Lecture #7:

◎ Pavement Management Systems Workshop
Handouts:
Zimmerman, K. A., "Pavement Management Systems Workshop," 1996 International Road Federation Asia-Pacific Regional Meeting, Nov. 17-22, 1996, Taipei, pp. 57-92.

I. Introduction

Growing Backlog of Rehab Needs
Major Components of a PMS
Forecast Future Conditions
Identify Optimal Timing for Pavement Rehab
(Figure 1- Impact of Rehab Timing on Cost)

II. Pavement Management & PMS Components

2.1 Introduction

Various PMS Definitions:

APWA: "... A systematic method for routinely collecting, storing, and retrieving the kind of decision-making information needed to make use of limited maintenance (and construction) dollars."

AASHTO: "... to improve the efficiency of decision making, expand its scope,

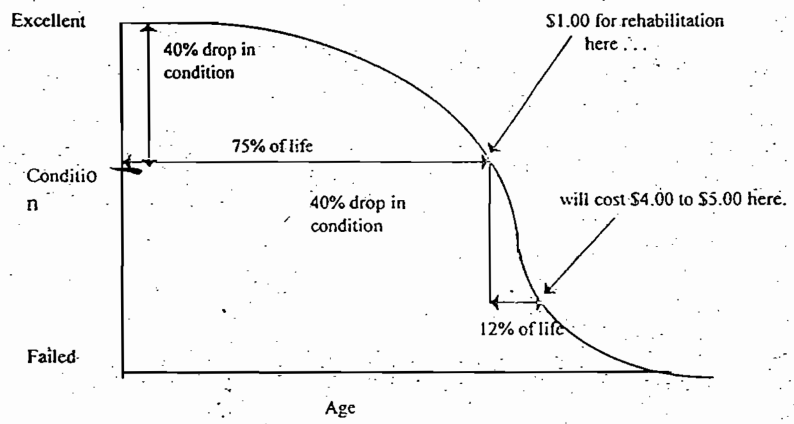

Figure 1. Impact of Rehabilitation Timing on Cost (1)

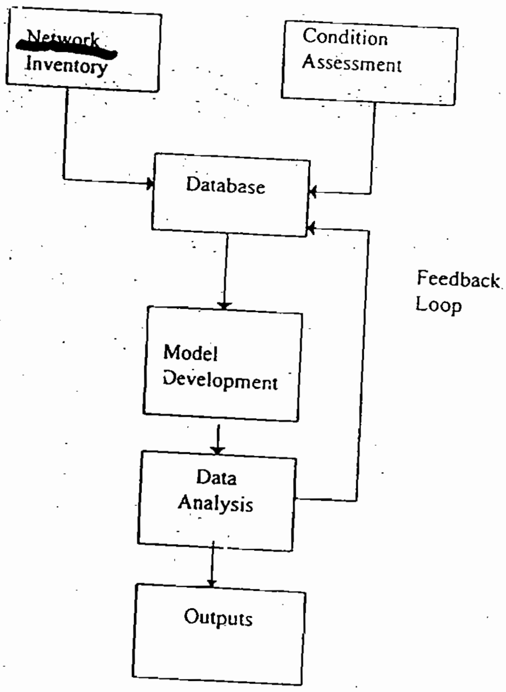

Figure 2. Pavement Management Components

provide feedback on the consequences of decisions, facilitate the coordination of activities within the agency, and ensure the consistency of decisions made at different management levels within the same organization."

[... Most Recommendations from a PMS are Made at the Network Level, ...]

2.2 Components of a PMS (Figure 2)
Network Inventory, Condition Assessment, Database, Model Development, Data Analysis, System Outputs & Feedback

2.3 Network Inventory
Pavement Length & Width, Location Reference Identifiers, As-Built Materials & Thickness, Traffic Data, Surface Type, Non-Destructive/Destructive Test Results, and Maintenance Histories
[Guidelines: The Data Should be Fairly Easy to Obtain ..., Should Serve a Purpose]

2.4 Condition Assessment
Evaluate Current Pavement Condition

An Objective & Repeatable Procedure
Network Level for Airports: PCI
Project Level: PCI & NDT Results
Entire State Highway Network: PCI is Impractical; Automatically Collect Roughness, Profile, and Rutting at Traffic Speeds
Video Inspection Van (Figure 3)
Distress Identification Workstation (Figure 4)
NCHRP Synthesis 203: Data Collection

- Most Agencies Collecting Distress & Roughness as part of their PMS
- Many Agencies Collecting Friction Data, but do not incorporate it into their PMS Decisions (=> Used for Wet Weather Accident Reduction Programs)
- Half Agencies Collecting Deflection Information Only for Project-Level Designs, Not Network Level Planning

2.4.1 Distress

Common Distress Types: Cracking, Rutting, Joint Deterioration, Durability Cracking, Punchouts, etc. => To Generate a Distress Index, PSI, Priority Rating, Other Indices

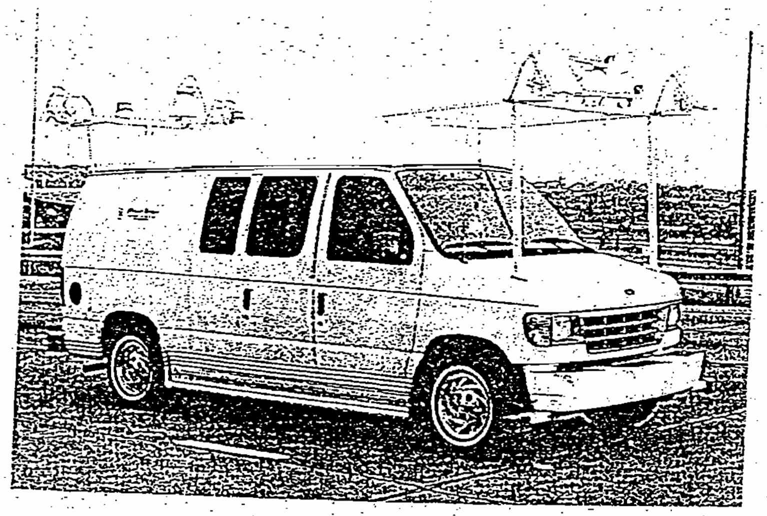

Figure 3. Video Inspection Van

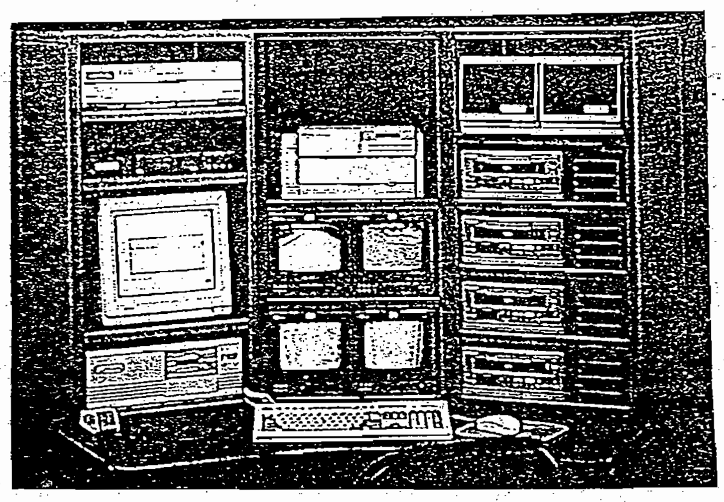

Figure 4. Distress Identification Workstation

2.4.2 Roughness

Roughness, or Ride Quality Ratings
International Roughness Index (IRI)
World Bank: Four Classes
  Precision Profile, Other Profilometer Methods, IRI Estimates from Correlation Equations, Subjective Ratings and Uncalibrated Measures
South Dakota Profiler (Class II): most commonly used equipment in U.S.

2.4.3 Uses of Condition Data

A Distress Index, or Individual Distress
Thresholds for Each Distress Type
Decision Tree for Individual Distress (Fig.5)

2.5 Database

2.5.1 Database Content and Structure

Decisions Supported by a PMS Database (Table 1)
PMS Database: Inventory Data, Traffic Data, Construction/Maintenance Histories, Condition Information
Dynamic Segmentation (Fig. 6)

Table 1. Decisions Supported By a PMS Database

Project Level Management	Network Level Management
Planning	Planning
Design	Programming
Construction	Policies
Maintenance	Standards
Rehabilitation	Procedures
Performance Measurement	Specifications
	Special Studies
	Research

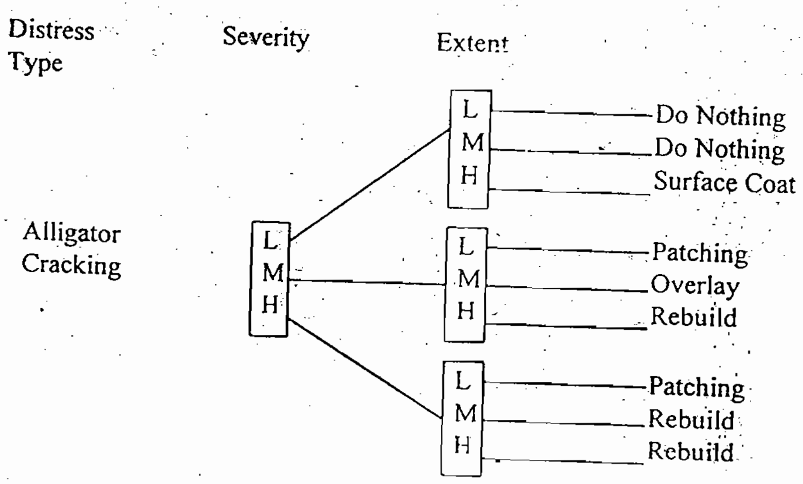

Figure 5. Decision Tree for Individual Distress

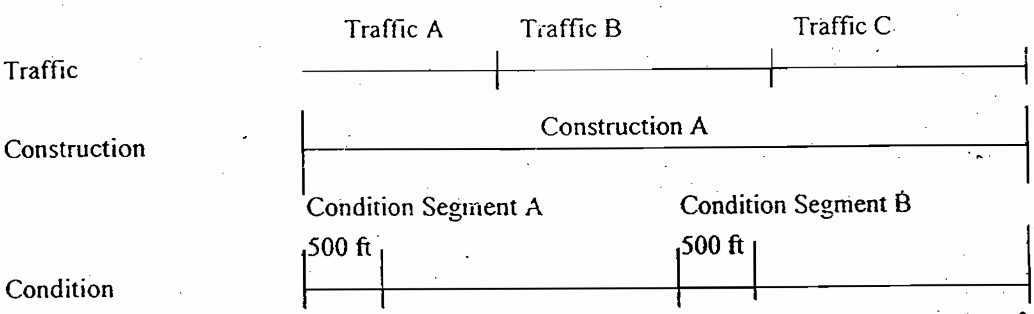

Figure 6. Illustration of Dynamic Segmentation

uniform section vs. fixed length

2.5.2 Importance of Data in a PMS

Performance Modeling
Project and Treatment Selection
Network Trade-off and Impact Analysis
Maintenance Program Development
Design Inputs

2.5.3 Data Integrity and Database Maintenance

2.6 Model Development

2.6.1 Performance Modeling

Predict future Pavement Condition, Analyze Pavement Life Cycle Costs, Estimate the Type and Timing of Maintenance & Rehab Needs, Provide Feedback

1. Deterministic Models
2. Probabilistic Models: Based on Markovian Theory (Table 2)
3. Individual Segment Models & Family Models (Figure 8)
4. Expert Models
5. Regression Models Supplemented with Expert Opinion
6. Updating Performance Models

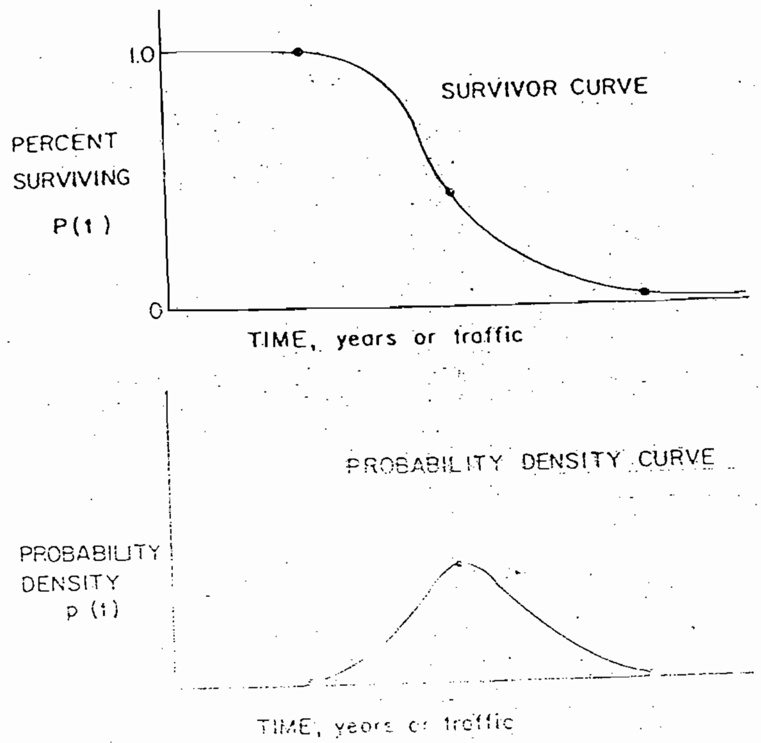

Figure 1. Survivor Curve and Probability Density Function for Survival.

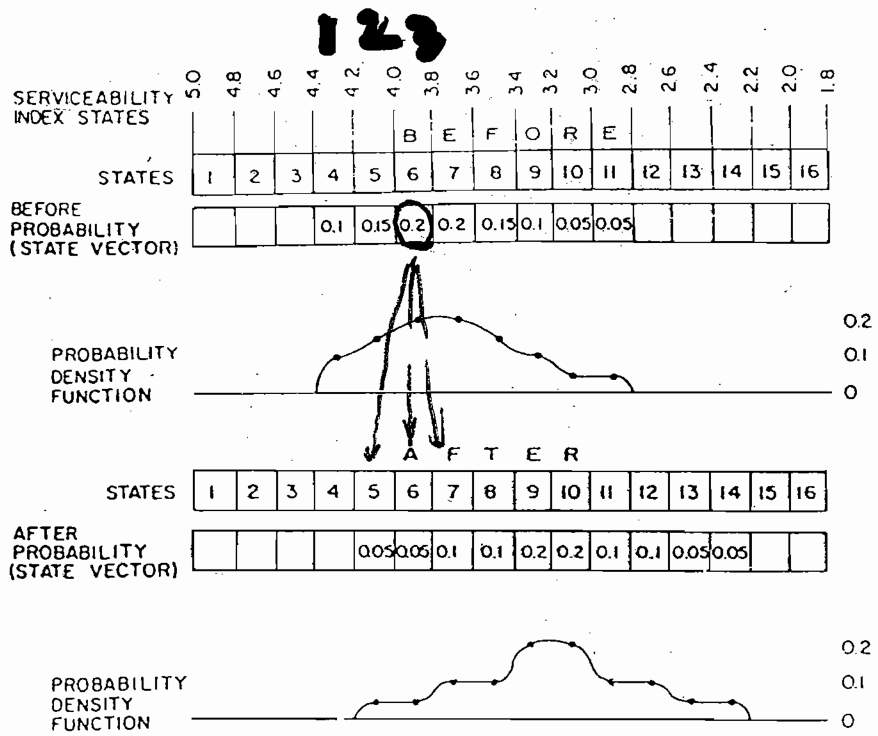

Figure 2. Before and After Serviceability Index State Vectors.

Table 2. Sample Markov Transition Probability Matrix

	State 1 (81-100)	State 2 (61-80)	State 3 (41-60)	State 4 (21-40)	State 5 (0-20)
State 1 (81-100)	0.9	0.1			
State 2 (61-80)	0.05	0.65	0.3		
State 3 (41-60)		0.05	0.5	0.35	0.1
State 4 (21-40)			0.05	0.75	0.20
State 5 (0-20)				0.05	0.95

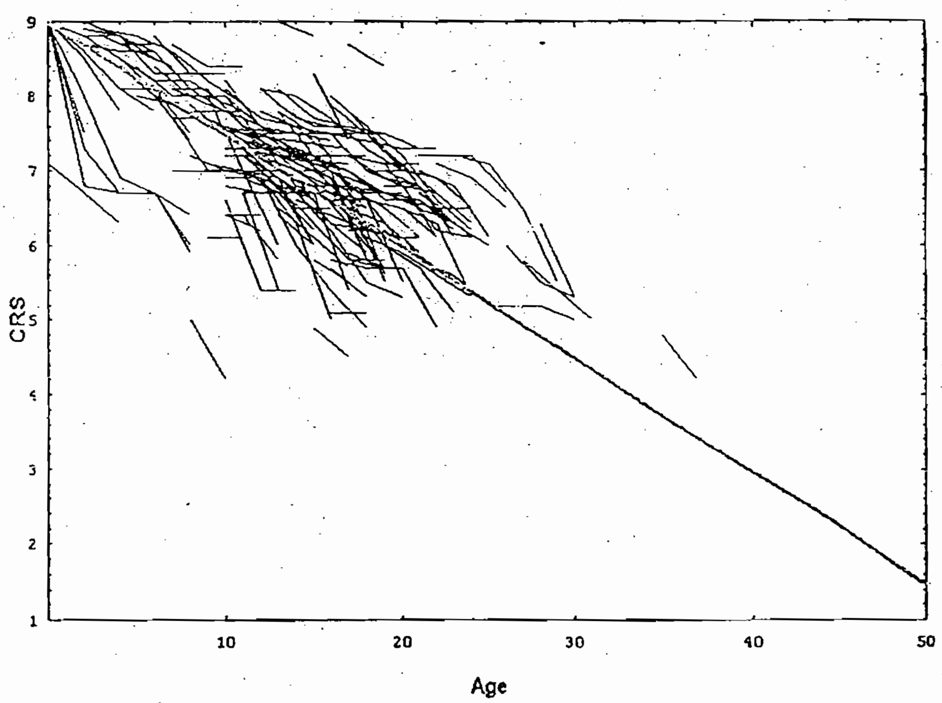

Figure 8. Sample regression model developed for the Illinois Department of Transportation (10)

The Markov process describes a probable "before" and "after" condition of the pavement. The "before" condition is described by probabilities that the pavement will be found in each of the assumed finite number of states as is illustrated in Figure 2. The "after" condition is described in a similar manner as illustrated in the same figure. However, the probabilities are shifted downward to lower condition states which are described by ranges of serviceability index.

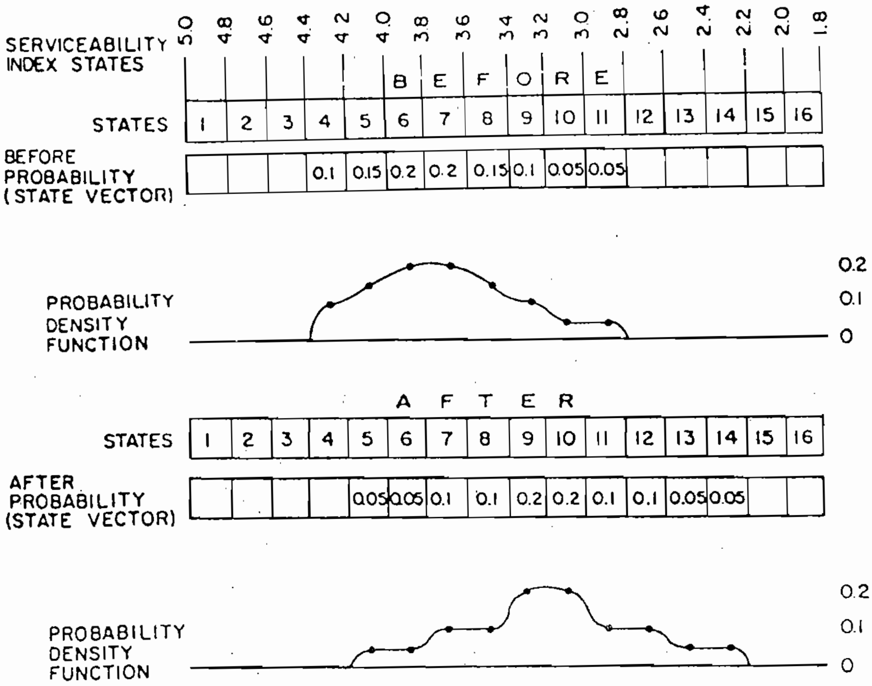

Figure 2. Before and After Serviceability Index State Vectors.

Markov transition matrices can be constructed for any process of pavement deterioration and, especially if the assumptions that are made for Markov processes are valid, they can be used reliably to simulate the overall performance of a network of pavements of similar types with similar weather and traffic patterns.

Semi-Markov Models of Pavement Deterioration Processes

The Semi-Markov processes are identical in every respect with Markov processes except that it is assumed that the process is only stationary during piecewise increments of time. This is actually more realistic since it recognizes that the condition of the pavement and changing weather and traffic conditions cause an alteration in the transition process.

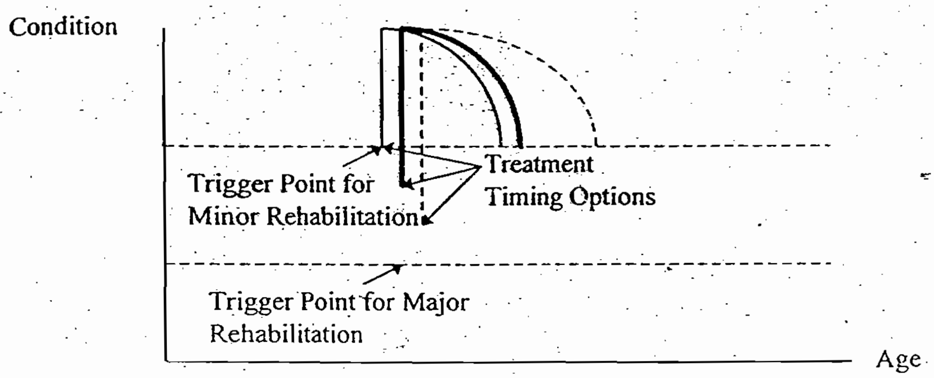

Figure 9. Sample Timing Options for Minor Rehabilitation (12)

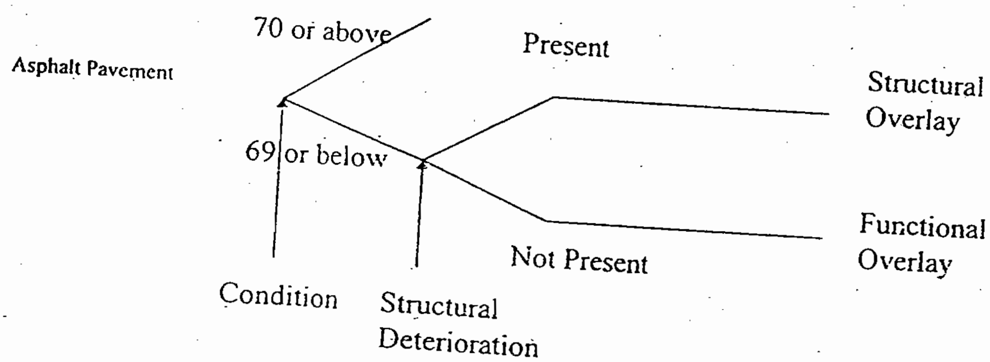

Figure 10. Sample Decision Tree

2.6.2 Project & Treatment Strategy Development

1. Single and Multiple Treatment Strategies
2. Single Treatment Strategy Approaches
3. Multiple Treatment Strategy Approaches
4. Tools Used to Develop Strategies: Decision Trees (Figure 10), Decision Matrices (Table 4), Rules
5. Types of Treatments Considered in Strategy Development: Rehabilitation Categories
6. Specific Treatments
7. Updating Strategy Models

2.7 Data Analysis

2.7.1 Benefits Provided by a Multi-Year Analysis

2.7.2 Difference Between Ranking, Prioritization, and Optimization

1. Ranking: Ranking by Condition, Initial Cost, Cost & Timing, Life-Cycle Cost, Benefit/Cost Ratio
2. Prioritization
3. Optimization

2.7.3 Single-Year vs. Multi-Year Prioritization Advantages & Disadvantages

2.7.4 Components of Multi-Year Prioritization

Table 5. Sample Network

Section ID	Condition Level
Route 67, from Milepost 1-4.9	67
Route 67, from Milepost 5-9.9	82
Route 67, from Milepost 10-13.5	52
Route 14, from Milepost 1-3.9	71
Route 14, from Milepost 4-5.9	74
University Avenue, between Lincoln and Sixth	85

Using a simple ranking procedure based on addressing the worst pavements first, the ranked list presented in table 6 would be prepared.

Table 6. Ranked Listing of Projects

Route 67, from Milepost 10-13.5
Route 67, from Milepost 1-4.9
Route 14, from Milepost 1-3.9
Route 14, from Milepost 4-5.9
Route 67, from Milepost 5-9.9
University Avenue, between Lincoln and Sixth

Table 7. Sample Network With Traffic Levels

Section ID	Condition Level	Traffic Factors
Route 67, from Milepost 1-4.9	67	1.0
Route 67, from Milepost 5-9.9	82	1.5
Route 67, from Milepost 10-13.5	52	1.0
Route 14, from Milepost 1-3.9	71	0.5
Route 14, from Milepost 4-5.9	74	0.5
University Avenue, between Lincoln and Sixth	85	1.0

Table 4. Example Decision Matrix

Treatment	Committed Components		Surface Components		Operational Components				
	Distress	Surface Type	Struct Cond	Ride	Funct Class	ESAL	Width	Thick	ADT
	0-100	Type	0-54	0-5	Type	Range			
Thin O/L (<=2.5 inches)	65-85	AC	15-35	Any	Any	0-74	>=27'	Any	<=750
Thin O/L (<=2.5 inches)	70-85	AC	15-30	Any	Any	0-74	>=33'	Any	751-2000
Thin O/L (<=2.5 inches)	70-85	AC	15-30	Any	Any	0-74	>=39'	Any	>= 2001
Thin O/L (<=2.5 inches)	65-85	AC	15-25	Any	Any	75-100	>=27'	Any	<=750
Thin O/L (<=2.5 inches)	70-85	AC	15-25	Any	Any	75-100	>=33'	Any	751-2000
Thin O/L (<=2.5 inches)	70-85	AC	15-25	Any	Any	75-100	>=39'	Any	>= 2001
Thin O/L (<=2.5 inches)	0-99	AC		< 2.5			>=39'		>= 2001

1. Pavement Performance Analysis
2. Pavement Preservation Strategies and Treatments
3. Investment Analysis
4. Project Selection Process

2.7.5 Data and Analysis Requirements of Multi-Year Prioritization

2.7.6 Other Factors That Influence the Analysis Process

2.8 System Outputs & Feedback

Reports and Other Outputs: Reports, Graphics, Maps, CAD, GIS

Feedback Loop

III. Benefits to Using Pavement Management

1. Provide An Automated Procedure
2. Improve Long-Term Effectiveness
3. Understand the Impact of Project Timing or Treatment Selection
4. Improve Forecasting Future Needs
5. Provide timely & Accurate Information
6. Provide a Quantifiable Assessment of Network Condition
7. Evaluating Various Rehab Strategies & Option Trade-offs

Pavement Performance Analysis

Inventory data (surface type, location, etc.)
Geometry
Age
Historical conditions
Current conditions
Environmental factors
Traffic estimates

Pavement Preservation Strategies and Treatments

Feasible treatment types
Conditions under which each treatment is considered feasible
Cost of each treatment
Expected life of each treatment

Network Investment Analysis

Expected life of each treatment
Cost of each treatment (life-cycle cost or initial cost)
Agency policies and practices

Project Selection Process

Project limits
Project scope (bridges, pavement needs, etc.)
Prioritization factors
Project cost
Project constraints
Available resources

Agency Policies & Practices

By multiplying the condition index by the traffic factor, a new ranking number is developed and the revised rank of projects is reflected in table 8.

Table 8. Revised Ranked List With Traffic Levels Considered

Section	Ranking Index (Condition * Traffic Factor)
Route 14, from Milepost 1-3.9	36
Route 14, from Milepost 4-5.9	37
Route 67, from Milepost 10-13.5	52
Route 67, from Milepost 1-4.9	67
University Avenue, between Lincoln and Sixth	85
Route 67, from Milepost 5-9.9	123

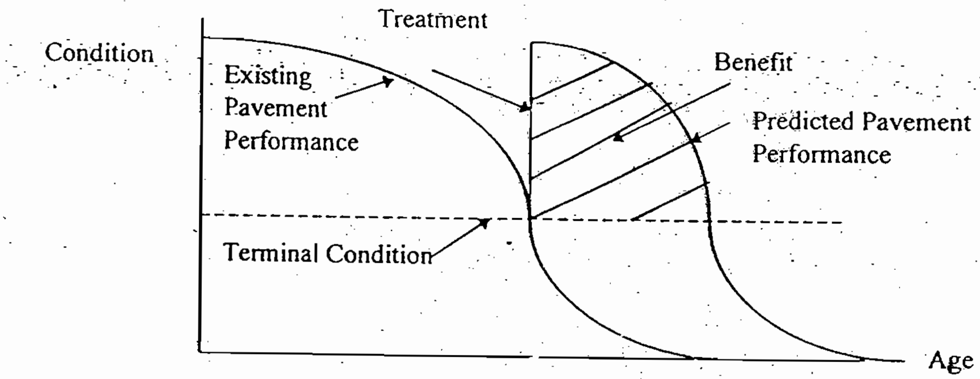

Figure 11. Illustration of treatment benefit.

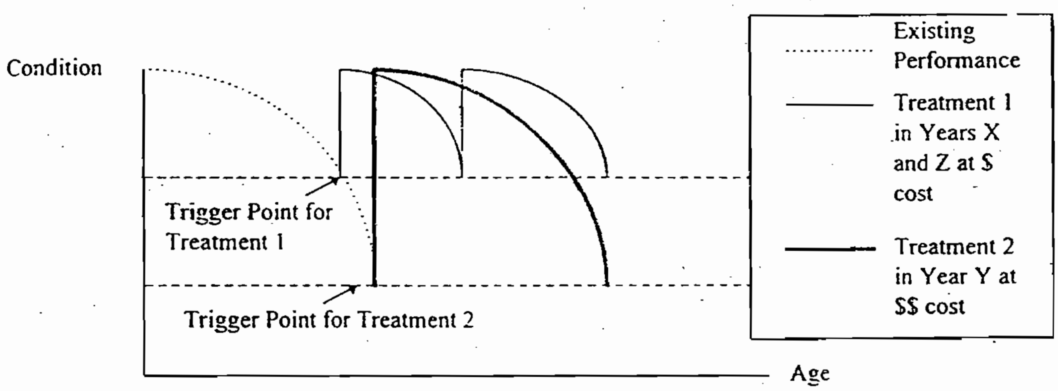

Figure 12. Feasible timing of rehabilitation options for one section.

8. Analyze the Consequences of Various Funding Levels
9. Provide a Sound Basis for Allocating Resources
10. Provide Objective Info to Balance Political and Other Subjective Inputs
11. Enhances Agency's Credibility
12. Provide Valuable Feedback
13. Improve Communications
14. Allow to Answer "What-if" Questions

etc...

IV. Summary

D. N. Geoffroy "PMS Management Needs" Sep 24-26 1991 FHWA's PMS Symposium.

- Why do we need to develop and implement a PMS? What are the reasons over and above the FHWA mandate?

- What are the products of a PMS and how will they be used and by who?

- What are the benefits of system implementation?

- How much will the system cost? What are the required resources in personnel, equipment, and funds to develop, implement, and operate the PMS? What are the available sources for the funding? If resources are committed, what impact would there be on other programs?

- What is the schedule for development and implementation?

- What have other State Highway Agencies been doing in developing a PMS? (Benchmarking)

- What are the objectives of the proposed system? The proposed system objectives must be SMART, that is;

    (1) Specific - The objectives must be clearly written to inform executive management exactly what the system will do and to show that the system developers clearly understand what is to be achieved, and what is expected from them.

    (2) Measurable - The objectives must be measurable so that executive management can determine when each objective has been achieved.

    (3) Achievable - The objectives must be achievable given the resources available for system implementation.

    (4) Relevant - The objectives must pertain only to the PMS proposal. Development and implementation of a pavement management system should not be used as an opportunity to implement other activities extraneous to the PMS.

    (5) Timely - The system objectives must be implemented within the prescribed time frame to comply with the FHWA requirements.

A clearly written proposal which addresses the answers to these basic questions will assist executive management in making the decision to commit resources to PMS development. Approval of the proposal is a major step in assuring the top-level support necessary for successful system development and implementation.

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III. Expectations

Once approval is obtained, system development commences. Since considerable resources will be required, executive management is likely to take a special interest in the PMS development effort. Expectations by executive management may include the following:

- **The system must play an integral role in the decision-making process.** A PMS is more than a system to collect data. It is more than a set of technical tools. It is the framework within which the SHA makes decisions regarding the repair and maintenance of its pavement structures.

- **The system is not a "black box".** A PMS should serve as a decision-support system. Outputs from a PMS should not be used to usurp engineering expertise, but rather to complement and enhance the decision-making process.

- **The system should be cost-effective.** Data is a valuable corporate commodity. It is expensive to collect and process. Data should only be collected if it is used as part of the decision-making process. Required PMS outputs must be determined first. System inputs should include just the data necessary to generate these outputs.

- **The system must be comprehensive.** The PMS should address the full spectrum of pavement decision-making throughout the SHA. The system should encompass both network-level and project-level pavement management activities. Examples of network-level activities include determining system condition, setting pavement goals, identifying resource needs, allocating resources, and developing a program of pavement projects. Project-level activities include treatment selection based on life-cycle cost considerations, project design, and project construction.

- **PMS implementation must make a difference.** The decisions made using a PMS should be different (and better) than the decisions made before the system was implemented. If not, executive management will question the reasons why resources and time were invested in the first place.

- **The PMS must provide credible results.** Within each SHA there are a cadre of engineers who are known throughout the organization for their expertise in selecting projects and treatments. Executive management may seek the opinion of these experts regarding the reasonableness of the decisions made using the PMS. If the "in-house experts" don't support the PMS because the results are

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not credible, Executive Management will lose confidence in the system output and support for the PMS effort will decline.

- **The PMS must be institutionalized.** The system, when implemented must become an integral part of the day-to-day operations of the line decision-makers in the SHA. The PMS cannot be operated in a small separate unit in one corner of the organization which depends upon the knowledge and experience of one "pavement manager" or the presence of a champion in executive management for its survival. Someday, that one person will leave and with the person will go the SHA's operational PMS.

- **Implementation should not adversely affect organizational harmony.** Unfortunately, the implementation of a PMS may lead to "turf battles" within an organization. Different functional units may see a PMS as an opportunity to increase their influence on the SHA decision-making process. Care should be taken throughout system development to assure that the organizations affected by implementation of a PMS keep the interest of the entire organization in mind. Executive management prefers not to have to settle turf battles by choosing between competing subunits. Generally, other options which do not require this choice will be pursued such as selecting an independent or neutral third party to take the lead in developing the PMS.

- **The PMS should be capable of providing early benefits.** Early benefits of a PMS will show executive management that an immediate return is being made on their investment. This will not only promote the support of management but will also increase the probability of future financing for PMS activities.

  Phased implementation of a PMS is one way to assure early products. The phasing can take different forms. For example, in New York State, the PMS is being implemented in three stages - crawl, walk and run. Crawl stage activities basically involve the development of methodologies and technical tools to sharpen the existing pavement management process. Walk stage activities focus on further development of technical tools and the automation of these tools in a micro-computer environment, while run stage activities focus on the mainframe computer as the host for the PMS. This type of approach to phased implementation may not be appropriate for other SHA's, but the important point is that early benefits should be realized from any PMS development efforts.