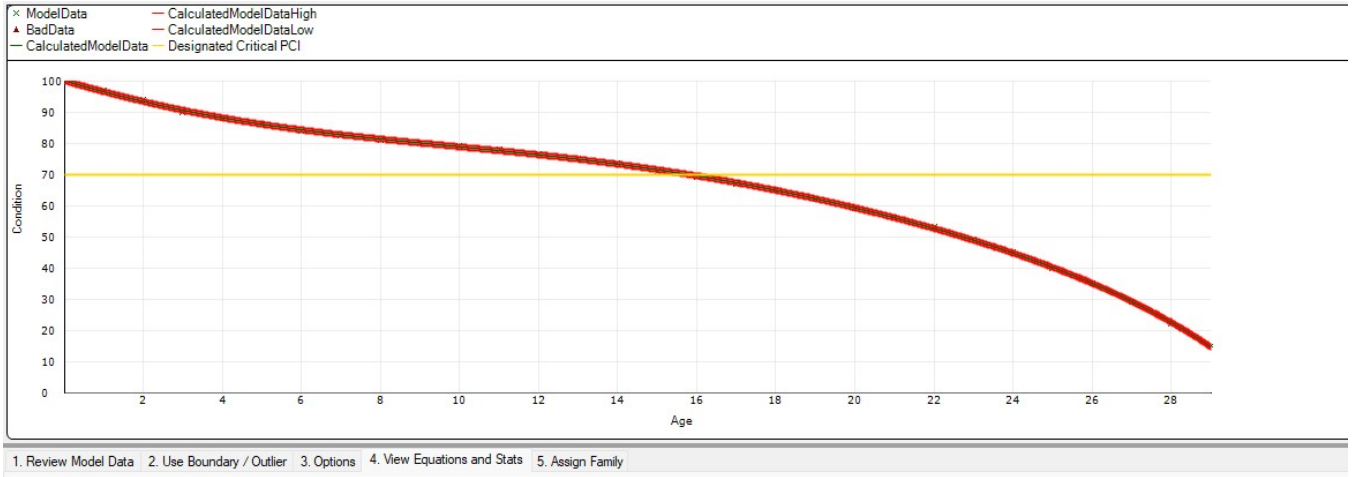
Appendix A. Asphalt Pavement Performance Curves

The predictive modeling (family modeling) process groups pavements of similar construction, subjected to similar traffic loads, weather, and other factors that affect the pavements life. The historical data on pavement condition can be used to build a model to predict future performance of a group of pavements with similar attributes. In Paver, this model of a pavement's life is referred to as a "family."

The performance curve plays a significant role in the development of a network-level budget analysis. If the deterioration rate of the curve is too steep, the required budget to repair these pavements increases. If the deterioration rate of the curve is too flat, the required budget to repair these pavements will be insufficient.

Both situations are mistaken, but when analyzing over a brief period, like 5 years, the change at any point over that period needs only be close initially. Constructing models that can accurately predict the performance of any road is an iterative process that is refined from the results of multiple condition surveys. Historical maintenance data are useful but can be initially misleading because they will have many outliers particularly if the data are not being collected specifically for this purpose.

Figure A-1 below shows the results from the performance model based on maintenance history data.



1 * (100 - 3.67159628868103 X^1 + 0.144980370998383 X^2 + 0.0137058598920703 X^3 - 0.00187948334496468 X^4 + 7.00004311511293E-05 X^5 - 9.10479229787597E-07 X^6) PCI Pts

Appendix B. Pavement Condition Index (PCI) Formula

Step 1: In a Network Level PMS, a survey of a limited number of sample units per section is sufficient. A sample area is defined as an area of 2,500 square feet plus or minus 1,000. A section is viewed as the smallest management unit when considering the application and choice of maintenance and repair (M&R) treatments.

$$PCI_s = PCI_r = \frac{\sum_{i=1}^{R} PCI_{ri} \times A_{ri}}{\sum_{i=1}^{R} A_{ri}}$$

Where

PCI_s = PCI of a pavement section

PCI_r = area weighted average PCI of random (or representative) sample units

PCI_{ri} = PCI of random sample unit number i

A_{ri} = area of the random sample unit *i*

R = total number of inspected random sample units

Step 2: If additional sample units are inspected, they can be used to enhance the section PCI as follows:

$$PCI_a = \frac{\sum_{i=1}^{A} (PCI_{ai} \times A_{ai})}{\sum_{i=1}^{A} A_{ai}}$$

$$PCI_s = \frac{PCI_r(A_s - \sum_{i=1}^{A} A_{ai}) + PCI_a \times \sum_{i=1}^{A} A_{ai}}{A_s}$$

PCI_a = area weighted average PCI of additional sample units

PCI_{ai} = PCI of additional sample unit number *i*

A_{ai} = area of additional sample unit *i*

A_s = total section area

Step 3: Using customer-defined constraints, such as the desired level of service, available rehabilitation technologies, or budgets, paving plans are developed in the Pavement Management System.

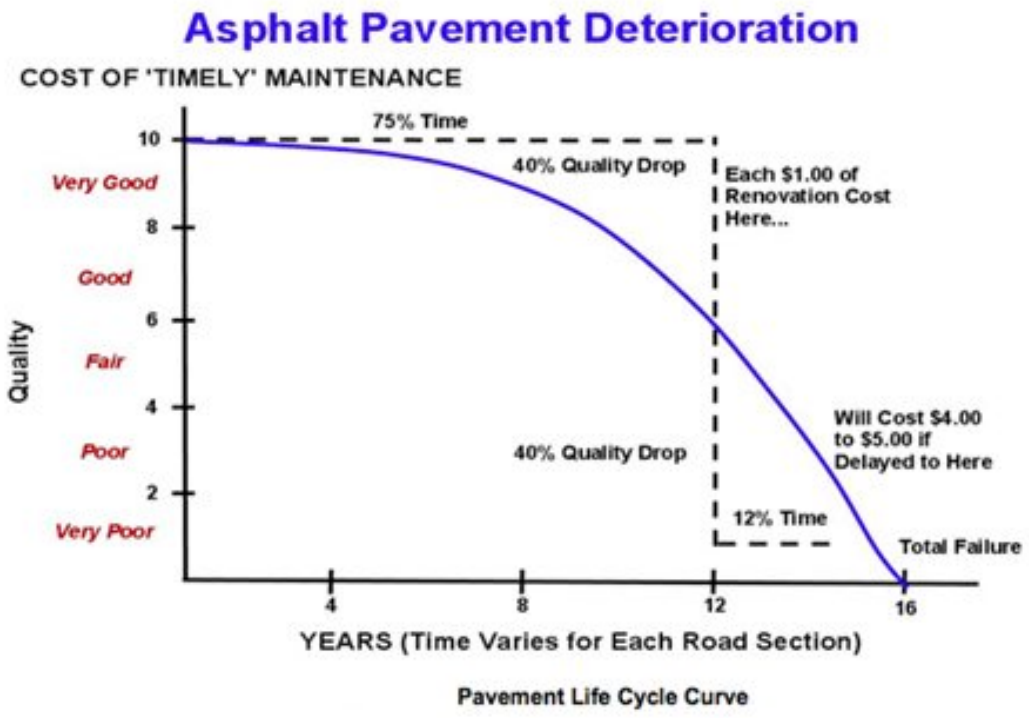
Appendix C. Principles of Pavement Management

An excellent way of maximizing the return on investment for the money that exists for road maintenance, given the persistent shortage of funding for maintaining street systems, is to implement a Pavement Management System.

Pavement management is a systematic approach to maximizing the life of a pavement network while optimizing the use of constrained funding. It can encompass planning, budgeting, funding, designing, constructing, monitoring, evaluating, maintaining, and rehabilitating a pavement network.

A Pavement Management System provides tools and methods for finding and implementing the best Maintenance & Rehabilitation (M&R) strategies. Repairing streets when they are still in fair condition costs less over their lifetime than waiting to fix roads that have fallen into poor condition. In other words, the proactive approach of routine pavement management means less money wasted on frequent roadway reconstruction and a potential savings of millions of dollars.

This process is illustrated below. It details how prompt intervention can delay the inevitable total reconstruction for as long as practical. If repairs are delayed until a road is rated in "Fair" condition or worse, the cost of rehabilitation becomes 4 to 5 times more expensive than for those roads in "Good" condition. This means that without preventative pavement maintenance, the cost of rehabilitation will be prohibitively expensive.



A Pavement Management System also provides a way to store an accurate inventory of all roadways, enriched with links to easements, as-built records, and historical documentation. The breadth and depth of information they hold, including digital images of roadways, baseline pavement condition data, and reviews of deterioration over time, are invaluable resources for measuring and tracking the effectiveness of Maintenance and Rehabilitation strategies.

Successful pavement management system programs let agency decision-makers develop reliable performance models for the roadway, which can be used to generate sound policies and long-term rehabilitation strategies, budgets, and timetables.

Another compelling reason for implementing a Pavement Management System is the Governmental Accounting Standards Board (GASB) Statement 34. This regulation requires agencies that collect taxes to manage a long-term, fixed infrastructure asset to either:

- **Option #1** - Implement financial accounting controls to effectively depreciate and plan for the replacement of fixed assets.
- **Option #2** - Implement an asset management system that provides a mechanism to gauge and budget for the long-term rehabilitation and/or maintenance of assets.

This study completed on the roadway network can be used as the basis for achieving GASB 34** compliance, either as the foundation for the inventory and valuation of the network (Option #1) or as the foundation of an asset management system (Option #2).

**Although it is not needed to meet GASB 34 standards, it is recommended to follow the industry's best practices regarding monitoring their infrastructure.

The Pavement Management Process

The figure below depicts the three unique, but equally important, steps that comprise the Pavement Management Process.

The Pavement Management Process

1. System Configuration

System configuration involves identifying all roadways of the project network and assigning them a unique identifier. Each section has attributes such as physical characteristics (length, width, etc.), pavement type, and road classification. As part of the system configuration, the network is linked to a GIS map.

2. Field Data Collection or Field Surveys

After system configuration is completed, every roadway in the system is surveyed, and its condition is assessed using the following criteria:

Surface Distress

Using high-definition digital images, technicians evaluate the distress of the roadways they travel on. They record pavement conditions such as cracking, potholes, and raveling, which are examples of surface distress.

Pavement distresses recorded during this survey are itemized in **Table 1.1**, with respect to the pavement type (AC=Asphalt Pavement and PCC=Portland Cement Concrete).

Description of Surface Distresses Recorded by Transmap

Pavement Distresses for Asphalt Pavement

Alligator Cracking **Block Cracking** **Bleeding** **Edge Cracking** **Transverse and Longitudinal Cracking**	**Patching and Utility Cut Patching** **Potholes** **Rutting** **Weathering** **Raveling** **Bumps and Sags, Corrugations and Depressions**

Severity

Once distress has been identified, its severity (Low, Moderate, High) is attached to the appropriate record and its count, e.g., the number of potholes, square footage (area covered by cracking), or linear feet (length of a specific crack) are added as well.

In a Network Level PMS, a survey of a limited number of sample units per section is sufficient. A sample area is defined as an area of 2,500 square feet plus or minus 1,000. A section is viewed as the smallest management unit when considering the application and choice of maintenance and repair (M&R) treatments. All field survey data collected in samples are summarized on a section-by-section basis. Each section constitutes a unit of data to populate the Pavement Management System.

Other data collected during field surveys include the pavement width, the pavement type, GPS coordinates, and digital images.

3. Analysis and Reporting

The results of a Pavement Management System analysis provide a quantitative performance score called Pavement Condition Index (PCI).

Pavement Condition Index (PCI) is an engineering terminology representing the surface condition of the pavement on a scale of 0 to 100. For example:

- PCI of 100 is a pavement in perfect condition.
- PCI of 0 is a pavement that is destroyed.

The PCI is a distress-based condition index, i.e., specific distresses in the pavement are identified and tallied, and the type, severity, and extent of each distress are used to calculate a single number representing the pavement condition. The higher numbers reflect better pavement. The formula used to calculate the PCIs is in **Appendix B**.

All condition ratings of the field surveys are captured at sample areas and combined to calculate one value, which represents the PCI of a pavement section using the area weighted average.

Maintenance and Rehabilitation Planning

Key Analysis Inputs

All Pavement Management Systems require user input to establish budget estimates and pavement Maintenance & Rehabilitation (M&R) plans. During the Boot Camp, decisions were made that affected the pavement rehabilitation program in a variety of ways. The key inputs are:

- The M&R pavement preservation categories
- The M&R pavement treatment type
- The PCI ranges assigned to the M&R categories
- The Critical PCI
- Unit cost for each pavement treatment type
- Expected life of the treatment type
- Agency budget and length of the planning period
- The budget is needed to achieve a target PCI at the end of the planning period
- Desired deferred maintenance at the end of the planning period

Boot Camp Notes can be seen in Appendix D of this report.