs *(1)*. In pavement management, the external needs are defined by the users of the roads, i.e. the driving public. External needs are also defined by the providers of funding for development, design, contruction and maintenance of a highway system. In other words, a quality product is defined by the user, not the producer.

Slide 14-4



Slide 14-4

Notes:

Some of the generally agreed principles of Total Quality are as follows:

- Top management commitment to TQM
- Employee belief in management’s commitment to TQM
- Leadership: executives and managers who see their role as customer advocates, strategic planners, barrier removers, and “walkers of the talk”
- An unending, intense focus on customer’s needs, wants, expectations and requirements, and a commitment to satisfying them
- Decision-making based on data, measurement, and statistical inference, rather than opinions

Slide 14-5

14

General Principles

- **Process control equals variation reduction**
- **Continuous improvement**
- **Process improvement vs. production inspection**
- **Prevention vs. fixing problems**
- **Collaboration in organization**

Slide 14-5

Notes:

- A view of process control that embraces reduction of variation, rather than just meeting the specification, to create customer satisfaction
- A commitment to continuous improvement, that is, “if it ain’t broke, improve it”
- Focus on process improvement versus production inspection
- Focus on prevention of problems rather than fixing problems

An organizational climate based on collaboration and trust instead of competition

Slide 14-6

14

General Principles of Total Quality

- **Cross-functional teamwork**
- **Concurrent product/service development**
- **Customers and suppliers as partners**
- **Management focus on long-term results**

Slide 14-6

Notes:

- A lean organizational structure which depends on cross-functional teamwork, not vertical organizational hierarchies
- An approach to product/service development which is more concurrent than sequential and uses cross functional groups working as a team
- A view of customers and suppliers as partners, not adversaries
- Management focus on long term results rather than short term profits and schedule

Ask participants for examples.

Slide 14-7

14

MassPQP

- Massachusetts Pavement Quality Partnership
- A joint public/private effort to achieve quality pavements through the application of TQM principles and partnering methods

Slide 14-7

Notes:

The Massachusetts Pavement Quality Partnership is a joint public/private effort to achieve quality pavements through the application of TQM principles and partnering methods.

Just completed Phase 1 – 1998.

Slide 14-8

14

Reason for MassPQP

- Realization that pavement quality was deteriorating
- Lack of expertise within design and construction community
- Interest in NQI
- Desire to institutionalize PMS

Slide 14-8

Notes:

One of the key factors for driving the state highway agency in Massachusetts into a quality program was the realization that pavement quality was deteriorating. There was a lack of expertise within the design and construction community, whether public or private *(3)*. At the same time, the state was interested in the National Quality Initiative (NQI), so the Massachusetts Highway Department (MHD) began to focus on quality pavement construction and design. One goal was to get pavement management institutionalized into the system. The work effort was strongly supported by the top-level management. This was instrumental in getting the program started. Support came from the commission as well as the state's Chief Engineer.

Slide 14-9

14

Five Objectives

- **Define pavement quality**
- **Assess level of pavement quality**
- **Develop long-term Strategic Plan**
- **Identify implementation actions**
- **Provide support, guidance to front-line workers**

Slide 14-9

Notes:

The goal of the MassPQP is to "establish and maintain high quality pavements in a cost effective manner". In order to achieve this goal, the following five objectives were established:

- Define Quality Pavements in clear and measurable terms
- Assess the existing level of pavement quality in Massachusetts highways
- Develop the primary elements of a long-term "blue print" or MassPQP Strategic Plan
- Recommend further actions necessary for implementation of the MassPQP Strategic Plan
- Provide support, guidance and a "synergistic environment" to front-line workers in the implementation of the MassPQP Strategic Plan

Slide 14-10

14

Defining Pavement Quality

- **Smoothest practical ride**
- **Safest pavement surface**
- **Least possible maintenance**
- **Lowest life-cycle cost**
- **Most environmentally friendly**

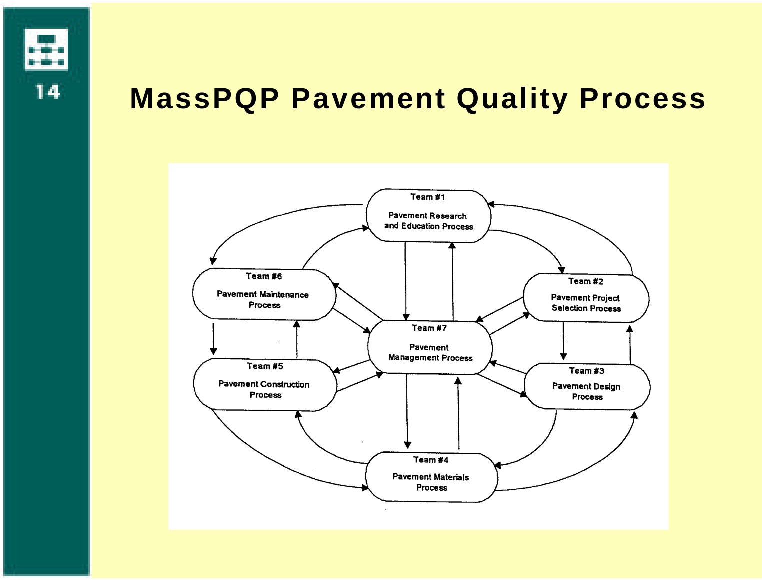
Slide 14-10

Notes:

The heart of the MassPQP proposal is to create a group of pavement quality “Work Teams” that reflect the relationship of the major functional activities associated with the pavement process. Seven teams were assembled as shown on the slide.

In the MassPQP Stategic Plan, thefirst six processes form an outer ring to indicate their need for continuous internaction and communication during the pavement life-cycle. Located at the core of these six processes is Pavement Management. This indicates how the Pavement Management Process serves as the nucleus of the MassPQP Pavement Quality Process. In a CQI environment, the Pavement Management Process gathers important input from and provides needed information to each of the other six pavement processes. A diagram of this seven process realtionship is shown in Figure 14.1.

Slide 14-11



Slide 14-11

Notes:

The MassPQP Steering committee and Work Teams determined that a “quality pavement” might be defined as possessing five quantifiable and measurable “characteristics” as shown on the slide.

Slide 14-12

14

Measuring Pavement Quality

- **Criteria - what should be measured**
- **Tools - how best to collect and analyze data**
- **Target Levels - where performance level is expected**
- **Frequency - when criteria should be measured**
- **Responsibility - who should measure criteria**

Slide 14-12

Notes:

The MassPQP work teams identified draft *Criteria*, *Tools*, *Target Levels*, *Frequencies*, and *Responsibilities* for measuring each of the five characteristics of a quality pavement.

- Criteria represents **What** should be measured.
- Tools identify **How** best to collect and analyze the data associated with each of the specific measurement Criteria, which MassPQP ultimately selects.
- Target Levels represent **Where** the performance level is expected to be for each of the measurement Criteria selected.

They are the "optimal" measurement values, which the MassPQP believes can and should be achieved by a Quality Pavement system. Until sufficient measurement data from Massachusetts pavements has been collected and statistically evaluated, appropriate Pavement Quality Target Levels cannot be established by the MassPQP.

- Frequency identifies **When** each of the Criteria should be measured. Depending on the Criterion being measured, there may be multiple intervals at which measurement should be made.

Responsibility indicates **Who** should measure the specific Criteria. Assignment of responsibility will be dependent upon when the measurement is required and will be developed for each of the measurement Criteria selected. Figure 14.4 illustrates the results obtained.

Slide 14-13

Constructing a Pavement Quality Process

- **Flow chart development**
- **Structured problem-solving**
  - **- Process issues**
  - **- Process improvements**
  - **-Action plans**

Slide 14-13

Notes:

- Figure 14.6 shows examples of pavement quality issues and proposed pavement quality process improvements. It should be noted that this does not represent a complete or fail-proof list of statistically based process improvements.

Slide 14-14

Pavement Management Process Improvement

- **Expand and improve PMS database**
- **Get feedback from all other processes**
- **Incorporate all branches of pavement design**
- **Train district personnel in PMS process**

Slide 14-14

Notes:

Since the backbone of the Strategic Plan is the Work Team Action Plans, focusing on their implementation is of utmost importance. In the MassPQP, the seven work teams will meet regularly and initiate activities necessary to implement each of their Action Plans. Action Plans may need to be revised to reflect new information or changed circumstances once implementation begins. A sample action plan is shown in Figure 14-7.

Slide 14-15

Summary

- **Primary objective of PMS**
  - **- Improve pavement quality**
- **Quality management also seeks to improve quality**
  - **- Construction**
  - **- Design**
- **PMS is the core of any quality management program**

Slide 14-15

Notes:

Improving and maintaining pavement quality in a cost-effective manner is the primary objective of a PMS. The larger picture, in terms of quality management, is to also to improve quality in other aspects of a state highway agency that affect pavements, such as maintenance and construction.

This module attempts to illustrate how a PMS fits into a quality management program. As was shown in Figure 14.1, PMS is necessary, indeed it forms the core of the entire program when the goal is a quality pavement.

§ Build in some questions for participants.

Slide 14-16

Instructional Objectives

- **Identify the fundamental principles of Total Quality**
- **Become familiar with the application of Quality Management**

Slide 14-16

Notes:

Review the objectives for this module.

WORKSHOP 1: SETTING UP A PMS

Purpose:

The purpose of the workshops is to encourage an active discussion of pavement management among the participants. A sample state network has been prepared for participants, who are assumed to be the pavement engineers for the fictional state of Ecotopia. A copy of the handouts that are included in the Course Workbook is included on the following pages.

The workshops are intended to assist participants in the process of developing and implementing a PMS for Ecotopia. They will use the information presented in modules that have just been covered. The discussions among participants will generate more thought on the steps involved, and the challenges that will have to be faced.

There are four workshops that have been prepared. The first will take place after Modules 1-4 have been taught. The second workshop occurs at the conclusion of Modules 5-8, and finally, the third workshop after Modules 9-12 have been completed.

Objectives:

Workshop 1 steps the participant through the initial stages in the development and implementation of a PMS for a state agency. The participant will plan and consider some of the issues that have been brought up in Modules 1 to 4, and prepare an outline for a PMS.

Approach:

Divide the participants into work groups between 5-8 in size. Each group should be composed of participants from different agencies and with different backgrounds. This is to encourage an exchange of ideas from different departments within an agency as well as between agencies. In order to do this, the instructors must note the names and agencies of each individual during the introductions.

- Before the groups begin work, the instructor must review the information provided in the workshop materials e.g. background, objectives etc.
- Each group must physically get together in a circle to discuss their plans. The following instructions are to be emphasized to each group.
- Each group must select a spokesperson that will summarize the discussions for the group and then make a presentation at the conclusion of the workshop. The spokesperson must also act as facilitator if necessary, and ensure that the opinions of all members of the group are equally represented.
- The instructors will circulate among all the groups and listen, advice, offer comments and suggestions as needed. The instructors should take care not to dominate the discussions at any time.

- After approximately 60 minutes, ask one or two groups to present their results. Ask the other groups to discuss the presentations and stimulate discussions by asking the following types of questions:
  - What are the objectives of the PMS?
  - What effect does the information on Ecotopia have on their decisions, if any?
  - What are some of the constraints identified?
  - How are the participants going to justify the resources required?
  - How does the information presented in Modules 1-4 affect their decisions?
  - What is the pavement network? (i.e. Total System, or National Highway System)
  - What kind of database will be used?
  - What location referencing system should be used? Is GPS needed? GIS?
  - What types of inventory information should be included? Why? GPR?
  - What kind of historical information is needed? Why?
  - What kind of quality control is needed?
  - What data elements should be included in the historical database? Why?

Reference:

Modules 1-4 and Workshop 1 materials in the Participant's Workbook

Duration:

90 minutes

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

Workshop 1 materials in Course Workbook

Distance Learning:

For a distance learning class, it will be necessary to appoint a facilitator at each remote site to assist the groups in their discussion. Any questions that groups may have can be either phoned or faxed to the instructors at the transmitting site. These numbers will be provided at the beginning of the course.

WORKSHOP 2: DATA COLLECTION

Purpose:

The purpose of the workshops is to encourage an active discussion of pavement management among the participants. A sample state network has been prepared for participants, who are assumed to be the pavement engineers for the fictional state of Ecotopia. A copy of the handouts that are included in the Course Workbook is included on the following pages.

The workshops are intended to assist participants in the process of developing and implementing a PMS for Ecotopia. They will use the information presented in modules that have just been covered. The discussions among participants will generate more thought on the steps involved, and the challenges that will have to be faced.

Objectives:

In Workshop 2, participants will the students will begin to fill in the basic plan and layout of the PMS that was developed in the previous workshops. They will define the data elements that will be collected and maintained in the database system based on the information presented in Modules 4-7.

All elements included in the proposed PMS plan should be justified and an estimate of first costs and/or annual costs to include in the PMS.

In addition, the participants will be asked for the specific development of a condition index following the engineering process described in Module 6.

Approach:

Divide the participants into the same work groups as in Workshop 1. The groups may either use the same spokesperson as before or change to a new one. Before the groups begin work, the instructor must review the information provided in the workshop materials e.g. background, objectives etc.

- Each group must physically get together in a circle to discuss their plans.
- Each group must select a spokesperson that will summarize the discussions for the group and then make a presentation at the conclusion of the workshop. The spokesperson must also act as facilitator if necessary, and ensure that the opinions of all members of the group are equally represented.
- The instructors will circulate among all the groups and listen, advice,

offer comments and suggestions as needed. The instructors should take care not to dominate the discussions at any time.

§ After approximately 1 to 1.5 hours, ask one or two groups to present their results. Ask the other groups to discuss the presentations and stimulate discussions by asking the following types of questions:

C What basic file system should be used?

C What location referencing system should be used?

C What data elements should be included in the historical database?

C What data elements should be included in the monitored database?

C What condition index will be used? (ride, cracking, etc developed by the group)

C What survey procedure will be used?

C Will other data elements be collected? (drainage, structure etc.)

C Which data elements defined above are needed to support the goals defined in the first workshop.

C What level of traffic information will you include in the database?

Reference:

Modules 4-7 and Workshop 2 materials in the Participant's Workbook

Duration:

2 hours

Equipment:

Laptop computer, multimedia projector

Teaching Aids:

Workshop 2 materials in Course Workbook

Distance Learning:

For a distance learning class, it will be necessary to appoint a facilitator at each remote site to assist the groups in their discussion. Any questions that groups may have can be either phoned or faxed to the instructors at the transmitting site. These numbers will be provided at the beginning of the course.

WORKSHOP 3: PEFORMANCE MODELS & IMPLEMENTATION

Purpose:

The purpose of the workshops is to encourage an active discussion of pavement management among the participants. A sample state network has been prepared for participants, who are assumed to be the pavement engineers for the fictional state of Ecotopia. A copy of the handouts that are included in the Course Workbook is included on the following pages.

The workshops are intended to assist participants in the process of developing and implementing a PMS for Ecotopia. They will use the information presented in modules that have just been covered. The discussions among participants will generate more thought on the steps involved, and the challenges that will have to be faced.

Objectives:

This workshop is designed to provide the course participants with an opportunity to build on the pavement management system design from the earlier workshops. During this workshop, the participant will outline a modeling approach that will be used for the development of pavement deterioration models. The participant will also investigate the use of prioritization or optimization for program development. Finally, the participant will design feedback system and outline plans for addressing implementation issues that may be expected within the organization.

Participants will utilize the information presented in Modules 8 to 13.

Approach:

- Divide the participants into the same work groups as before. The groups may either use the same spokesperson as before or change to a new one. Before the groups begin work, the instructor must review the information provided in the workshop materials e.g. background, objectives etc.
- Each group must physically get together in a circle to discuss their plans.
- Each group must select a spokesperson that will summarize the discussions for the group and then make a presentation at the conclusion of the workshop. The spokesperson must also act as facilitator if necessary, and ensure that the opinions of all members of the group are equally represented.
- The instructors will circulate among all the groups and listen, advise, offer comments and suggestions as needed. The instructors should take care not to dominate the discussions at any time.
- After approximately 1 to 1.5 hours, ask one or two groups to present

their results. Ask the other groups to discuss the presentations and stimulate discussions by asking the following types of questions:

- Are there additional data elements that will be needed to implement the models you design?
- How will you maintain the data over time so that the models can be updated regularly?
- Will you use optimization or prioritization?
- What will you need to implement this approach?
- Who should be involved in the process?
- How will you explain the system recommendations to management?
- Do you envision the need for an iterative process to develop the multi-year program or will the system recommendations suffice?
- How does your group propose to use the pavement management information within your organization?
- Who will benefit from this information?
- How frequently will they need the information?
- Is the network-level information satisfactory for the feedback you propose?
- How will you overcome institutional issues?
- Are there any issues that you think may be insurmountable?
- How will you maintain support from top management?
- What level of resources will you need in the future to maintain the system?
- What obstacles can be anticipated using this approach?
- How does it match up with the data requirements defined in an earlier workshop?
- How will the performance models be used outside of the pavement management area? Will this require any changes to the proposed plan?
- Are the resources available to implement this strategy?
- Did the workshop participants justify their decisions?
- What do you think will be the hardest institutional issue to address?
- How will you demonstrate the benefits of pavement management to top management?

Reference:

Modules 8 to 13 and Workshop 3 materials in the Participant's Workbook

Duration:

2 hours

Equipment:

Laptop computer, multimedia projector, flipchart, overhead projector, blank transparencies, transparency pens

Teaching Aids:

Workshop 3 materials in Course Workbook

Distance Learning:

For a distance learning class, it will be necessary to appoint a facilitator at each remote site to assist the groups in their discussion. Any questions that groups may have can be either phoned or faxed to the instructors at the transmitting site. These numbers will be provided at the beginning of the course.