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IMPLEMENTING PAVEMENT MANAGEMENT SYSTEMS FOR LOCAL AGENCIES - STATE-OF-THE-ART/STATE-OF-THE-PRACTICE

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A report of the findings of
ICT-R27-87
Implementing Pavement Management Systems for Local Agencies

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16. Abstract

Pavement management systems have proven to be an effective tool for management of large state and metropolitan pavement networks. Although smaller agencies no doubt have similar operational and organizational needs and face the same general challenges as larger agencies, there are still many county and municipal agencies in Illinois that have not implemented pavement management systems. Regardless of whether this is due to the lack of adequate resources to establish the initial database and set up the system, or whether there is a general lack of technical expertise to implement the program, local agencies are in need of a methodology for effectively managing the various components of their pavement network.

As a part of this research two documents were produced including a state-of-the-art/state-of-the-practice synthesis and a set of guidelines to assist local agencies in selecting and implementing a pavement management system that is suitable for their needs.

This synthesis document provides details on pavement management systems in terms of data collection methodologies and rating systems, software programs, and local agency implementations in the U.S. Also documented are the results of a current practice survey disseminated to local agencies in Illinois, as well as case studies of selected agencies in Illinois that have a pavement management system implemented in their jurisdictions.

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The research team is thankful for the assistance provided by the project's Technical Review Panel (TRP) members and other IDOT staff with their assistance throughout the progress of this project.

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EXECUTIVE SUMMARY

Pavement management systems (PMS) are used by agencies to assist in identifying cost-effective strategies for preserving a pavement network and determining the level of funding required to meet agency goals for desired levels of service. Pavement management systems have proven to be effective tools for management of large state and metropolitan pavement networks. Although smaller agencies no doubt have similar operational and organizational needs and face the same general challenges as larger agencies, there are still many county and municipal agencies in Illinois that have not implemented pavement management systems.

The purpose of this research project is to develop a set of guidelines and recommendations that can be used by local agencies in appropriately implementing PMS. In order to establish a set of guidelines that will provide the best assistance in the implementation process, agencies should first be aware of the processes followed by other local agencies who have successfully implemented PMS. This synthesis was used to help craft the implementation guide and provides information on the state-of-the-art and state-of-the-practice regarding local agency PMS implementation, and includes a summary of information collected during the following:

- Literature search focused on PMS data collection methodologies, rating systems, pavement management software programs, and pavement management processes implemented by local agencies throughout the U.S.
- Current practice survey distributed to local agencies in Illinois.
- Case study interviews of selected local Illinois agencies regarding the details of their pavement management practices.

LITERATURE REVIEW

A literature review was performed to collect information regarding data collection methodologies, pavement management software programs, and pavement management processes implemented by local agencies throughout the U.S. The search revealed that there are various approaches for collecting pavement condition data. Since the collection of pavement condition data can be an expensive and time consuming process, it is important that the survey approach and methodology selected suits individual agency needs and available resources. Pavement condition data can be collected using automated or manual methods and can be based on measured or estimated rating assessments. There are a variety of data collection methodologies and corresponding rating systems that have been adopted by local agencies throughout the U.S. The literature review details three rating systems to cover a range of complexities in terms of the procedures and methods, including Pavement Condition Index (PCI), Pavement Surface Evaluation and Rating (PASER), and the Condition Rating Survey (CRS).

Several pavement management software programs are available both in the public and private sector. Information is presented on eight software programs, including MicroPAVER, RoadSoft GIS, StreetSaver, Utah Local Technical Assistance Program Transportation Asset Management System, PAVEMENTview and PAVEMENTview Plus, PavePro Manager, PubWorks, and RoadCare. Other informal options are available to agencies to manage pavement data. These types of programs include pen and paper based-systems, database and spreadsheet programs such as Microsoft Access or Excel, or Geographic Information System (GIS)-linked tools.

In order to assist local agencies in Illinois with identifying an appropriate pavement management system, the practices of 24 sample local city or county agencies throughout the U.S. were documented. Summaries of the characteristics of their pavement management systems are contained in this synthesis.

Through this research, institutional issues that may hinder implementation of PMS by local agencies were also identified. One such issue was that there may be limited technical and financial resources available at the local agency level. There may also be some perceived complexities of pavement management software and tools that may reduce the likelihood of adoption and continued use of a PMS. The implementation guide developed for this project, which is provided under a separate cover, provides recommendations for addressing these and other issues during the implementation process.

CURRENT PRACTICE SURVEY

To analyze the current practice of pavement management systems, a state-of-the-practice survey was created using an online survey tool and distributed to local agencies in Illinois. The purpose was to gain an understanding of local agency PMS implementations and to identify representative agencies to be included in the case studies. The survey focused on information needed to determine the type of PMS used by Illinois agencies and details on their practices. The survey included a variety of questions, such as:

- What procedure does your agency use to collect condition data?
- What type of condition rating does your agency use to evaluate pavement condition data?
- Describe the type of software program used at your agency.

The survey was distributed to a total of 347 local agencies in Illinois, including 245 municipalities and all 102 counties. A total of 115 responses were received. Some of the key findings of the state-of-the-practice survey are summarized below.

- Most of the responding agencies with PMS are located in jurisdictions with populations of 49,999 or less, with the highest percentage of respondents in the 25,000 to 49,999 range. This finding signifies that not all pavement management systems are implemented by large agencies.
- Of the responding agencies with PMS, 79 percent are affiliated with the Metropolitan Planning Organizations in their jurisdiction.
- Almost 75 percent of the agencies with a PMS have implemented it for more than five years, and nearly half have implemented it for over ten years.
- The majority of responding agencies with PMS use paper or electronic spreadsheets, with or without the use of a PMS software program.
- Nearly 70 percent of responding agencies indicate that they perform windshield surveys to collect pavement condition data, and a majority of the respondents said they use more than one method to collect data.

The state-of-the-practice survey also asked agencies that have a PMS implemented if they would be willing to serve as a case study agency for the project. The case study agencies were selected to represent a range of agency types, sizes, pavement management software programs, data collection strategies, and analysis methodologies. Once case study agencies were selected, on-site interviews were conducted to obtain details and insights into their PMS implementation and practices.

CASE STUDIES

The case study agencies that were interviewed in Illinois include Champaign County, Edgar County, McHenry County, Stark County, City of Macomb, City of Naperville, and the Village of Villa Park. The software programs used by these agencies include RoadCare, PAVEMENTview, MicroPAVER, PavePro, internally or externally developed spreadsheets, and fully customized, self-created software programs.

Information highlighted in the case study section illustrates the steps followed in the implementation of a PMS at the agency, successes in the implementation, and the implementation challenges faced by the agency. The review also provides a detailed illustration of agency-wide experience in the implementation efforts undertaken and the characteristics of the PMS selected for the particular agency. This information can be used by other local agencies in adopting an effective implementation strategy. A few key excerpts from the interview process include:

- The City of Naperville feels that “due to the state of the economy, the pavement management system has become more important.”
- Since Champaign County implemented their PMS, they are “now able to reduce political pressure,” when making pavement management decisions.
- The need for Edgar County’s PMS was recognized as the County wanted to have a systematic process in place for completing the “right work at the right time for the right reasons.”
- McHenry County encourages other agencies, “Don’t try to implement a PMS all at once, slowly integrate the program into your routine.”
- Stark County decided to implement a PMS because they “wanted to have more *engineering* behind decisions.”

SUMMARY

This report provides a synthesis of the literature search, the current practice survey of local agency pavement management systems, and the case study interviews that were conducted as part of this study. This document is a supplement to the *Implementation Guide* developed as a separate document under this research study.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ADT	Average Daily Traffic
APN	Asset Priority Number
ARA	Applied Research Associates, Inc.
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
CIP	Capital Improvement Planning
CIPR	Cold-In-Place Recycling
CRS	Condition Rating Survey
DMI	Distance Measuring Instrument
DOT	Department of Transportation
ESAL	Equivalent Single Axle Load
GASB	Government Accounting Standard Board
GIS	Geographic Information System
GPS	Global Positioning Systems
HAMS	Hillsborough County Asset Management System
ICT	Illinois Center for Transportation
IDOT	Illinois Department of Transportation
IMS	Infrastructure Management Services
IPMP	Iowa Pavement Management Program
IRI	International Roughness Index
LLC	Lowest Life Cycle
LTAP	Local Technical Assistance Program
MCs	Master Curves
MDOT	Michigan Department of Transportation
MFT	Motor Fuel Tax
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission
OCI	Overall Condition Index
ODOT	Ohio Department of Transportation
OPI	Overall Pavement Index
PASER	Pavement Surface Evaluation and Rating
PCC	Portland Cement Concrete
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PDA	Personal Digital Assistant
PMA	Pavement Management Application
PMS	Pavement Management Systems
PQI	Pavement Quality Index
PSI	Present Serviceability Index
RAP	Reclaimed Asphalt Pavement
RSL	Remaining Service Life
SEMCOG	Southeast Michigan Council of Governments
TAMS	Transportation Asset Management System
TRP	Technical Review Panel
USACE	United States Army Corps of Engineers

CHAPTER 1 INTRODUCTION

Pavement management systems (PMS) are used by agencies to assist in identifying cost-effective strategies for preserving the pavement network and for determining the level of funding required to meet agency goals for desired levels of service. These activities are conducted using pavement inventory and condition information stored in the pavement management database and pavement analysis models, which include pavement deterioration models, treatment rules, and cost models. An agency can use its PMS to evaluate various pavement rehabilitation, maintenance, and preservation strategies and estimate the impact of those strategies on the future condition of the pavement network for various budget levels.

Pavement management systems have proven to be an effective tool for management of large state and metropolitan pavement networks. Although smaller agencies no doubt have similar operational and organizational needs and face the same general challenges as larger agencies, there are still many county and municipal agencies in Illinois that have not implemented pavement management systems. Regardless of whether this is due to the lack of adequate resources to establish the initial database and set up the system, or whether there is a general lack of technical expertise to implement the program, local agencies are in need of a methodology for effectively managing the various components of their pavement network.

The Illinois Center for Transportation (ICT) conducted a research project to develop guidelines and recommendations that can be used by local agencies in implementing a PMS. In order to develop the guidelines, a synthesis of the state-of-the-art and state-of-the-practice was prepared and is documented in this report. The guidelines and recommendations for implementing local agency pavement management systems are contained in a separate document entitled the *Implementation Guide*. This synthesis is a compilation of information from a literature review, survey of local agency practices in Illinois, and follow-up interviews with a select number of local Illinois agencies.

This report is organized into the following chapters:

1. Introduction
2. Pavement Condition Survey Methodologies
3. Pavement Management System Software Programs
4. U.S. Local Agency PMS Implementations
5. State-of-the-Practice Survey
6. Case Studies
7. Summary and Conclusions

CHAPTER 2 PAVEMENT CONDITION SURVEY METHODOLOGIES

Pavements age with time and gradually deteriorate due to environmental effects, traffic loadings, and other factors. Resources for maintaining and repairing roads can be efficiently managed so that the money is spent in the right place at the right time by knowing the current condition of the pavement network and the rate at which it deteriorates. Many local agencies have recognized the benefits of performing regular pavement condition surveys to evaluate the existing pavement conditions and to allocate maintenance and construction funds.

Acquiring the pavement condition data needed for the management of a pavement network can be an expensive and time consuming process. Therefore, it is important that the selected pavement condition survey approach closely matches the available resources. The collection of pavement condition distress data can either be a measured or estimated process and can be collected using automated or manual methods. The definition of these types of data collection approaches and general methodologies are as follows:

- *Measured pavement condition data* – Distress information is quantified and a condition rating is calculated based on the measured quantities of specific distress types. Pavement conditions are typically categorized by distress type (cracking, rutting, raveling, etc.) and then by severity (high, medium, or low). In this procedure, a sophisticated structure would identify the distress types and the severity, and it would be supported by specific measurements.
- *Estimated pavement condition data* – Distress quantities are estimated or an overall rating is assigned based on the rater's judgment. Pavement conditions are observed and the pavement sections are rated based on their overall condition, with or without estimates of specific distresses.
- *Manual data collection* – Manual data collection is "pavement condition data collection through processes where people are directly involved in the observation or measurement of pavement properties" (Flintsch and McGhee, 2009). In manual surveys, distresses are often assessed or measured from a moving vehicle (windshield surveys) or while "walking" the pavement.
- *Automated data collection* – Automated data collection is the "process of collecting pavement condition data by the use of imaging technologies or by other sensor equipment" (Flintsch and McGhee, 2009) such as profiling devices. These technologies may be equipped altogether on a mobile van or separately on trailers attached to a vehicle.

To have a pavement management system that can be maintained over time, it is critical that the data collection and analysis methods be selected to match the technical and economic resources within a local agency.

The following sections provide details of some widely used pavement condition survey methodologies and rating systems adopted by local agencies throughout the U.S. for measured and estimated assessments. Although many variations among these methodologies exist, sample methods are presented to cover a range of complexities in terms of the survey procedures and methodologies used in pavement management systems. Other survey procedures not presented in this document include creating a fully customized rating system that specifically meets agency needs or utilizing a simplified 'good, fair, poor' rating. When using a customized rating or a 'good, fair, poor' rating it may be difficult for the agency to later convert their ratings to another type of system in the future. Examples of customized rating systems and 'good, fair, poor' rating systems are documented in Chapter 6 of this synthesis. The rating methodologies presented in this section are those that are well documented and commonly used.

2.1 MEASURED SURVEY METHODOLOGIES

2.1.1 Pavement Condition Index Survey

The Pavement Condition Index (PCI) survey methodology was developed by the U.S. Army Corps of Engineers, adopted by the American Public Works Association and ASTM International (formerly the American Society for Testing and Materials), and documented in ASTM D6433, *Standard Test Method for Roads and Parking Lots Pavement Condition Index Surveys* (ASTM 2009). The PCI methodology is a rating system that measures the pavement integrity and surface operational condition based on a 100-point rating scale, as shown in figure 1. According to this methodology, the pavement network is first divided into branches (e.g. individual roads), sections (e.g., segments with consistent work history), and sample inspection units.

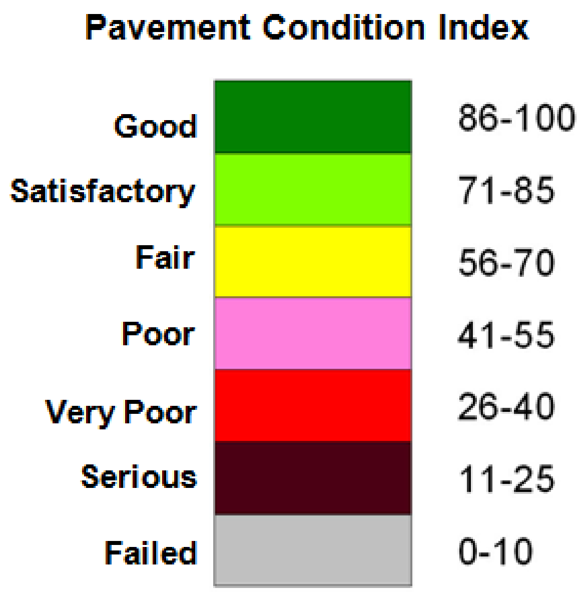


Figure 1. Pavement condition index ratings.

Pavement surveys are conducted for sample units. A sample unit is a selected small segment of pavement of required size, which is then inspected in detail. For example, sample units in asphalt-surfaced pavements are approximately 2,500 square feet, plus or minus 1,000 square feet. A representative percentage of sample units are randomly selected and inspected. Detailed pavement condition surveys are conducted by identifying the type, severity, and amount of each distress in representative sample units selected according to systematic sampling procedures.

A total of 39 distress types (20 types for asphalt pavements and 19 for concrete pavements) are defined with three levels of severity (e.g. high, medium, or low) (ASTM 2009). Each combination of distress type, severity, and extent has a deduct value associated with it, which is determined using available graphs for different types of distresses. Distresses that are considered to be more damaging to the pavement (such as fatigue cracking) have higher deduct points associated with them than distresses that are less critical (such as transverse cracks). Once each distress' deduct value is determined, they are added together to get the total deduct value for that sample unit. This value is then adjusted depending on how many distresses were used. The deduct values are subtracted from a perfect score of 100 to determine the PCI for that sample unit. A weighted average of all the PCIs for the inspected sample units within a single section are then used to represent the condition of that section. Many pavement management system software programs (discussed in Chapter 3) can calculate the PCI value based on the distress inputs entered into the software.

2.2 ESTIMATED SURVEY METHODOLOGIES

2.2.1 Condition Rating Survey

The Condition Rating Survey (CRS) is used by IDOT to evaluate the condition of pavement (Illinois Department of Transportation 2004). The rating system values range from 1.0 to 9.0 in 0.1 value increments. A CRS rating of a 1.0 denotes a total failure of a pavement, and a CRS rating of 9.0 denotes a newly constructed pavement surface. A summary of the rating system is provided below:

- Poor (1.0 ≤ CRS ≤ 4.5): The pavement is critically deficient and in need of immediate improvement.
- Fair (4.6 ≤ CRS ≤ 6.0): The pavement is approaching a condition that will likely necessitate improvement over the short term.
- Satisfactory (6.1 ≤ CRS ≤ 7.5): The pavement is in acceptable condition (low end) to good condition (high end) and not in need of improvement.
- Excellent (7.6 ≤ CRS ≤ 9.0): The pavement is in excellent condition.

The Condition Rating Survey Manual developed in April 2004 provides several images of distress ratings to aid the surveyor in properly selecting a CRS rating for a section. Figure 2 below shows an example of an asphalt pavement with a CRS of 5.9 versus a CRS of 5.8.

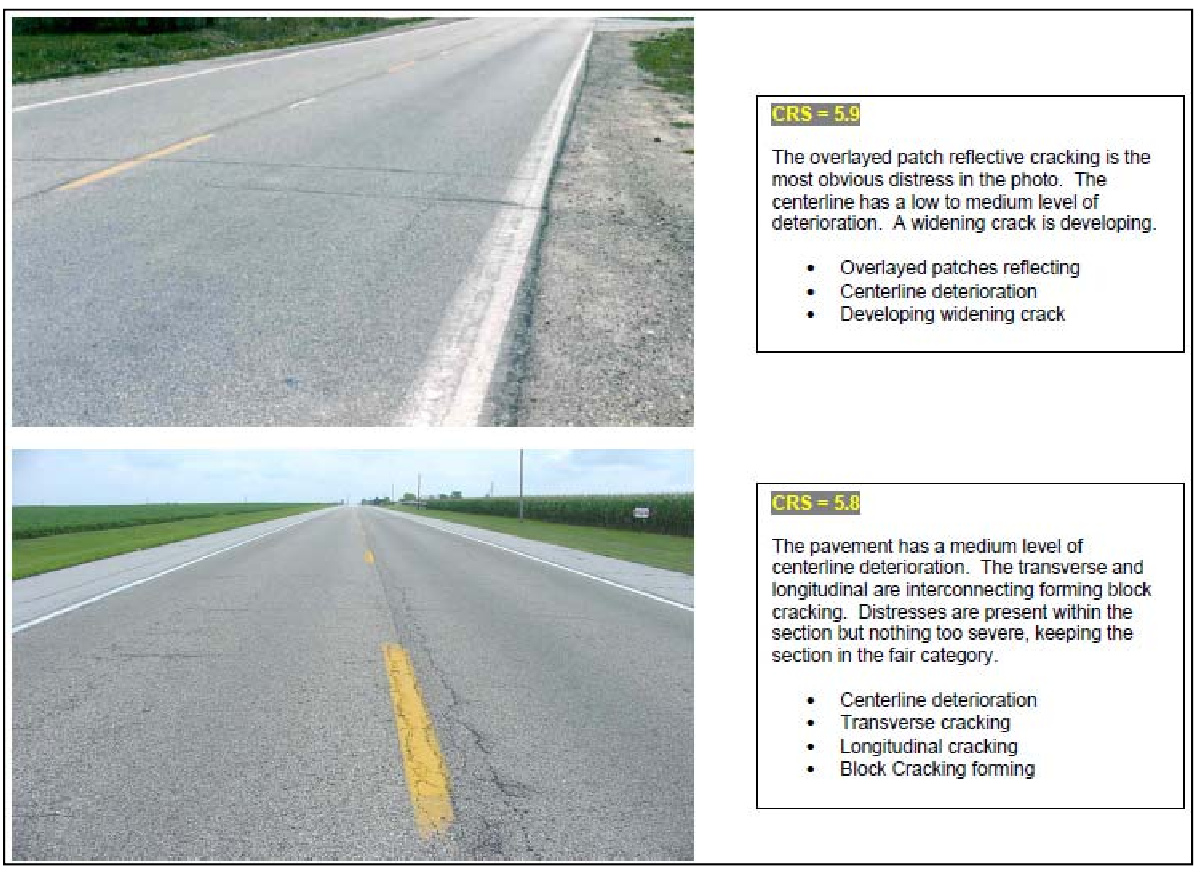


Figure 2. CRS of 5.9 versus CRS of 5.8 (Illinois Department of Transportation 2004).

It is important to note that the CRS methodology used by IDOT for state roads is considered a measured survey. IDOT had developed algorithms to incorporate some measured distresses such as roughness and rutting into pavement performance calculations. However these developed algorithms are based on state road structures and are not applicable to local agency road systems. CRS is used by local agencies as an estimated methodology since the manual contains a series of photographs depicting a variety of pavement conditions which relate to a CRS rating value. Therefore, state agencies may use the CRS as a measured and calculated rating, but local agencies may use the CRS as an estimated way of rating their local road network.

2.2.2 Pavement Surface Evaluation and Rating System Survey

The Pavement Surface Evaluation and Rating System Survey (PASER) is a system for visually rating the surface condition of a pavement on a scale from 1 to 10, with 1 being a pavement in failed condition and 10 being a pavement in excellent condition. The PASER rating procedure is based on a series of photographs and descriptions for each of the individual rating categories (a sample is shown in figure 3) that are used by a rater to evaluate the overall condition of an individual pavement segment.

The general condition of the roadway is first determined (e.g. new pavement, pavement in poor condition). Next, the pavement distresses are evaluated subjectively and the rater selects an appropriate surface rating, as per the PASER manual. Individual pavements may not have all of the types of distress listed for a particular rating, but the general description should match what is observed in the field. The PASER rating scale can generally be translated into the maintenance categories shown in table 1.

Table 1. PASER Ratings Related to Maintenance and Repair Strategies.

PASER Rating	General Description of Maintenance/Repair Needs
9 & 10	No maintenance required
8	Little or no maintenance
7	Routine maintenance, crack sealing and minor patching
5 & 6	Preservative treatments (seal coating)
3 & 4	Structural improvements and leveling (overlay or recycle)
1 & 2	Reconstruction

Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that PASER ratings be updated every two years, with an annual update being desirable (Walker et al. 2002).

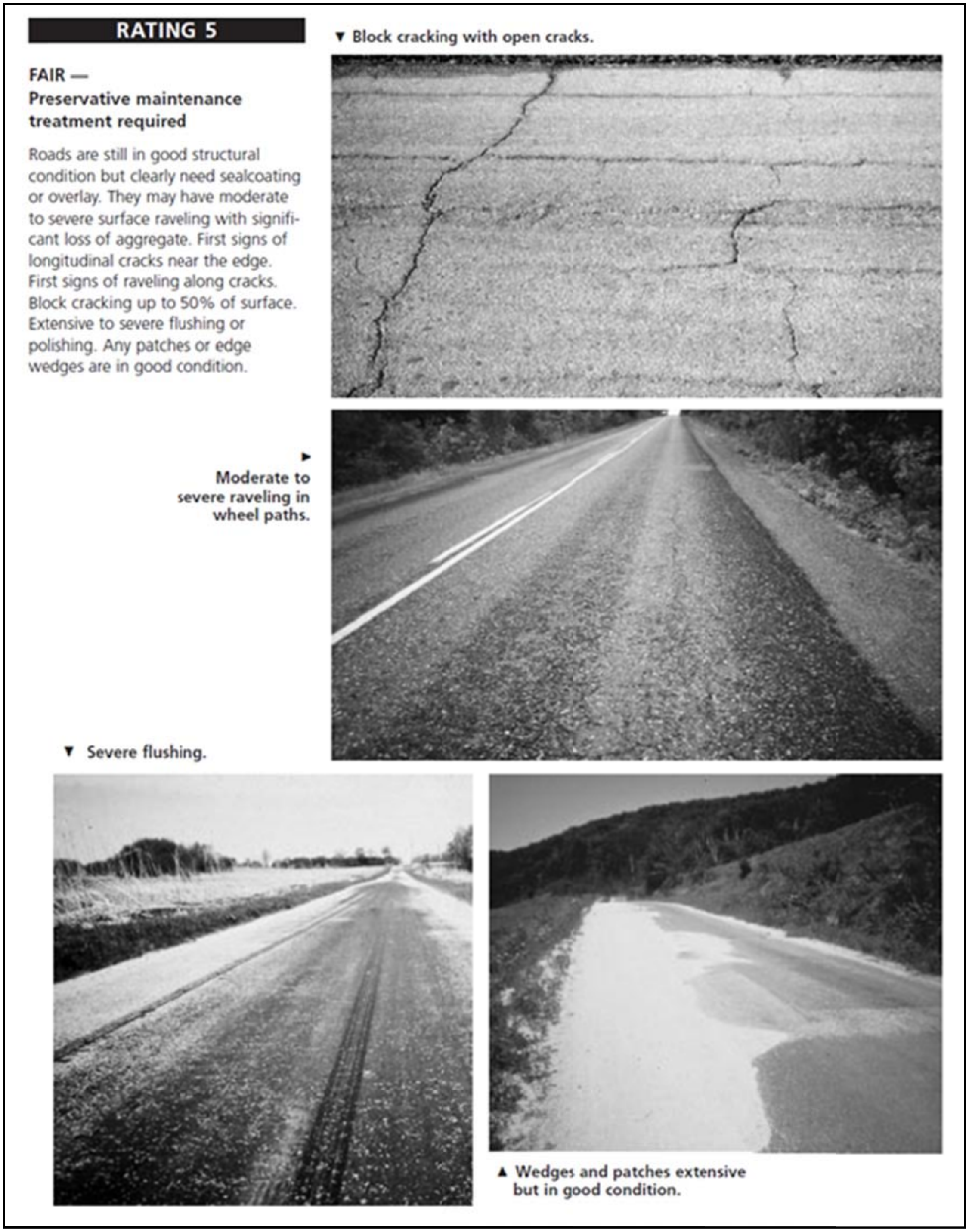


Figure 3. Sample visual distress and PASER rating for asphalt pavement with a rating of 5 (Walker et al. 2002).

CHAPTER 3 PAVEMENT MANAGEMENT SYSTEM SOFTWARE PROGRAMS

As part of this research project, a variety of commonly used PMS software programs were investigated, including public and private domain software. The public pavement management software programs are typically developed under the support of government agencies or universities. In general, the cost of these programs is reasonable and may even be free to candidate agencies.

The private domain software programs available are typically developed by consulting or software firms. The cost of private PMS programs is generally higher than the public domain software. The producers of private software programs also often provide other support services (e.g., implementation services, pavement condition inspection services, etc.).

The following sections present details, features, and costs of eight software programs available on the market: four public domains and four private domains. These software programs were selected due to their large scale use throughout the U.S. and/or because they are of interest to local agencies in Illinois. Several other types of software for pavement management are available, but given the scope of this study they have not been discussed.

3.1 PUBLIC SOFTWARE PROGRAMS

The four public PMS software programs described in this synthesis include:

1. MicroPAVER by the U.S. Army Corps of Engineers.
2. RoadSoft GIS by Michigan Tech Transportation Institute at Michigan Technological University.
3. StreetSaver by the Metropolitan Transportation Commission of nine counties in the San Francisco Bay Area, California.
4. Utah Local Technical Assistance Program (LTAP) – Transportation Asset Management System (TAMS).

3.1.1 MicroPAVER

MicroPAVER was originally developed in the mid-1980s by the U.S. Army Corps of Engineers (USACE) to help the Department of Defense manage maintenance and repair for its vast inventory of pavements (U.S. Army Corps of Engineers 2010). Major supporters of MicroPAVER include U.S. Air Force, U.S. Army, U.S. Navy, Federal Aviation Administration, and Federal Highway Administration. Clients of MicroPAVER include more than 600 agencies and consulting firms.

MicroPAVER is a decision making tool for the development of cost effective maintenance and repair alternatives for roads and streets, parking lots, and airfields. The software allows for the storage and creation of the following: pavement network inventory, pavement condition rating, pavement condition performance prediction development, present and future pavement condition prediction through condition analysis, and maintenance and repair needs determination through the analysis of different budget scenarios (USACE 2010).

The MicroPAVER inventory consists of relationships between networks, branches, and sections. In addition to the standard data fields, the inventory has user-defined fields to meet specific management requirements. The pavement condition data can be automatically updated based on work history information entered by the user.

Field inspection data, which is based upon distress type, severity level, and specific quantities of distress, are entered into MicroPAVER. This data is used by the program to calculate the PCI to note the condition of the roadway segment. Images and comments for an individual section can be entered into the system.

MicroPAVER's prediction modeling function identifies and groups together pavements with similar characteristics ("pavement families") such as traffic, weather, and other factors that affect the pavement's performance. The models estimate the future performance of the "family" based on historical pavement condition data, as shown in figure 4.

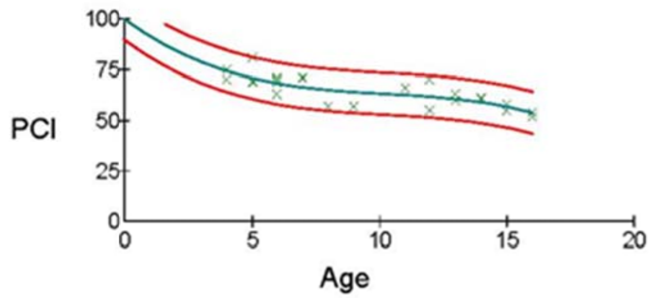


Figure 4. MicroPAVER-family model (USACE 2010).

The condition analysis feature within MicroPAVER examines the changes in the pavement condition over time. Past inspection data are compared to present inspection data to determine the effectiveness of the maintenance and repair strategies. Future conditions without any maintenance or repair strategies are also estimated. The evaluation of pavement sections is based on the results from previous inspections, last construction date, and their family models. Pavement conditions can be viewed on Geographic Information System (GIS) maps in addition to tables and graphs provided by the report for projected conditions based on the prediction models, as shown in figure 5.

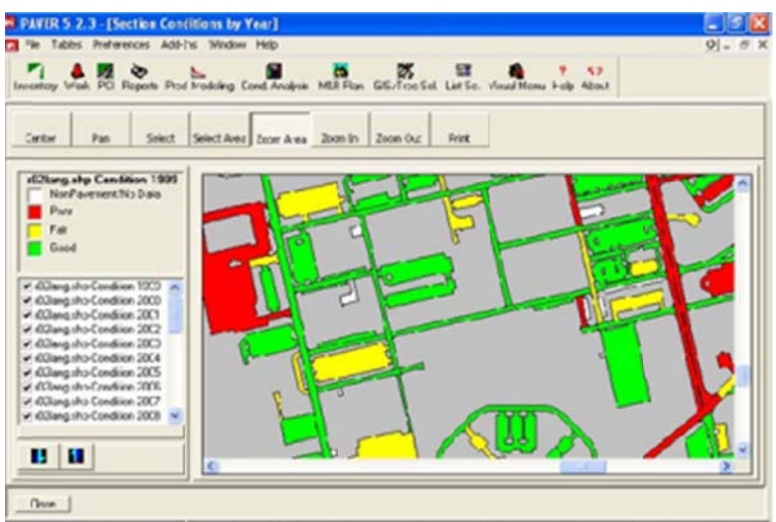


Figure 5. Condition analysis and work planning outputs displayed in MicroPAVER's internal GIS (USACE 2010).

The maintenance and repair planning feature allows for planning, scheduling, budgeting, and analyzing alternative maintenance and repair strategies. Work plans are specific to the user's needs since a user inputs agency-specific pavement management practices and costs.

There are five reporting tools in the reports feature of MicroPAVER, including summary charts, standard reports, re-inspection reports, user-defined reports, and GIS reports. Summary charts allow the user to graph and compare any two variables in the database. Standard reports include branch listing, work history, branch condition, and section condition reports.

3.1.2 RoadSoft GIS

RoadSoft GIS was developed by the Michigan Tech Transportation Institute at Michigan Technological University (Michigan Technology University 2006). It has been used throughout the state of Michigan for more than ten years. Clients of RoadSoft GIS include the Michigan Department of Transportation, Federal Highway Administration, over 200 cities and villages, and almost 100 county road agencies in Michigan and throughout the U.S. RoadSoft is able to store information on roads as well as other assets such as signs, culverts, guardrails, pavement markings, traffic counts, and traffic crashes. For each asset in the database, the following may be stored, in addition to information pertaining to specific types of assets:

- Location of the asset using linear referencing or Global Positioning System (GPS) coordinates.
- Physical description.
- Construction, maintenance, inspection and rating information.

The Pavement Management Module of RoadSoft allows road surfaces to be rated according to the PASER rating system. To assist with the data collection, a laptop and portable GPS locator may be setup with RoadSoft GIS, which allows for data input while inspecting the roadway. Using the PASER rating system and the laptop with a GPS locator, roadway inspections can occur in a vehicle traveling 15 to 30 miles per hour. A sample database and input screen from RoadSoft for the road inventory module is shown in figure 6.

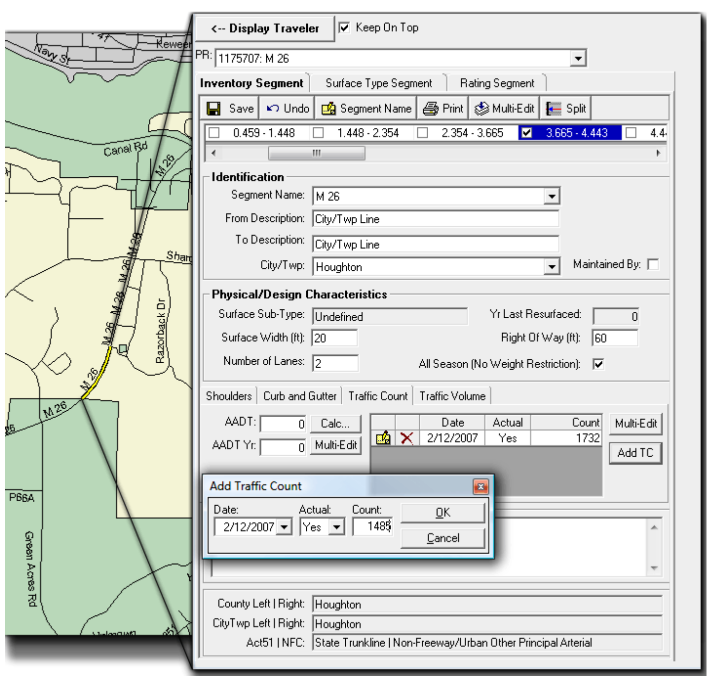


Figure 6. Road inventory module interface and sample map (MTU 2006).

The Road Inventory Module allows the agency to enter information about legal, physical, and condition characteristics of the roadway. Roadway segments in the GIS base map can be linked to inspection data, construction history, traffic volume, and scheduled maintenance, as well as the inventory data.

When a rating is entered into the program, a deterioration model is generated to determine the remaining service life of the pavement. The deterioration model uses the rating and the surface type to generate an expected lifespan of the segment and determine when the segment will reach a critical maintenance threshold.

RoadSoft's Strategy Evaluation Module allows an agency to determine a maintenance plan for their entire roadway network based on different surface types. In this module, a user can define maintenance treatments in dollars or lane miles over the life of the plan. The module generates graphs based on these maintenance treatments to show the money spent; the percentage of good, fair, and poor roads; the lane miles of activities performed; and the average remaining service life for each year of the plan. Examples of these graphs are shown in figure 7.

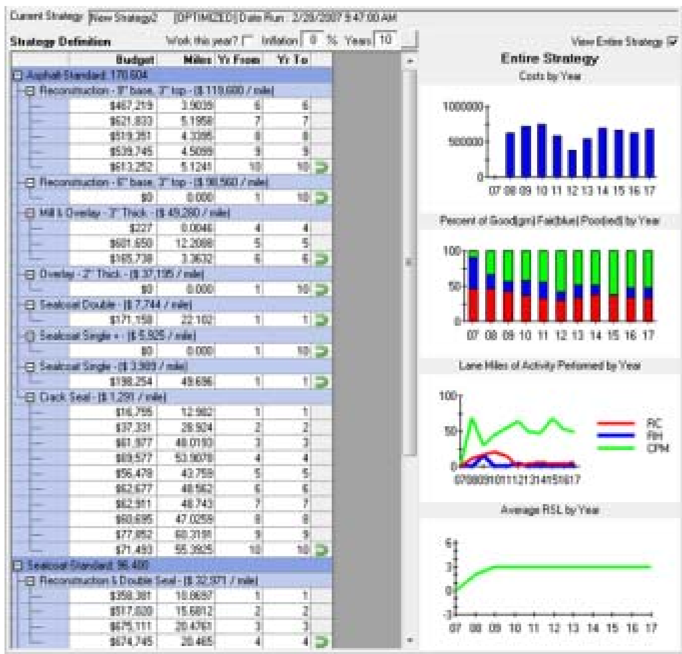


Figure 7. RoadSoft GIS-sample output from the strategy evaluation module (MTU 2006).

RoadSoft GIS comes with more than 50 standard reports for all assets and can generate a number of custom reports using the report and filter tool. The data from generated reports may be exported for use in other database programs, and the entire GIS file may be exported for use in other GIS applications.

3.1.3 StreetSaver

StreetSaver was developed by the Metropolitan Transportation Commission (MTC), the agency for transportation planning, financing, and coordinating for nine counties in the San Francisco Bay Area, California (MTC 2009). StreetSaver has been in use for the more than 20 years by over 100 users in the San Francisco Bay Area and more than 250 users nationwide and internationally.

This software program uses a modified PCI as the method of rating the pavement surface condition. The PCI in StreetSaver is calculated based on seven distress types and three severity levels. For example, the distresses for asphalt pavements include alligator cracking, block cracking, distortions, longitudinal and transverse cracking, patching and utility cuts, rutting and depressions, and weathering and raveling. Once the PCI is determined, StreetSaver generates a deterioration curve, as shown in figure 8.

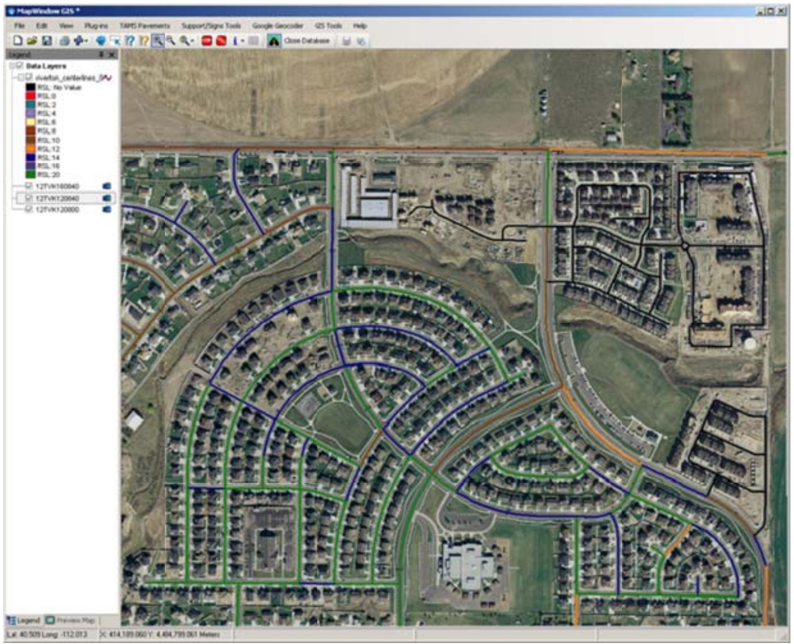


Figure 8. StreetSaver-deterioration curve (MTC 2009).

StreetSaver allows the user to perform analyses based on budget constraints. The Budget Needs analysis determines the amount of money needed to bring the network condition to a predefined level. The Budget Scenarios analysis develops a list of pavement sections recommended for treatment based on the budget specified by the user. The program is able to store multiple budget scenarios, which allow comparisons of the condition of the roadway network for different budget constraints. The Event-Based analysis allows the user to compare the impacts of different events, such as maintenance treatments, on a roadway segment. The Project Selection analysis allows the user to designate portions of the road network for running project-specific scenarios to customize rehabilitation programs.

StreetSaver has 30 standard reports and graphs, as well as a built-in Custom Report Wizard that allows customization of reports. StreetSaver also has a Government Accounting Standard Board Statement 34 (GASB-34) Reporting Module that facilitates the reporting of pavement assets to comply with the GASB-34 requirements.

Third-party, optional products developed by consulting firms are available at an additional cost, such as a GIS Linkage, Viewer, and Electronic Data Collector.

3.1.4 Utah Local Technical Assistance Program – Transportation Asset Management System

The Utah LTAP TAMS was developed by the Utah Local Technical Assistance Program at Utah State University (Utah Transportation Center 2010). The TAMS software allows for the management of other assets such as signs, street segments, condition ratings, analysis, and treatment types in addition to pavements. The software contains a set of tools to help cities and counties manage their transportation networks on an individual project or network level. TAMS includes a GIS interface that allows a user to select individual transportation asset features (figure 9).

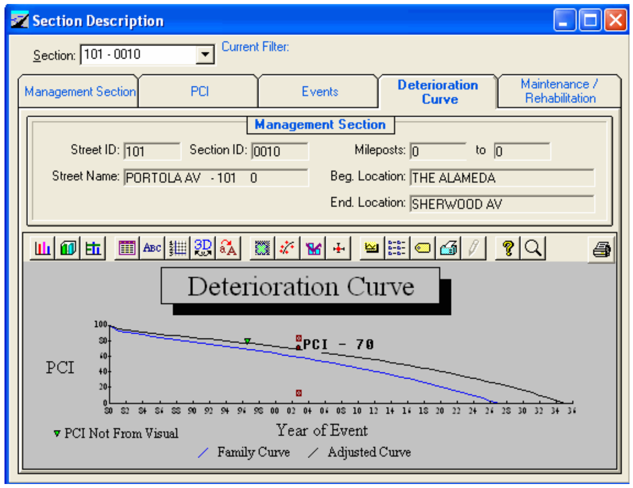


Figure 9. Utah LTAP TAMS sample GIS interface (Utah Transportation Center 2010).

All assets can be accessed using the GIS interface or by manually looking up each asset. In the main inventory form, users are able to add, change, and look up any data related to that specific asset. The module is capable of inventorying more than 20 physical attributes along with the pavement distress condition. From this inventory, the resulting level of service or remaining service life and recommended treatment can be determined based on the governing distress.

The user is able to apply a virtual treatment or multiple treatments to any part of the network and then view the overall performance and associated costs. The user can also add future project dates and update maintenance and rehabilitation work, and the program automatically calculates the segment's new remaining service life.

The TAMS is able to perform custom queries and create customized reports that may be exported to Microsoft Word or Excel. There are also several predefined reports for condition data, inventory data, and treatment recommendations. Pie charts are available to compare attributes such as governing distress, functional classification, and remaining service life. The user can also create performance charts that compare the pavement conditions and applied treatments to determine the optimum use of resources.

3.2 PRIVATE SOFTWARE PROGRAMS

The private PMS software programs highlighted in this synthesis include:

1. *PAVEMENTview and PAVEMENTview Plus* by Cartegraph.
2. *PavePRO Manager* by Infrastructure Management Services (IMS).
3. *PubWorks* by Tracker Software Corporation.
4. *RoadCare* by Applied Research Associates, Inc.

3.2.1 PAVEMENTview and PAVEMENTview Plus

PAVEMENTview and PAVEMENTview Plus were developed by Cartegraph, located in Dubuque, Iowa (Cartegraph Products 2011). The PAVEMENTview program is a component of the overall Cartegraph system that allows users to manage pavements while the overarching software allows agencies the ability to oversee a variety of assets (e.g., signs, pavement markings, bridges, stormwater, sewers, water, lights, etc.).

PAVEMENTview includes an inventory module for road segments and databases for classification, type/dimension/material, structure, and geometry details for each road segment. PAVEMENTview Plus features allow for the ability to create (Cartegraph Products 2011):

- Capital improvement planning (CIP) scenarios.

- Network-level and segment-level performance modeling.
- Budget requirement schedules.
- User-defined decision trees for maintenance preferences.
- Network priority rating calculations for individual road segments that can be used to prioritize work plans.
- Maintenance, rehabilitation, and reconstruction policy decision matrix set up by the user.

In PAVEMENTview, the user may enter condition data for each sample unit inspected along a road segment. Online distress libraries with images and distress data are available to aid in the data collection. After all inspection data is entered into the program, the Overall Condition Index (OCI) of the roadway segment is calculated. The future performance of the road segment is determined and the remaining service life is estimated. After the remaining service life is estimated, routine and recurring maintenance activities can be scheduled in the software program and historical activity logs can be maintained.

PAVEMENTview has options to customize the program to the user's needs. The user may rename fields, create custom forms, and add custom fields to track additional information. For additional customization, an agency may attach digital photos, electronic files, and computer aided design (CAD) documents to individual records. A sample database in PAVEMENTview is shown in figure 10.

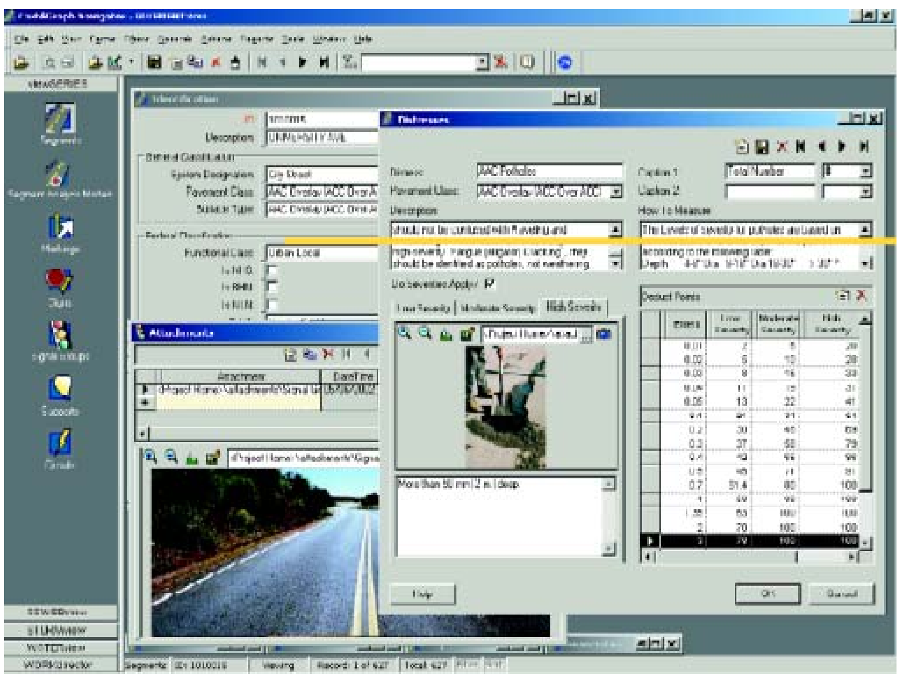


Figure 10. PAVEMENTview plus-sample database (Cartegraph Products 2011).

PAVEMENTview Plus is additional software within the Cartegraph suite that enables the user to plot and compare Capital Improvement Program scenarios. Network priority ratings can be calculated for individual road segments. User-defined decision trees or a maintenance, rehabilitation, and reconstruction policy decision-matrix can be used for maintenance prioritization. This software is able to analyze the impact of different maintenance alternatives and compare different scenarios by performance and cost. Performance predictions for individual segments or segment groups can also be generated.

PAVEMENTview and PAVEMENTview Plus have predefined reports, along with customizable reports. PAVEMENTview's predefined reports include pavement overview report, pavement detailed report, traffic summary report, and pavement inspection report. PAVEMENTview Plus's predefined reports include those listed above and budget summary report, budget surplus report, and recommended segments report. PAVEMENTview also has a GASB-34 module which produces a financial summary form and financial reports based on the depreciation or modified approach, as per federal requirements.

3.2.2 PavePRO Manager

PavePRO Manager is a pavement management software developed by Infrastructure Management Services (IMS) consulting firm. It provides roadway inventory, integration of GIS and visual digital imaging, reporting features, and budget scenarios. The software stores pavement distress information, roughness, rutting, shoulder conditions, drainage, and environmental conditions (Infrastructure Management Services undated).

The user is able to add a module for storing digital images. Within this module, the user can upload a sequence of still images or digital video files, which can be associated with a particular street, roadway segment, or asset.

PavePRO's inventory database stores information for segments or block sections. The street inventory includes name, limits, pavement type, length, and width fields, among others. Each attribute can be used to sort and filter the data.

Through integration with ArcView GIS, the user can generate maps or make queries on any data in the pavement management database. A user can define or modify any part of the network and still maintain the link to GIS.

When performing analysis on the road network, PavePRO considers surface distress, traffic, truck loading, roughness, rutting, drainage, curb and gutter, and climate conditions. The analysis performed by the software is based on remaining service life assessment, which aids in estimating rehabilitation and budget needs for a specified time period. The analysis also includes indicators on how the pavement may respond to loading and how it may perform with the different rehabilitation or maintenance options. To determine maintenance and rehabilitation strategies, the software analyzes ten strategies for each analysis year and selects the option that presents the greatest benefit to the network. The user can define an annual budget, and the rehabilitation strategies are then selected based on the cost-benefit ratio; or the user can define a level of service, and then the software selects the optimum rehabilitation or maintenance strategy. The software is also able to assess, store, and recall multiple "what if" scenarios.

The reports generated by PavePRO are customizable by the user and are exportable to a number of different applications, such as Microsoft Excel. The software can be used with data collected by automated collection devices or with manual surveys and updates.

3.2.3 PubWorks

PubWorks is an asset management program developed in 1997 by the Tracker Software Corporation. PubWorks was first used as a special project in Pitkin County, Colorado. As of 2010, PubWorks has been used by more than 300 counties and municipalities throughout the U.S. (Tracker Software Corporation 1997-2010).

The PubWorks software is able to track many fixed asset inventories, including streets, roads, bridges, signs, culverts, guardrails, parks, and buildings. The core module is used for asset management and job costing, which allows inventories of all assets, equipment, employees, crews, activities, projects, routes, and materials to be maintained.

PubWork's asset data collector module is a GPS program that allows the user to develop an inventory of fixed assets and perform inspections on the assets on a laptop. This module is integrated with the PubWorks database; therefore, the module's data is updated when new information is added. The module allows work history of each asset to be tracked, and the user can create schedules and work assignments for any asset. Depending on the user’s preference, the module can be run manually by the user, automatically through a vehicle-installed distance measuring instrument (DMI), or automatically through a laptop-connected GPS.

The work order module helps keep track of work plans for recurring times on all or any of the assets in the database. The module is also capable of forming a ‘to-do’ list and assigns resources when job costing is automatically performed. In GIS MapViewer, a graphic representation of the status, cost, and other details of the work order can be seen.

The GIS MapViewer can be integrated into PubWorks (figure 11), allowing the user to customize maps to represent data. Through MapViewer, the user can look up work performed on assets, see service requests for an asset, recognize trends, analyze costs, locate any work that needs to be completed, and resolve issues over jurisdiction.

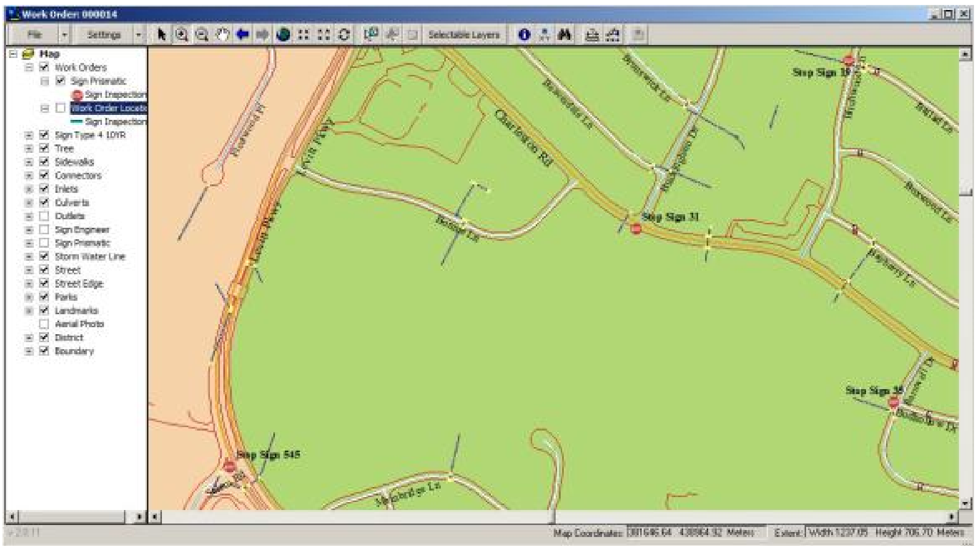


Figure 11. PubWorks example GIS MapViewer (Business Management Systems, Inc. 2010).

3.2.4 RoadCare

RoadCare is a pavement management system developed by Applied Research Associates Inc. (ARA) (Applied Research Associates 2011). It consists of client-side and web-based infrastructure management tools, including optimization of benefits and costs, optimization of remaining service life, asset management, GIS, image viewer tools, data warehousing, and data viewer tools. The software uses data to determine appropriate short- and long-term maintenance and repair needs for the road network. Other features of the software can determine:

- Future pavement deterioration rates.
- Current repair needs for network and the associated costs.
- Implications to pavement condition if maintenance is deferred and the associated costs.
- The effect on other projects when one project is selected.
- The impact on performance goals with each project.

To calculate pavement condition, data based on the type, severity, and extent of key pavement distresses are collected by the agency and uploaded to the RoadCare software. The software is also able to analyze pavement condition based on the overall pavement structural capacity and the International Roughness Index (IRI). The data from the condition survey is plotted versus the pavement age, and performance models are updated and revised each time additional data are collected. RoadCare also has Image Viewer software to allow a series of digital images to be uploaded, and a virtual drive of the network can be viewable from the office. The software has a web-based application and the database can be accessed via any internet-connected computer, eliminating the need to install the database software and large files onto agency computers.

RoadCare can provide a multi-year maintenance and rehabilitation plan based on the data collected, a treatment matrix that triggers the maintenance or rehabilitation strategy for each segment, and the available budget. To determine the appropriate plan, a simulation of candidate projects for each year are run, and projects with the highest benefit-to-cost ratio are identified. Figure 12 provides a sample maintenance strategy selection matrix that could be used within the software to define treatment selection.

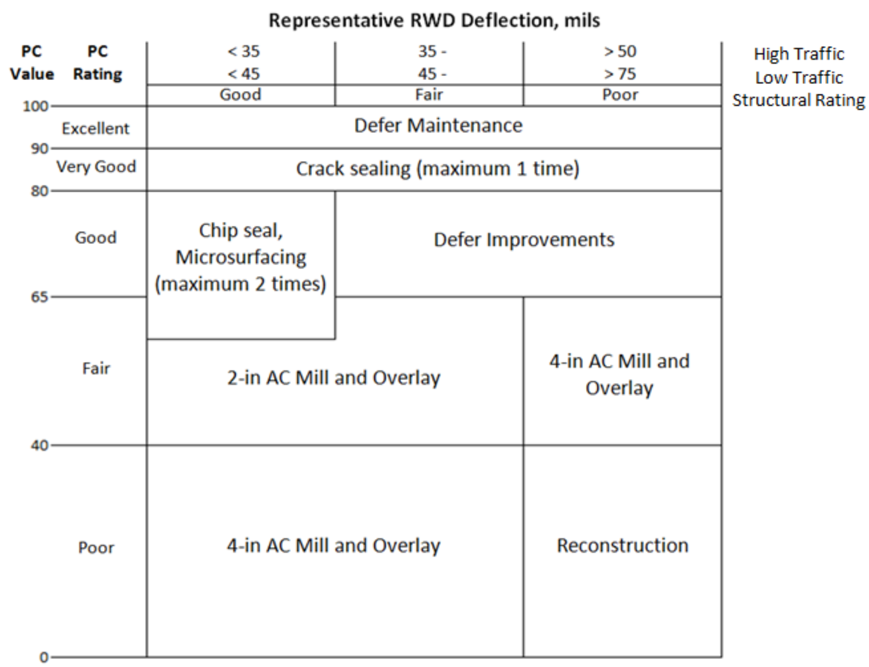


Figure 12. Maintenance strategy selection matrix – RoadCare (ARA 2011).

RoadCare can also generate “what if” scenarios using varying budget amounts and rehabilitation strategies. If the agency has a GIS program, all data used in RoadCare can also be formatted and uploaded with the GIS viewer (figure 13).

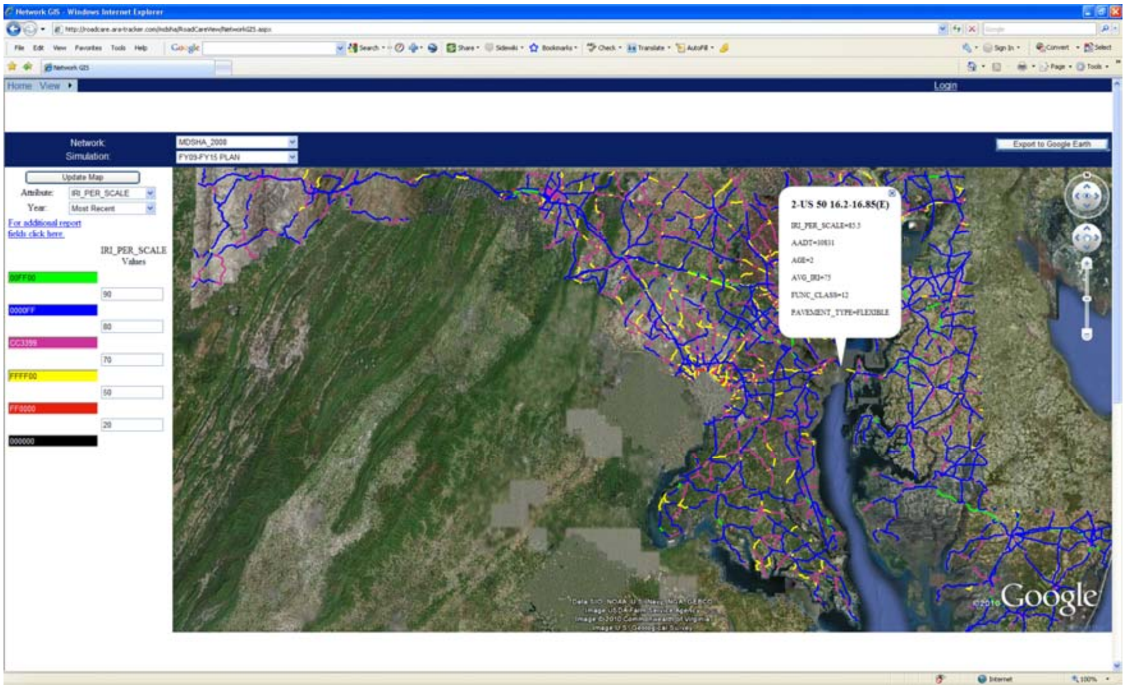


Figure 13. Sample GIS viewer with data input – RoadCare (ARA 2011).

3.3 SUMMARY OF PMS SOFTWARE PROGRAMS

Table 2 provides a comparison of the various features of the eight pavement management software programs highlighted in this synthesis. Since the features and products may change over time, the vendor website is provided as a reference for further details and contact information. Those interested in these products should contact the vendors to obtain any updated information and costs.

Table 2. Comparison of Pavement Management Software Features[1].

CRITERION DESCRIPTION	PAVEMENT MANAGEMENT SOFTWARE PROGRAMS							
	PUBLIC				PRIVATE			
	MicroPAVER	RoadSoft GIS	Utah LTAP TAMS	StreetSaver	RoadCare	PAVEMENTview Plus	PubWorks	PavePro Manager
Vendor	U.S. Army Corps of Engineers	Michigan Technological University - Center for Technology & Training	Utah Local Technical Assistance Program	Metropolitan Transportation Commission	Applied Research Associates	Cartegraph	Tracker Software Corporation	Infrastructure Management Services
Website	www.apwa.net	www.roadsoft.org	www.utahltap.org	www.mtcpms.org	www.ara.com	www.cartegraph.com	www.pubworks.com	www.ims-rst.com
Laptop Data Collection	Yes	Yes	Yes	Additional program needed	*	Yes	Yes	*
Ability to Analyze Other Assets	No	Yes, signs, pavement markings, traffic counts, & traffic crashes	Yes	Yes, sidewalks, lights, sign, curb and gutter, & user-defined	*	Yes, sewer, signal, sign, storm, bridge, & lights	Yes, bridges, signs, culverts, guardrails, parks, & buildings	*
Default Pavement Condition Rating Measure	PCI	PASER	RSL	PCI	PCI, IRI	OCI	PASER	*
Analyzes Different Maintenance Strategies	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Analyzes Different Budget Scenarios	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
GASB 34 Reporting	No	Yes	No	Yes	*	Yes	Yes	*
GIS Integration	Yes	Yes	Additional Software needed	Additional Software needed	Additional Software needed	Additional Module-GIS director or own software	Addition module MapViewer needed	Additional software needed
Customization Capabilities	Yes	Only certain aspects	Yes	Yes	*	*	Additional modules available	Additional modules available
Cost (2011)	APWA members $995; non-members $1095	Contact vendor for more information	Utah-free/Out of state $500	$1500+, contact vendor for more information	Varies, contact vendor	Varies, contact vendor	Varies, contact vendor	Varies, contact vendor
User's Manual	Yes	Yes	Yes	Yes	*	Yes	Yes	*
Technical Assistance	Training courses or four-part web-based training	Telephone or web-based training	Free Telephone or paid on-site arrangements	4-day training class twice per year and customized on-site training	*	On-site or web-based training; technical support by phone	Formal training at 1 day per module, free updates, software helpdesk	*

[1] PCI – Pavement Condition Index; PASER – Pavement Surface Evaluation and Rating System; RSL – Remaining Service Life; IRI – International Roughness Index; OCI – Overall Condition Index

(*) Denotes: Unable to obtain information at this time. Contact vendor for more information.

CHAPTER 4 U.S. LOCAL AGENCY PMS IMPLEMENTATIONS

In order to assist the local agencies in Illinois with identifying which type of PMS would best suit their needs, documentation on 24 sample local city or county agencies throughout the U.S. was obtained and reviewed. These agencies were identified by querying several research engines such as the Transportation Research Board, National Association of County Engineers, American Public Works Association, and through general internet queries. Also the researchers were looking to provide details on innovative approaches taken by agencies with respect to their PMS. Literature on several more agencies were identified than is documented in this synthesis; these were excluded due to the year published being more than ten years ago or because the information on the PMS characteristics was limited. The following sections provide details of the characteristics of the pavement management systems for the identified local agencies (listed in alphabetical order).

4.1 BOWLING GREEN, KENTUCKY

The City of Bowling Green, Kentucky is responsible for maintaining 470 lane-miles of roadways (Lashlee et al. 2004). The city contracted a consultant, Stantec, Inc., to implement its initial pavement management system and to conduct subsequent inspections and surveys on a routine basis. Pavement surface distress and roughness (ride condition) data are collected each year for half of the city's road network. To supplement this data, deflection and structural capacity data are collected on arterials and collectors once every three years using the Dynaflect, an electro-mechanical device. Automated vans record the longitudinal roughness and pavement surface distresses. The following 13 distresses are inventoried for asphalt pavements: patching, rippling and shoving, raveling and streaking, flushing and bleeding, distortion, excessive crown, edge cracking, alligator cracking, pot holes, map cracking, longitudinal cracking, transverse cracking, and rutting. On Portland cement concrete (PCC) pavements, the 13 distresses inventoried include: patching, scaling, raveling, polishing, distortion, C & D cracking, coarse aggregate loss, potholes, joint sealant loss, linear cracking, transverse cracking, joint spalling, and joint faulting.

The city uses the Pavement Management Application (PMA) software to store all data collected during the surveys. The PMA evaluates four different parameters: Surface Distress Index, Ride Comfort Index, Structural Adequacy Index, and Pavement Quality Index (PQI). Each road segment is classified under a certain functional classification and pavement type (i.e. asphalt or PCC). Each functional classification is given a minimum acceptable PQI score, and when the PQI falls below the minimum for a given road segment, it is considered in need for rehabilitation.

To determine which road segments are going to be rehabilitated, an economic analysis is performed. When the needs outweigh the current budget, an iterative life-cycle cost and benefit cost ratio analyses are performed. The most cost-effective techniques and projects are chosen, as well as those that have the most benefit to their location. In other words, those segments with a high value of cost effectiveness are prioritized over those with lower values.

When the first analysis was completed in 1998, the average PQI was 8.0 and gradually decreased to 7.4 by the year 2001. In 2002 and 2003, an increase in the PQI to 7.6 was observed. It was determined that if the PMS is consistently and correctly applied to the system, the PQI is expected to reach an average of 7.9 by 2013. This would result in only 32 miles of roadway (or 13.6 percent of the network) below the minimum acceptable PQI value. If no rehabilitation is performed on the network, it was estimated that the PQI would fall to 5.5 by 2013, which would mean that 67.3 percent of the network would be below the minimum PQI value.

It was observed that almost 68 percent of the network would need rehabilitation work by 2013. A ten-year rehabilitation program was developed to identify strategies that could be applied to each individual pavement section in each year of the program. To determine how the budget allocation for the rehabilitation program would affect the pavement system, the city performed a budget analysis for four different scenarios: do nothing, unlimited resources, $650,000 per year, and $1,000,000 per year, as shown in table 3.

Table 3. Budget Analysis Scenarios - City of Bowling Green, KY (Lashlee et al. 2004).

Year	Do Nothing	Need Driven	$650,000 Annually	$1,000,000 Annually
	Average PQI	Average PQI	Average PQI	Average PQI
2004	7.7	8.7	7.9	8.0
2005	7.4	8.6	7.9	8.3
2006	7.2	8.5	8.0	8.4
2007	6.9	8.4	8.1	8.3
2008	6.7	8.3	8.1	8.2
2009	6.4	8.2	8.1	8.1
2010	6.1	8.1	8.1	8.0
2011	5.9	8.1	8.0	8.0
2012	5.6	8.0	8.0	7.9
2013	5.3	8.0	7.9	7.9

The results shown in table 3 indicate that the city would be able to maintain a PQI of at least 7.9 using their current budget level of $650,000.

As a result of their efforts, the city is able to evaluate and quantify the condition of the road network in an objective and repeatable fashion and to estimate the rehabilitation requirements of pavements in the network over a specified programming period. They are also able to develop a ten-year pavement rehabilitation program for the street network for the current funding scenarios and to estimate the impact of the current funding scenarios on the condition of the street network.

4.2 CHITTENDEN COUNTY, VERMONT

In 2003, Sadek, Kzasnak and Segale described the preliminary experience of Chittenden County, Vermont in the development of a framework for an Integrated Infrastructure Management System, which included a PMS in addition to five other transportation system components (Sadek et al. 2003). The authors concluded that “a lot of additional work still needs to be done in order to achieve this goal” of establishing a systematic approach to transportation asset management. To do so, the authors indicated that more data are required and their recommended procedures need refinement (Sadek et al. 2003).

Chittenden County’s pavement management system utilizes MicroPAVER software and a PCI rating. They selected MicroPAVER for a variety of different reasons including its user-friendliness, data management and analysis capabilities, and capability to link to GIS (Sadek et al. 2003). The software’s GIS feature allows the county to integrate other models of their transportation system components. In addition, there was already a city in Chittenden County using MicroPAVER.

A condition index for the road network was calculated using a weighted average of the PCI values for all sections of roadway according to the length and number of lanes for that section. A condition budget curve was then generated from the MicroPAVER output which allowed various budget level scenarios and overall road condition levels to be analyzed. Specific pavement repair needs were identified.

In addition to the analyses in MicroPAVER, the county developed a regression equation to determine the relationship between budget level and improvement of the road network condition. The resulting model is shown below, where b is the budget level in units of 100,000 dollars:

$$C_{pav} = 73.35 + 1.848 * b + 1.845 * 10^{-4} * b^2$$

The starting condition used (i.e., the constant in the equation) is the overall network condition rating for the year under investigation prior to any maintenance, and C_{pav} is the estimated condition rating predicted for a given budget level.

Chittenden County experienced some problems when implementing their PMS. Different municipalities in the region were using different PMS software programs and, therefore, using different condition measures. It was recommended that the pavement management ratings be standardized throughout the county, allowing for easier data sharing and providing a more consistent method of allocating funds in Chittenden County, Vermont (Sadek et al. 2003).

4.3 DELHI TOWNSHIP, OHIO

Sotil and Kaloush conducted a research study to develop pavement performance models for Delhi Township, Ohio (Sotil and Kaloush, 2004). The township has had a successful, unique PMS in place since 1988 to maintain their 55 miles of roadway. Their PMS is based on PCI ratings determined from pavement condition data collected to quantify distresses by type and severity.

In Delhi Township's PMS database, pavements were grouped based on the following characteristics: pavement surface type (flexible, rigid, composite), Average Daily Traffic (ADT), road classification (arterial, collector, local), and service life to failure. To collect the data required to determine and prioritize proper maintenance strategies, the township performed riding surveys for 100 percent of the road network on a bi-annual basis. Once the PCI is calculated, the construction/maintenance strategies identified by the township are developed and prioritized.

The authors stated that "one constant challenge is the use of historical pavement condition data to predict future pavement deterioration. Pavement performance models developed from historical records may vary depending on the type of data that is being modeled" (Sotil and Kaloush, 2004). In order to refine the models used in the township's PMS, Master Curves (MCs) were developed using a sigmoidal shape function for a group of pavement sections with similar characteristics (a sample curve is shown in figure 14). MCs with a service life of 20 to 25 years were considered to be an optimum fit of the condition data.

The authors concluded that the MCs derived to predict pavement deterioration provided "good representation of the field performance" and "good prediction of the remaining pavement service life" for Delhi Township's pavement network.

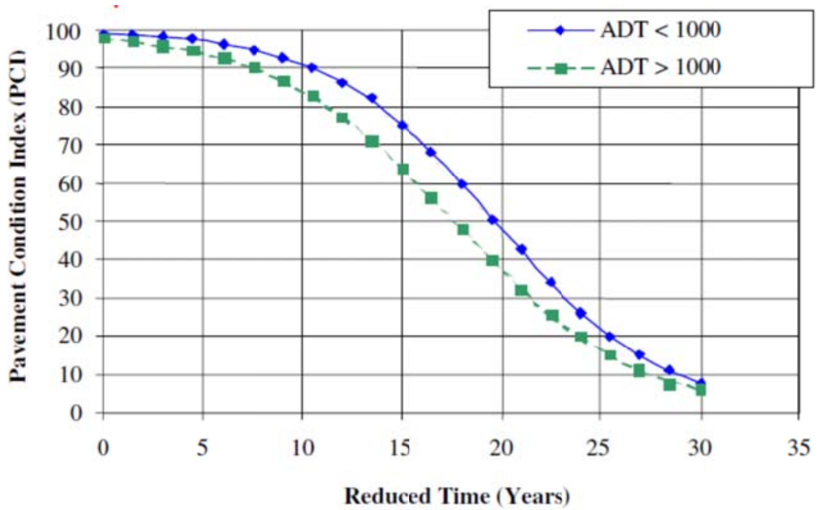


Figure 14. Sample Master Curve.

4.4 DUBLIN, OHIO

The City of Dublin, Ohio is responsible for maintaining 419 lane miles of roads, 268 miles of curb and gutter, 98 miles of sidewalk, and 29 miles of bike paths, which is inventoried on an annual basis (Kindra and Tennyson, 2001). While inspecting the condition of the roads, the city divides pavement distresses into three categories: surface defects, pavement distortion, and pavement cracking. Once the distresses are identified, they are further broken down into 16 elements that are rated from Level 1 to Level 5 for severity and density. The levels assigned to each element are then summed, and that total value is subtracted from 100. This condition rating is used to determine what type of corrective action is to be taken, and color-coded maps are generated based on the rating. Table 4 shows the rating range and the corrective action recommended at each stage, as used by the City of Dublin, Ohio.

Table 4. Corrective Action versus Rating Table - Dublin, Ohio (Kindra and Tennyson, 2001).

Rating	Corrective Action
95 – 100	No Action Needed
85 – 95	Crack fill & Small Patch
75 – 85	Grind 2" => Install 2.25" of 448
65 – 75	Grind 4" => Install 3 " of 301, 1.25" of 448
60 – 65	Grind 4" => Install 3" of 301, 1.25" of 448, Undercut 5
0 – 60	Grind 6" => Install 4" of 301, 2.25" of 448, Undercut 15

The City of Dublin also performs a structural analysis to determine the strategy for maintenance and rehabilitation projects. This structural analysis entails determining the serviceability of the road segment, the amount of traffic it carries, and the remaining life of the pavement. This information is then used to assign the segment a structural number.

4.5 FOLSOM, CALIFORNIA

With a reported population of 65,600 in 2004 and 237 miles of roadway, the City of Folsom, California has become increasingly concerned with their pavement management needs (City of Folsom 2005). They estimated that without a PMS and assuming the whole network was in need of replacement, the cost to replace their network would be $328 million. Therefore, the city implemented a PMS to routinely repair the network over time.

In 2004, an update of the city's inventory and road network condition was performed using PCI ratings. The average PCI for the city's network in 2004 was 85.06 ("good" condition), with individual values on pavement segments ranging from below 40 to100. Without their PMS by the 2009-2010 fiscal year, the PCI would have fallen to an estimated value of 57.71 which is considered "fair" condition but lies on the border of "poor" condition.

When the city began their pavement management initiatives in 1999, they used the MicroPAVER software to manage their inventory data. By 2004, the city changed their software to GBA Street Master, which is capable of storing all road inventory data and has the following additional features: GIS mapping interface, coordinates with other modules used by the city (e.g., sanitary sewer and water distribution systems), and automatically updates repairs.

The City of Folsom conducts pavement inspections (walking surveys) using in-house staff and developed their own data collection form to document all necessary data. Each year, city staff surveys all of the arterial roadways and one-fifth of the secondary roadways. Therefore, the entire roadway network is re-surveyed once every five years. Riding comfort and drainage are recorded and rated on a scale from 0 to 10, as well as the extent and severity of 11 different road distress conditions on a scale from 0 to 3. Some of the road distress conditions surveyed include surface defects, surface deformations, and cracking. The distress values are then entered into the Street Master software where the PCI rating is computed.

Using the pavement condition rating, the Street Master software generates lists of all recommended repair needs and their costs. The recommended maintenance strategies based on PCI ranges used by the City of Folsom are as follows:

Rating	Strategy
100-85:	No maintenance
84-75:	Seal coat
74-55:	Overlay
54-0:	Reconstruct

The Street Master software prioritizes segments based on the PCI values and maintenance strategies. Segments requiring critical overlay have highest priority, followed in order by critical seal coat, reconstruction, overlay, and seal coat. Other factors considered when prioritizing projects include efficiencies of scale, available funding, targeted funding, community priorities, type of roadway, PCI thresholds by type of roadway, equity between types of maintenance activity, minimum frequency for preventative maintenance, professional judgment, coordination with utility maintenance activities, and coordination with new development activities.

4.6 GENESSEE COUNTY, MICHIGAN

Genesee County, Michigan has jurisdiction of 1,938 lane miles of road (Genesee County 2008). To help manage their pavement network, the county utilizes the PASER system and RoadSoft software program to evaluate and analyze the collected data. The county updates the PASER ratings every year. In 2007, 58 percent of their network was in "good" condition (rating of 5 or better).

In RoadSoft, once ratings are determined for all segments within the road network, maintenance strategies are recommended for various ranges of PASER values. Examples are illustrated as follows:

- If a segment is rated between PASER values of 8 and 10, the system requires routine maintenance. Routine maintenance is day-to-day scheduled activities such as street sweeping, cleaning drains, or crack sealing.

- If rated between 5 and 7, capital preventive maintenance is required, which will help slow down the deterioration of the segment. Examples of capital preventive maintenance are partial depth joint repairs and seal coating.
- If rated between 1 and 4, rehabilitation or reconstruction of the segment is required since the structural integrity of the segment has failed.

After the county analyzed its budget scenario of approximately $7.4 million in 2007, they concluded that there was not enough funding for capital repairs and total reconstruction. In order for the average network Remaining Service Life (RSL) to increase, the county needs to have a capital preventive maintenance program. Due to the limited funds, the county is micro-resurfacing, overlaying, and crack sealing to maintain its roads in good condition.

To stretch their investment, the county updates their pavement management program regularly, collects and updates the pavement condition data annually, considers rehabilitation strategies, determines additional funding sources, redistributes funds, creates new funding sources, and maintains flexibility when using funds.

4.7 HILLSBOROUGH COUNTY, FLORIDA

Hillsborough County, Florida recently implemented a comprehensive asset management program for its roadway and storm water infrastructure (Federal Highway Administration 2005). In contrast to their previous system, which dealt with corrective maintenance strategies instead of preventive maintenance strategies, the new system includes forecasting elements necessary to perform multi-year budgeting of maintenance, operations, and capital replacement of assets as needed. The county first conducted inventories of its assets, which includes 6,200 lane miles of paved roads, 4.2 million feet of storm pipe, and 14,000 intersections. The assets were given a rating of “good”, “fair” or “poor” and were incorporated into a management information system, known as the Hillsborough County Asset Management System (HAMS). HAMS includes roadway and storm water modules linked to GIS.

Hillsborough County uses HAMS in conjunction with economic analysis tools to anticipate and prioritize maintenance and replacement needs. The county plans to continue incorporating more economic analysis tools and management systems into the HAMS framework, such as the county's crash-reporting database.

The county’s use of their asset management system is already yielding substantial benefits to the Public Works Department and the residents of Hillsborough County. These benefits include improved financial efficiency and improved communication with the citizens. Even though data collection and implementation of the system has cost more than $3 million, the county expects that the improved proactive capital, repair, rehabilitation, and replacement planning will lead to greater savings and efficiency in annual costs. The system has also helped the county better respond to the public’s questions regarding planned improvements for traffic signals, pavements, sidewalks, drainage maintenance, traffic signs and pavement markings.

4.8 IOWA COUNTIES

The Iowa Pavement Management Program (IPMP), a statewide PMS, was developed and implemented in Iowa by researchers from Iowa State University’s Center for Transportation Research and Education (Smadi et al. n.d.). The IPMP covers 23,500 miles of roads maintained under three levels of government (state, county, and city). Their implemented pavement management process has the following elements:

- Database of data elements needed to conduct pavement management analysis.
- Collection of pavement condition data to populate the databases.

- Decision support tools to conduct pavement management at each level of government.
- Delivery of data to the respective jurisdictions.

The IPMP maintains road inventory data, pavement history data, and pavement distress data for all levels of government and distributes the data to the individual jurisdictions. The road inventory data is provided by the Iowa Department of Transportation (DOT), the pavement history data is provided by the individual agencies, and the pavement distress data is collected centrally through the use of an automated data collection van (the ARAN van from *Roadware Corporation)*.

The IPMP consists of four main components: road inventory, roadway cartography, pavement history, and pavement condition. Details are as follows:

- The road inventory component includes information such as pavement length, pavement width, average annual daily traffic, street name, surface type, shoulder rating, surface rating, drainage rating, jurisdiction, traffic year, traffic profile, speed limit, and number of rehabilitations.
- The roadway cartography component is a one-to-one graphic relationship between a roadway cartographic element provided by Iowa DOT and the records in the base record inventory system. This provides access to inventory records corresponding to certain graphic representations of a roadway.
- The pavement history component includes surface type, pavement thickness, and construction/rehabilitation cost.
- The pavement condition component contains information on cracking, potholes, patches, rutting, and ride quality. The automated van takes video images of the roadway which are digitized and processed to identify, quantify, and classify the pavement distresses.

Road agencies in Iowa have varying software and hardware resources, which the IPMP must consider when delivering data to individual jurisdictions. The agencies are expected to use the data for their own pavement management activities. The IPMP distributes the pavement distress data to jurisdictions in paper format and electronically in spreadsheet format. Some agencies may also receive the pavement distress data in a GIS-compatible format or may receive access to the IPMP database, since one approach will not accommodate all users.

4.9 JACKSON COUNTY, MISSOURI

Jackson County, Missouri contains 500 miles of roadway, including highways, suburban roads, and rural roads. Before the county implemented a PMS, they only selected road segments in poor condition for improvement. This practice was not cost effective and the poorly maintained roads were a safety hazard to motorists; the county was receiving many complaints from the public about the roadway conditions. They determined that they needed a PMS that would be comprehensive, since Jackson County contained both low and high volume roads and would have planning capabilities to prioritize maintenance activities, allocate resources, and determine the best maintenance plan.

In 1991, Jackson County developed a system to track and manage the condition of the county's roadways (Accela, Inc. undated). The information stored in this system included inventory data, condition data, and construction data. Specific elements contained in the databases included pavement type, location, length and width, deterioration rates, type and date of maintenance treatments, and preventive maintenance schedule. The new system allowed the county to assess the conditions of the road based on physical distresses, roughness data, friction data, and structural capacity. With this information, a PCI was calculated to allow the county to assess the condition of the roads. The PCI is automatically updated when roadway maintenance work is performed. They also implemented a performance modeling application to help them develop short- and long-term preventive maintenance plans for up to ten years. The application forecasts the current and future condition of assets based on a variety of data. This data is then used to develop multi-year preventive, rehabilitation, and maintenance programs, coordinate maintenance activities, forecast benefits and effectiveness of different treatments, and maximize a limited budget by using optimization and prioritization models.

The Jackson County PMS has proven to be very effective. The county saves more than $1 million each year since the roads are improved prior to complete pavement failure. From 1994 to 2004, the county experienced an increase of 14 percent in roads that were in good to excellent condition. In 2004, less than five percent of their roadways were classified as poor or failing. From 1995 to 2004, the county also experienced reductions in traffic crashes of over 50 percent, from 613 to 277 crashes, some of which may be attributable to the improved pavement conditions.

4.10 KANSAS CITY, MISSOURI

The City of Kansas City, Missouri maintains 2,200 centerline miles of road and had a population of 451,572 in July 2008 (Martin and Rokos 2008). The city began developing their PMS in the 1990s using Windows-based software, and by 2007 the system had developed into an advanced GIS-based system as an extension to the ArcView software. The city made major modifications to their PMS, including the addition of walking condition surveys by in-house technicians on one-third of the streets each year, and providing an updated rating every three years for all road segments. In the past, the city selected priority segments based on the time since the last treatment. Now, PCI values are used to rate each segment, which, among other benefits, helps the city explain their pavement prioritization to the public. The software is also able to select priority segments based on current condition, estimated traffic, and the benefit of each project. Analyses are also performed to assist in estimating future funding levels for the program.

The goal set forth by the city was to establish a PMS that identifies a proper road program funding level and provides the highest quality network at that level. The city has accomplished this by properly planning their road program, selecting candidate road segments for rehabilitation and maintenance, designing the pavement structure for those being rehabilitated, conducting quality assurance testing during the construction, and managing utility cuts through a permit inspection process.

4.11 LOS ANGELES, CALIFORNIA

The City of Los Angeles, California, one of the largest municipalities and most congested road networks, is responsible for approximately 7,200 centerline miles of roadways, 800 of which are alleys (Sauceda 2008). As an added challenge to the size of the city's network, Los Angeles has one of the oldest street networks in the country and nearly half of the network was built before World War II.

In 1998, the city began to implement a PMS using the MicroPAVER software and the PCI rating system. To obtain the average PCI over the entire network, the city follows a five step methodology:

1. Complete a comprehensive inventory of the road network, divided into various components such as branches, segments and units to facilitate the data collection efforts.
2. Manually route the network so that survey teams will be able to survey the pavement in the most efficient way possible.
3. Perform the condition survey using two automated vans to collect the distress data.

4. Process the information using customized software at a workstation and, using the data collected by the vans, identify and evaluate the distresses for type, quantity, and severity.
5. Perform the final analysis on the network in MicroPAVER. Life-cycle curves are developed and a critical PCI is found. Once all analysis is complete, the software recommends optimum maintenance and rehabilitation strategies, determines budget needs, and projects future road conditions based on various budget scenarios.

Since it is not possible to fund all the preventive maintenance projects required to maintain the current average PCI, the city incorporated other economical approaches in their PMS. They use municipal asphalt plants that produce 600,000 tons of hot mix per year that contain 20 to 25 percent Reclaimed Asphalt Pavement (RAP). There are studies and efforts being made in Los Angeles to raise the RAP value to 50 percent.

Another approach used by the city to reduce costs involves the use of Cold-In-Place Recycling (CIPR) technology. Some of the advantages of CIPR are less use of virgin aggregate, reduced construction time, reduced truck traffic in neighborhoods, increased environmental benefits, and reduced traffic congestion. CIPR saves the city enough money each year to pave an additional 10 miles of asphalt overlay.

In addition to the economical savings, the City of Los Angeles has incorporated sustainable practices into their PMS. For example, rather than using a conventional slurry seal, they use a pre-mixed, rubberized slurry seal is used which not only improves the quality and productivity of the slurry, but also reduces environmental impacts. Some of the environmental benefits include: 26,000 recycled tires for every 100 miles of streets that are slurry sealed, conserved landfill capacity, reduced dust and noise pollution, and elimination of bad odors during on-site mixing.

4.12 MARION COUNTY, FLORIDA

In 2002, Marion County, Florida began implementing a centralized asset management program for its roadway and storm water infrastructure systems (Amadoria and Wheeler, 2004). The asset management program was designed to facilitate a phased-implementation approach capable of expansion to include assets maintained by other county divisions. The road division maintains approximately 2,300 miles of paved road and 500 miles of unpaved road. A consultant was hired to capture satellite images of the roadways and then determine ways to integrate the satellite and aerial imaging into GIS. ESRI's ArcPad software was used to make the necessary mobile maps with full GIS capabilities for field use. The asset databases are comprised of data collected in the field and extracted from digital images. These databases allow the county to comprehensively track assets and costs associated with maintaining those assets. Short-term goals of the system include implementation of a comprehensive asset management system and PMS for facilities maintained by the County Road Division.

Detailed models were created by the county to estimate the performance and useful life of a pavement segment. Pavement analysis models were also developed to predict maintenance costs for the county-maintained road network at a specific service level. These models create scenarios that dictate when and where money will be spent to effectively manage the road network at a specific condition level. The county realized significant cost savings through the PMS. Additionally, Marion County's staff saved effort and time by collecting infrastructure asset data using ArcPad software-based personal digital assistants (PDAs) outfitted with GPS units.

4.13 MERCED COUNTY, CALIFORNIA

Merced County and its jurisdictions use a pavement management system to help maintain their 2,326 mile road network at an acceptable rating (Merced County Association of Governments 2009).

The county and townships use their own staff to survey the road network because they already have substantial knowledge about the condition of the network. The staff performs windshield surveys to update the pavement condition data that was initially collected by a consultant in 1998 and 1999.

The county selected the distress types that would be inventoried through their surveys by researching the variables included in pavement management programs, such as the Metropolitan Transportation Commission’s StreetSaver. They also researched MTC’s online asphalt condition and distress identification guidebook to help standardize all the inputs for their condition surveys. Table 5 summarizes the distresses and severities surveyed based on the findings from the MTC guidebook and the StreetSaver software.

Table 5. Pavement Distresses used in “Windshield Inspections” Surveys (Merced County Association of Governments, 2009).

Pavement Condition	Severity	Extent
Weather (drying)	Low, Moderate, Severe	Low (25-50%) Medium (50-75%) High (75-100%)
Linear Cracking (longitudinal/transverse)		
Block Cracking (paneling)		
Alligator Cracking (scaling)		
Rutting		
Ride	Good, Fair, Poor	Low, Medium, High
Drainage		

Depending on available resources, the jurisdictions and county use two different types of rating systems, including (Table 6):

- Overall Condition Index, which is a rating between 0 and 100 with 100 representing perfect condition.
- Qualitative condition, such as good, fair, poor.

Table 6. Overall Condition Indices Rating System Merced County, CA (Merced County Association of Governments 2009).

Overall Condition Index	Qualitative Condition	Description
85-100	Very Good	Good surface
75-85	Good	Minor-moderate cracking
40-75	Fair	Moderate-severe cracking
20-40	Poor	Severe cracking
0-20	Very Poor	Extreme structural damage; Failed

When determining what type of maintenance to perform, the county determined that preventive maintenance is most important. Figure 15 shows how many miles various preventive treatments will cover for the same money as one mile of reconstruction.

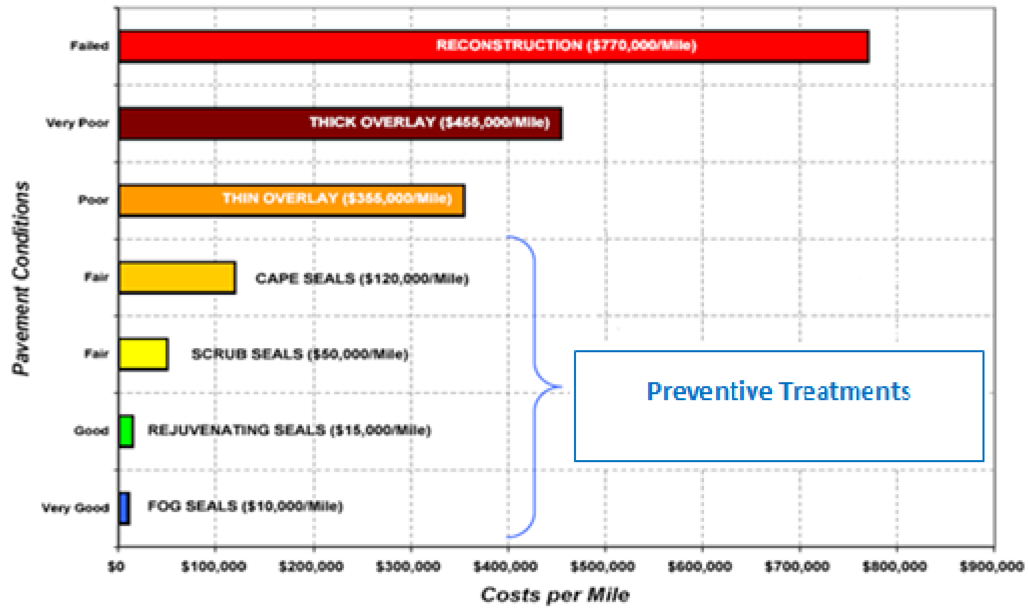


Figure 15. Cost comparison of pavement maintenance strategies, Merced County (Merced County Association of Governments 2009).

After the 2009 condition survey, the condition ratings and financial revenue and needs for the network in all jurisdictions were recorded (table 7).

Table 7. 2009 Pavement Condition and Needs by Jurisdiction Merced County (Merced County Association of Governments 2009).

Jurisdiction	Pavement Conditon		Annual Revenue	Preventive Maintenance Need	Rehab./ Reconstruct. Need	Total Need
	Rating	% of Network				
Atwater	Fair to Better	78%	$1.1 M	$2.5 M	$12.8 M	$15.3 M
	Poor and Worse	22%				
Dos Palos	Fair to Better	41%	$0.2 M	$0.7 M	$9.1 M	$9.8 M
	Poor and Worse	59%				
Gustine	Fair to Better	54%	$0.2 M	$0.2 M	$7.0 M	$7.2
	Poor and Worse	46%				
Livingston	Fair to Better	86%	$0.6 M	$1.1 M	$4.7 M	$5.8 M
	Poor and Worse	14%				
Los Banos	Fair to Better	78%	$1.3 M	$3.1 M	$17.7 M	$20.8 M
	Poor and Worse	22%				
Merced	Fair to Better	77%	$2,8 M	$ 4.0 M	$23.3 M	$27.3 M
	Poor and Worse	23%				
County of Merced	Fair to Better	75%	$7.7 M	$10.9 M	$89.0 M	$99.9 M
	Poor and Worse	25%				

Since the total financial need for total restoration of the network is multiple times higher than the revenue, each jurisdiction and Merced County must evaluate different budget scenarios to determine the best option. The cities and county are also prioritizing more preventive maintenance projects before rehabilitation and reconstruction projects since more miles of roadway can be maintained for less.

4.14 MODESTO, CALIFORNIA

The City of Modesto, California uses a PMS developed by the Metropolitan Transportation Commission (City of Modesto 2011). The city began using this system in 1989 and surveys approximately 1,130 miles of roads every two years for collectors and arterials, and every four to six years for residential roads, as the budget allows. A PCI value is assigned to each road segment, and then a PCI is determined for the entire network. The maintenance strategies currently in use in Modesto include potholes/minor patching, crack sealing, slurry seal, and cape seal. The rehabilitation strategies used in Modesto include overlay, in-place cold recycling, and reconstruction.

The City of Modesto used its PMS to determine the future PCI for the road network with different budget levels, and they discovered that a minimum of $14 million of funding would be needed for maintenance and rehabilitation strategies to improve the condition of their network in the future. Otherwise, the condition of the road network would continue to decline. This value of $14 million is approximately four times the amount of funding the city currently receives, which is $3.5 million annually.

4.15 PHILADELPHIA, PENNSYLVANIA

The City of Philadelphia maintains over 2,000 miles of road (Wolters et.al. 2002). Not only is the city working to establish a PMS that will help prioritize maintenance activities, but it will also help coordinate utility cuts into their maintenance schedule.

In 2001, a pilot PMS was developed. The city was divided into 44,000 road section segments approximately 500 feet in length, and intersections. Intersection locations were considered as separate entities so that they could be excluded if necessary. Each road segment was assigned a unique identifier for easy access in a GIS TIGER centerline file. The roads were segmented into smaller units to account for the complicated maintenance history of the roadway network. The GIS software helped to consolidate the network by providing a color-coded representation of the maintenance history and current conditions of the roadway network.

With a consultant's assistance, the city developed its own condition survey procedure, which was less complex than performing detailed walking surveys for PCI ratings, but more extensive than a simple windshield survey. Field data collection forms were created for each type of pavement and facilitated the data to be entered efficiently into the PMS software. The software then was able to provide a spreadsheet summary of all segments and their corresponding condition rating. The severity and the extent of each distress were estimated either from a vehicle or the sidewalk. The rater estimated the severity of each type of distress for a given pavement type as low, medium, or high, and then approximated the percent area affected of the total segment area (based on a 100 percent sample rate).

Seven distresses were rated for flexible pavements, including patching/potholes or utility cuts, alligator cracking, transverse distortions, longitudinal/transverse cracking, block cracking, weathering/raveling, and rutting depressions. Six rigid pavement distresses were surveyed, including joint spalling, faulting, divided slabs of four or more, corner break, longitudinal/transverse cracking, and patching/potholes or utility cuts. Since the city is comprised of approximately 280 blocks of historic streets, some are comprised of brick, granite block, cobblestone, or other materials. The distresses on these streets were based on a ‘good, fair, and poor’ scale and then evaluated using an overall index. The types of distresses surveyed for streets composed of alternative materials included corrugations, potholes, rutting, improper cross-section, roadside drainage, and loose aggregate.

The list of pavement preservation activities were directly developed by the District Engineers based on pavement needs for a three-year program. The maintenance lists were then sent to the Construction Engineer who established a priority list of maintenance needs for the city roads. Political concerns, utility plans, and geographic location were also taken into consideration when developing the prioritized final three-year program.

The City of Philadelphia implemented a PMS to provide the best possible pavement conditions on their road network. Additionally, to decrease budgets, the city begun using hot-in-place recycling, Novachip, and micro-resurfacing as part of their preservation program.

4.16 PIERCE COUNTY, WASHINGTON

Pierce County’s Road Operations Division in Washington is responsible for 3,054 lane miles of roadway. The road network is valued at over $4.5 billion and the Division spends over $15 million annually on maintenance, construction, preservation strategies, and improvements on the road network (Pierce County 2005). On preventive maintenance alone, more than $3.5 million is typically spent in a given year. To maintain the county’s road network, the Road Operations Division developed a PMS to determine maintenance and rehabilitation requirements, project priorities, and long-term planning strategies.

Every year, the county surveys one-half of the paved roadways in their network, which is approximately 700 to 800 centerline miles. The procedures and processes followed by the county are a modified version of the methodologies adopted by the Washington State Department of Transportation and as described in the Northwest Pavement Management Association’s *Pavement Surface Condition Rating Manual*. To collect distress data, walking surveys of each segment were conducted and the distresses observed were recorded by severity (low, medium or high). Some examples of distresses surveyed include rutting, alligator cracking, and longitudinal cracking.

After all field surveys were completed, a score from 0 (poor) to 100 (good) was assigned to each segment. The resulting scores were used to plan needs and assign priorities, as well as track the effectiveness of maintenance techniques and processes from previous years. Cost estimates of future maintenance and repair strategies needed to maintain an acceptable level of service were also determined.

The county used the concept of lowest life-cycle cost to determine rehabilitation needs. If a roadway is maintained on too short of a rehabilitation schedule, more money will be spent since repair work is being done too frequently. However, even more money will be spent if the rehabilitation schedule is too long since major repairs would then be needed. The optimal condition is met when the rehabilitation schedule costs the least but has the longest schedule possible. The average road network value using the lowest life-cycle cost is between 75 and 80. According to Pierce County’s rating distribution summary, a well-maintained system has, on average, approximately five percent of roads in poor condition, 25 percent in fair condition and 70 percent in good condition. The county’s Road System Condition Grades chart is depicted in figure 16.

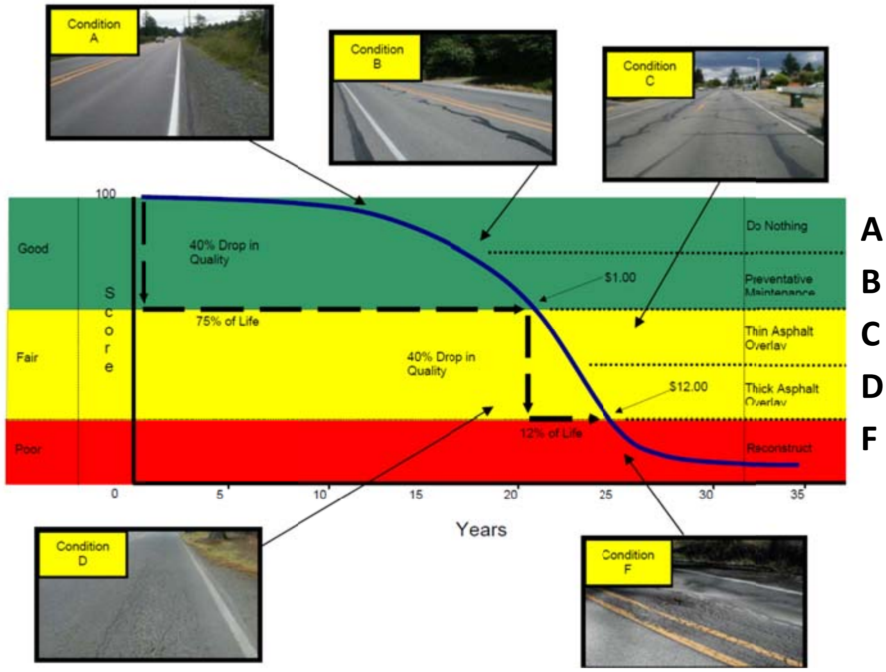


Figure 16. Road system condition grades, Pierce County, WA (Pierce County 2005).

By comparing the cost per lane mile for repair with the rehabilitation schedule for the actual lane miles of road in need of repair, the county was able to determine the lowest life cycle (LLC). Table 8 shows the resulting expected “Urban Life Cycle” and “Rural Life Cycle”, once rehabilitation is warranted for each functional classification of roadway.

Table 8. Expected Life Cycles (Pierce County 2005).

Urban Life Cycle (LLC)			Rural Life Cycle (LLC)		
Major Arterial LLC=18	Arterial Minor/Collector LLC=20 years	Local Access LLC=12 years	Rural Major Arterial LLC=18	Rural Arterial Minor/Collector LLC=20 years	Rural Local Access LLC=12 years
Year One- Asphalt Overlay	Year One – Asphalt Overlay	Year One – Chip seal/ Slurry Seal	Year One – Asphalt Overlay	Year One – Chip seal	Year One – Chip seal
Year Twelve – Chip seal	Year Fourteen – Chip seal	Year Six – Slurry seal	Year Fourteen- Chip seal	Year Six – Chip seal (New Cycle)	Year Eight- Chip seal (New Cycle)
Year Eighteen- Asphalt Overlay (New Cycle)	Year Twenty – Asphalt Overlay (New Cycle)	Year Twelve – Chip seal (New Cycle)	Year Twenty- Asphalt Overlay (New Cycle)	N/A	N/A
608 Lane Miles	337 Lane Miles	1187 Lane Miles	123 Lane Miles	377 Lane Miles	460 Lane Miles

Table 9 summarizes the county’s bi-annual preservation expenditures for road surface maintenance based on the LLC method. The costs shown are for resurfacing only and do not include any restorative or other maintenance costs.

Table 9. Bi-Annual Preservation Expenditures based on Lowest Life Cycle Model (Pierce County 2005).

Bi – Annual Preservation Plan		
Surface Treatment	Lane Miles / Year	Average Cost / Year
Contract Overlay	28	$1.6 million
Chip Seal Resurfacing	250	$1.625 million
Residential Slurry Seal	40	$0.255 million
Total	318	$3.48 million

By investing approximately 23 percent of their total $15 million budget on preventive maintenance, Pierce County staff believes that it will prolong the pavement service life, thus making their roads last longer.

4.17 SACRAMENTO COUNTY, CALIFORNIA

Sacramento County, California inspects its roadways either annually or once every three years, depending on the type of roadway (County of Sacramento 2011). After the inspections are completed, the pavement deficiencies, including cracks, patches, and utility trench cuts, are categorized and quantified. These deficiencies are entered into the computerized pavement management software and the PCI is calculated, with the values ranging from 0 (very poor) to 100 (excellent). Pavement conditions are classified as poor, marginal, fair, and good. The county's goal is to have 80 percent of all roads in each precinct classified as fair to good. Roadways receive periodic surface treatments that may include asphalt overlays, slurry seals, and chip seals. The type of surface treatment is based on the PCI value, the type of roadway, the amount and type of traffic, and other engineering factors. To help decide which roads are a priority, roads in residential areas are grouped into neighborhoods and then assigned an average PCI. Depending on available funding, residential roads in the neighborhood with the lowest PCI value will be treated first.

4.18 SEAL BEACH, CALIFORNIA

To help maintain the road network in the most economical way, the City of Seal Beach, California uses a PMS developed by in-house staff (City of Seal Beach 2002). Their pavement management database includes length, width, structural layers, age, and functional classification of each road segment, as well as the condition, cost, and maintenance history of each road segment. The city retained a consultant to conduct the pavement inspection surveys for the road network. Even though a PCI rating was used, the condition of the roads were rated based on visual inspections and sound engineering judgment, as opposed to measuring individual cracks and other distresses. The ratings, pavement condition descriptions and maintenance strategies used by the city are depicted in table 10.

Table 10. Pavement Conditions and Maintenance Strategies (City of Seal Beach 2002).

PCI Rating	Description of Pavement Condition	Maintenance Strategies
Very Good – Excellent (86 – 100)	The pavement is new or almost new and will not require improvement for some time, but may require localized minor repairs. The pavement is structurally sound and has very little or no roughness.	Seal every seven – ten years
Good – Above Average (75 – 85)	The pavement is in decent shape but has some surface defects indicating the need for routine maintenance. The pavement is generally structurally sound and has only minor roughness.	Seal every seven – ten years
Average (60 – 74)	The pavement has a fair number of defects such as cracking, material loss, depressions, etc. indicating the need for maintenance or repair. The pavement is beginning to become structurally deficient and may have noticeable roughness.	Slurry Seal or Rubber Chip Seal with Slurry Seal or 0.1' Asphalt Overlay. These may vary dependent upon the recommendation of the design engineer.
Below Average – Poor (41 – 59)	The pavement has significant defects such as major cracking, significant surface distortions and material loss indicating a need for rehabilitation (i.e. structural improvement). The pavement is structurally deficient and has noticeable roughness.	1" – 2.5" Asphalt or Rubberized Asphalt Overlay with Rubber Chip Seal. These may vary dependent upon the recommendation of the design engineer.
Very Poor (0 – 40)	The pavement has major defects indicating the need for major rehabilitation or reconstruction. The pavement is structurally unsound and very rough.	Full Street Reconstruction (4" Asphalt over 6-8" of Base) or 2"-2.5" Rubberized Asphalt Overlay with Rubber Chip Seal. These may vary dependent upon the recommendation of the design engineer.

Once the entire inspection is received from the consultant, the data is input into the city's computerized database. The segments are assigned a "priority score" based not only on the condition, but also on the functional classification, truck traffic, and matching funds. Weighting factors are used to calculate an overall composite "priority score" as follows:

Priority Score = 0.7(PCI Value) + 0.15(Functional Class Score) + 0.15(Truck Use Score) + Matching Fund Score

The City of Seal Beach focuses on the use of preventive maintenance strategies and provides the following rationale explaining why the strategies are more economical options (City of Seal Beach 2002):

- Reconstruction or resurfacing a road is far more expensive than seal coats and crack seal.
- By increasing the life expectancy of the pavement, the high cost of reconstruction and resurfacing is spread over a longer timeframe.
- By maintaining the streets at a 'good to fair' service level, non-scheduled maintenance and user costs are reduced to a minimal level.
- Seal coats are required on a regular basis, but their cost is offset by deferring reconstruction and resurfacing costs.

An economic analysis performed for the city's road network indicated that it would cost approximately $8 to $10 million to bring all the streets up to a "good" or "very good" condition, with an equivalent uniform annual cost of $460,000. If the city did not perform preventive maintenance and only reconstructed its roads, the equivalent uniform annual cost would be $1,177,000. Thus, the city would save over $700,000 per year by treating their roads routinely with preventive maintenance strategies.

The city also emphasizes the importance of material selection for use in roadway construction, maintenance, and rehabilitation since material type significantly impacts pavement life-cycle costs. The use of concrete and asphalt polymers, rubberized asphalt, and geotextile fabrics has been found to extend the life of a pavement as compared to conventional materials. The city has used both rubberized asphalt and geotextiles to reduce their road network costs.

As they continue to refine their pavement management program, the city intends to investigate more complex modeling programs that will evaluate the effect of various funding allocations. In order to accomplish this, they may hire a consulting firm which would cost $30,000 to $50,000. The city would recommend this option once larger revenue sources are acquired.

4.19 SONOMA COUNTY, CALIFORNIA

Sonoma County's Public Works Department is responsible for maintaining 1,387 miles of the county's 1,857 miles of roadway. Engineers manually collect condition data and record it on forms supplied by the StreetSaver PMS software program developed by the Metropolitan Transportation Commission (Saunders 2005). All pavement condition data collected in the field are entered, and the software is then able to perform budget analyses to establish maintenance needs. Since the PMS program output is limited to tabular datasets and reports, the county linked it with a GIS program, ArcGIS, to generate maps that show detailed pavement condition and maintenance information. The street maps are interactive, which allows engineers to show managers and funding agencies their street maintenance responsibility. With StreetSaver and ArcGIS linked, changes made to the GIS will automatically change in the PMS software. The county also developed an internal website so that county managers could immediately see the latest pavement distress maps and budget scenarios. This application allows planning, public works, and finance personnel access to StreetSaver's tabular data and GIS maps. The program is easy to understand, thus management personnel do not have any problems understanding where the pavements in poor condition are located.

4.20 SOUTHEAST MICHIGAN REGION

The Southeast Michigan Council of Governments (SEMCOG) helped the Southeast Michigan region recognize and further develop a regional PMS (SEMCOG 2003). The region consists of the Michigan Department of Transportation (MDOT), seven counties, and 21 local communities, all of which were using some form of an individualized PMS that was not standardized throughout the region. These systems cover 12,450 miles of roadway, which is 46 percent of the network. The goal of SEMCOG was to develop standards for collecting pavement data, develop a systematic approach to pavement rating systems, encourage interaction among road agencies, forecast future pavement needs more accurately, and more effectively address needs with limited resources.

SEMCOG created a survey that was distributed to road agencies throughout Southeastern Michigan to help determine what types of initiatives were being taken with PMS. SEMCOG contacted agencies that responded to having implemented a PMS prior to 1996 and that had populations over 50,000.

To help the region coordinate its PMS and develop a regional PMS, SEMCOG compiled pavement condition information to develop a list of deficient pavements in the region. This list helped agencies select projects to submit to SEMCOG for evaluation of regional benefits. To improve the consistency of a regional PMS, SEMCOG had several recommendations: 1) create a PMS coordinating committee with representatives from SEMCOG, MDOT, the counties, and local communities; 2) develop statewide and regional PMS priorities; 3) establish consistent data collection procedures and a standardized rating system; 4) document all benefits of a regional PMS; 5) identify alternate sources of funding for developing and maintaining a PMS; and 6) institute a PMS user's group that will provide insight to those with new PMS.

4.21 TINLEY PARK, ILLINOIS

The Village of Tinley Park, Illinois, home to more than 59,000 residents is responsible for the management of 240 miles of roadway. With the assistance of GIS, the village has used a PMS since the late 1990's (Better Roads 2006). The village's PMS analyzes and prioritizes the network based on four different work categories depending on available budget: preventive maintenance, rehabilitation, renovation, and reconstruction. In order to keep the inventory current, pavement condition data is surveyed once every four years. To determine which road segments are in need of attention, deterioration curves derived from the road network's past history are used, along with OCI ratings. The village's goal is to maintain an OCI value of 90 for the entire road network, which enables them to spread the budget over more miles of roads. Table 11 shows the savings the village has realized by retaining an OCI rating of 90 versus a rating of 80 or 85.

Table 11. Tinley Park, Illinois Savings with OCI rating of 90 (Better Roads 2006).

Overall Condition Index	**90**	**85**	**80**
Average Cost per Foot to resurface	$25	$30	$50
Number of years in Pavement Management Program cycle	12	12	8
Miles of Streets	240	240	240
Estimated Annual Cost	$2,640,000	$3,168,000	$7, 920,000

As shown in table 11, retaining the overall condition index at a rating of 90 is saving the village millions of dollars in comparison to a rating of 80.

4.22 TOOELE, UTAH

Through the Utah Local Technical Assistance Program (LTAP), the Utah Department of Transportation provides local agencies with a PMS and also assists in implementation efforts (Vasquez et.al. 2010). The City of Tooele's PMS covers approximately 144 miles of roadway. The PMS implemented in the city, supported through the Utah LTAP, "presents a real example of how useful a PMS can be for a local agency" (Vasquez et.al. 2010).

Employees from the Utah LTAP conducted a full roadway network survey in 2000, 2004, and 2009 for all partnering local agencies, including the City of Tooele. Focus was placed on the severity level and the extent of the distress for the following seven types: potholes/utility cuts, rutting, transverse cracking, longitudinal cracking, block cracking, edge cracking, and fatigue/alligator cracking. After the governing distress and its rating were determined, a corresponding distress table was used to establish the remaining service life, maintenance strategy, and suggested treatment.

All data collected in the field was entered into a computerized software program provided by the Utah LTAP. The software can then develop a pavement preservation strategy. The program is intended to be used with "good engineering judgment" and project level field inspections. To be most effective, it is meant to be a tool to help improve decision making skills and not replace them.

In 2000, the system helped develop a preservation strategy that would result in slight improvements in the current RSL of 10.8 years. By 2004, the RSL of the network decreased to 10.4 years. A majority of the City's $1,000,000 budget was allocated toward a two-step preservation strategy that would prevent the 19 percent of the network near failure from deteriorating further. Using the same budget of $1,000,000 over the next five years, the system developed step two of the preservation strategy that focused more on reconstructing the four percent of the network at terminal serviceability. In 2009, the average remaining service life of the street network increased to 11.4 years with only 0.3 percent of the network at terminal serviceability. If no preservation or rehabilitation work was performed, the system estimated that 32 percent of the network would deteriorate to a poor condition with about 8 percent at a terminal serviceability level by 2012. The City of Tooele's PMS is a simple but efficient way to manage the pavement network at the local level (Vasquez et.al. 2010).

4.23 TRAVIS COUNTY, TEXAS

In 2004, Travis County, Texas surveyed 1,220 miles of roadway using the ADVantage, Automated Distress Vehicle, system by Fugro Consultants LP (Kuennen 2005). The digital imaging survey was conducted at night to avoid daylight shadows that may interfere with the imaging. The van was driven over every roadway, taking 14-feet wide samples of images. The digital image capture system, data storage system, and data analysis system were all housed in the customized van with four strobe lights to provide optimal illumination for high resolution imaging. The images were fed into an onboard computer system where they were stored and analyzed to identify the quantity and severity of cracking. The data was analyzed for longitudinal, transverse, block, and alligator cracking patterns using optical character recognition based on pixel variations within the digital photos. The system automatically distinguished between manufactured joints and pavement distress.

The pavement distresses were identified, categorized, summed, and entered into their existing PMS database, PAVEMENTview Plus, and linked with their GIS. The county expects to update the inventory every few years using this automated technology. The output from the program helped the county develop their annual maintenance and work plans.

The PMS was also extremely helpful in generating GASB-34 reports and meeting federal requirements to include the value of long-lived assets, including roads, in their annual financial statements.

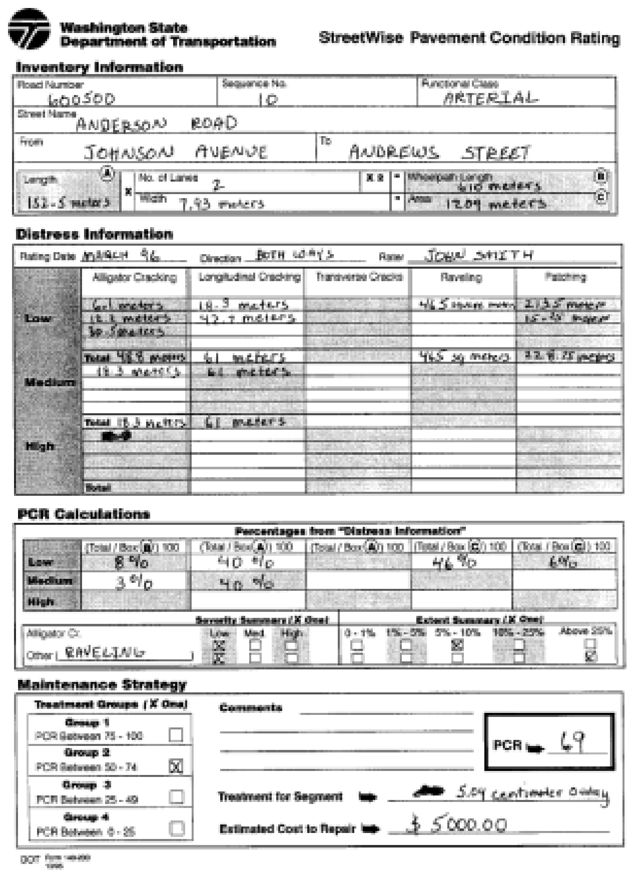
In terms of the condition of Pierce County's pavements, over 70 percent of the roads were rated 'fair to good'. However, a range of conditions were experienced in the county's four precincts from above 90 percent to well below 70 percent. The county's goal is to achieve overall pavement conditions between 'fair to good' to more than 80 percent within two years, not only for the county itself but also for the precincts.

4.24 WASHINGTON CITIES – BUCKLY, BURLINGTON, LANGLEY, PROSSER, AND STELACOOM

Researchers assisted small, rural cities in Washington with populations less than 22,500 by developing a "simplified" PMS. It was expected that this simplified system would not deviate from the principal requirements of other systems used in the state. The overall procedure for the simplified methodology involved the following five steps (Sachs and Sunde, 1996):

1. Gather the necessary inventory data.
2. Conduct the pavement condition evaluation.
3. Total the distress types and severity levels.
4. Select predominant alligator cracking percentage range and other predominant distress.
5. Look up the Pavement Condition Rating (PCR) in the table.

This system was simplified to the extent that the rural cities would not need to use a computer to determine the pavement condition; it could merely be calculated using paper and pencil. The data collection and analysis form developed for the simplified system is shown in figure 17. This technique was possible since the total mileage of streets that the cities were responsible for was quite low (approximately five miles of federal-aid roadways).


Washington State Department of Transportation

StreetWise Pavement Condition Rating

Inventory Information

Road Number	Sequence No.	Functional Class
600500	10	ARTERIAL

Street Name: ANDERSON ROAD

From: JOHNSON AVENUE To: ANDREWS STREET

Length (A): 152.5 meters × No. of Lanes: 2 × 2 = Wheelpath Length (B): 610 meters

Width: 7.93 meters = Area (C): 1209 meters

Distress Information

Rating Date: MARCH 96 Direction: BOTH WAYS Rater: JOHN SMITH

	Alligator Cracking	Longitudinal Cracking	Transverse Cracks	Raveling	Patching
Low	6.1 meters	18.3 meters		465 square meters	213.5 meters
	18.3 meters	42.7 meters			15.24 meters
	30.5 meters				
	Total 48.8 meters	61 meters		465 sq meters	228.75 meters
Medium	18.3 meters	61 meters			
	Total 18.3 meters	61 meters			
High					
	Total				

PCR Calculations

Percentages from "Distress Information"

	(Total / Box (B)) 100	(Total / Box (A)) 100	(Total / Box (A)) 100	(Total / Box (C)) 100	(Total / Box (C)) 100
Low	8 %	40 %		46 %	6%
Medium	3 %	40 %			
High					

	Severity Summary (X One)			Extent Summary (X One)				
	Low	Med	High	0 - 1%	1% - 5%	5% - 10%	10% - 25%	Above 25%
Alligator Cr.	☒	☐	☐	☐	☐	☒	☐	☐
Other: RAVELING	☒	☐	☐	☐	☐	☐	☐	☒

Maintenance Strategy

Treatment Groups (X One)

Group 1 PCR Between 75 - 100	☐
Group 2 PCR Between 50 - 74	☒
Group 3 PCR Between 25 - 49	☐
Group 4 PCR Between 0 - 25	☐

Comments

PCR 69

Treatment for Segment 5.04 centimeter overlay

Estimated Cost to Repair $5000.00

DOT Form 1996

Figure 17. Washington's simplified PMS data collection and condition rating form (Sachs and Sunde, 1996).

In terms of the rating methodology, Washington State's Pavement Surface Condition Rating Manual was used as a guide for certain distress types, and then respective deduct values were developed. The number of distress types was limited to two for ease of analysis. The focus was on distress types that would drive pavement maintenance decisions. A city using this procedure would use a 'look-up' table to find the appropriate deduct value for a given distress type and severity range. These deduct values would then be subtracted from 100 to obtain the PCR. Sample PCR tables used for individual distresses are shown in figure 18. It was reported that this process achieved the precision that the cities desired, yet it was simple enough to be easily implemented.

Alligator Cracking

	High	Medium	Low
0 to 1 %	79	86	93
1% to 5%	59	71	82
5% to 10%	43	58	72
10% to 25%	32	48	62
Above 25%	17	32	46

Longitudinal Cracking

	High	Medium	Low
0 to 1 %	89	100	100
1% to 5%	70	85	94
5% to 10%	46	74	87
10% to 25%	26	63	78
Above 25%	n/a	n/a	n/a

Figure 18. PCR tables for individual distresses used in Washington's simplified PMS (Sachs and Sunde,1996).

Also included with the system is a form to help determine corrective action and costs. The PCR is grouped into four ranges: 100 to 75, 74 to 50, 49 to 25, and 24 to 0. Each range is manually assigned a maintenance strategy based on individual experience or strategies other agencies are using. Costs are then estimated for each strategy based on similar projects from the previous year.

4.25 INSTITUTIONAL ISSUES

Researchers analyzed institutional issues that may hinder implementation of PMS by local agencies (Amekudzi and Attoh-Okine 1996). Major obstacles identified by the authors included:

- Technical and financial resources available at the local agency level may be limited.
- Pavement management is one of many management systems in infrastructure and thus competes with other administrative needs for transportation.
- Several local agencies that initially adopted a PMS discontinued its use thereafter, wasting large investments of funds and human resources. Generally, this is because local agencies are not able to resolve institutional barriers encountered as compared with larger agencies. "Larger agencies seem to have been better equipped to deal with these obstacles and finding ways of sustaining the productive use of PMS" (Adjo and Attoh-Okine, 1996).
- The use of a PMS in an agency is limited to a short period of time (typically a few weeks) when staff works with the software and prepares reports. This, coupled with the fact that pavement management is only one of many agency functions, contributes to an overall lack of support for the system.
- "Perceived complexities of pavement management software and analysis tools may reduce the likelihood of adoption and continued use of a PMS. Difficulties in the use of software tend to frustrate personnel and slow business considerably" (Adjo and Attoh-Okine, 1996), which increases the chance that the PMS will be abandoned.

The authors recommended that a Metropolitan Planning Organization (MPO) be used to address the barriers and challenges local agencies face with PMS. MPOs could be used to coordinate information management for the benefit of member agencies within their jurisdictions and help prioritize pavement needs at a regional level (Adjo and Attoh-Okine, 1996).

4.26 SUMMARY OF LOCAL AGENCY PMS

A summary of the characteristics and features of the 24 local agency PMS implementations throughout the U.S. included in this synthesis are highlighted in Appendix A.

CHAPTER 5 STATE-OF-THE-PRACTICE SURVEY

A survey was conducted to assess the current state-of-the-practice in local agency pavement management systems in Illinois. An online survey was distributed via email to 347 municipal and county engineers throughout the state. The purpose of this survey was to gain an understanding of local agency PMS implementations and to determine which agencies might be highlighted as case study examples. The survey focused on information needed to determine the type of PMS being used by the agency, along with additional questions seeking details of the PMS used. The survey instrument is included in Appendix B.

5.1 RESULTS OF THE SURVEY

The survey was distributed to a total of 347 local agencies in Illinois, including 245 municipalities and all 102 counties. Of the surveys distributed, a total of 115 responses were received from 34 counties, three road districts, and 78 municipalities. The geographical locations of the responding agencies are depicted on the map of Illinois in figure 19.

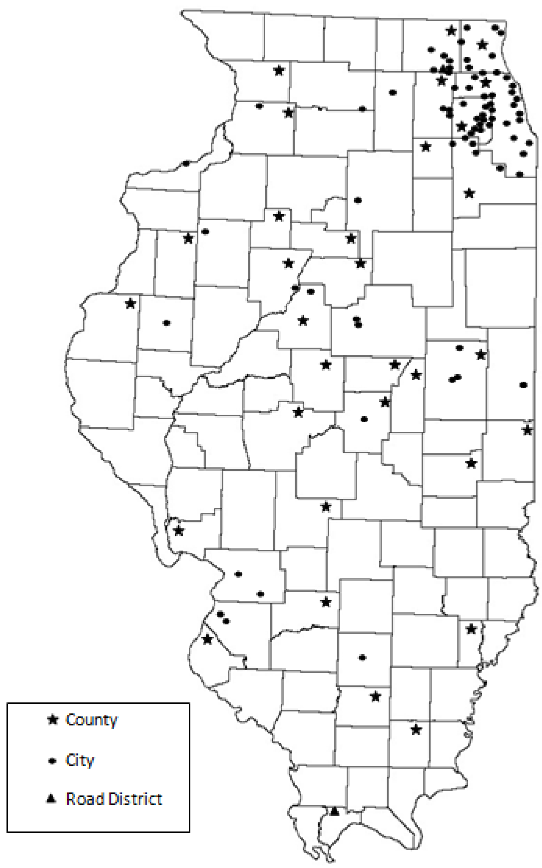


Figure 19. Spatial distribution of responding agencies in Illinois.

The response rate for the survey was 33 percent (115/347), which is higher than typical response rates of 20 percent. This may be due to the online distribution of the survey instrument using Survey Monkey, a web-based tool that allows the user to create surveys, collect survey data, and see results. Of the 115 respondents, 59 percent (68 agencies) have a pavement management system in place, while 41 percent (47 agencies) do not. It should be noted that although 68 agencies with a PMS and 47 agencies without a PMS responded to the survey, the number of responses to a particular question may be less. Respondents were not required to answer every question, and thus some may have been skipped. The number of actual responses for each question are indicated on the respective graphs.

For those agencies that do not currently have a PMS, a question was added to the survey to assess their interest in PMS. Figure 20 shows the distribution of agencies that do not have a PMS by their interest in learning more about them. Eighty-five (85) percent of agencies without a PMS are interested in learning more about them.

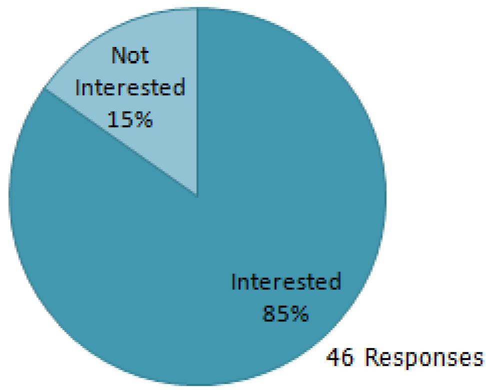


Figure 20. Responding agencies without a PMS by interest in learning more.

5.2 RESPONSES OF AGENCIES WITH PMS – JURISDICTION CHARACTERISTICS

Further analysis of the 68 agencies with PMS was performed to investigate patterns or trends in local agency implementations. These agencies were asked a series of questions about the characteristics of their jurisdiction including:

- The majority of your agency's road-miles are located in what area type?
- What is your agency type?
- What is the approximate population of your jurisdiction?
- How many lane miles of road does your agency maintain?
- Is your agency part of a Metropolitan Planning Organization?

Figure 21 shows the distribution of agencies by area type in which the majority of their road-miles managed are located. As seen in this figure, 63 percent of the responding agencies with a pavement management system have most of their road-miles located in a suburban area.

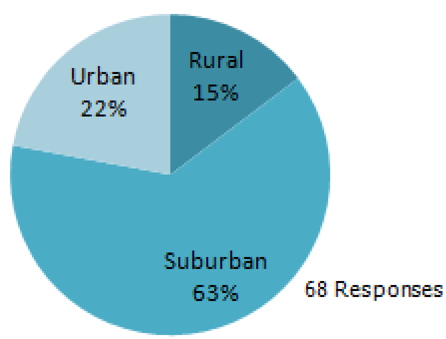


Figure 21. Responding agencies by area type.

Figures 22 and 23 show the type of agency and population distribution, respectively, of the responding agencies with a PMS.

Figure 22 shows that the majority (59 percent) of the responding agencies with a PMS are municipalities, while 37 percent are counties. Only a few responses were received from road districts. Analysis of figure 23 indicates that most of the responding agencies are located in jurisdictions with populations of 49,999 or less, with the highest percentage (34 percent) in the 25,000 to 49,999 range. This reveals that not all pavement management systems are implemented by large agencies.

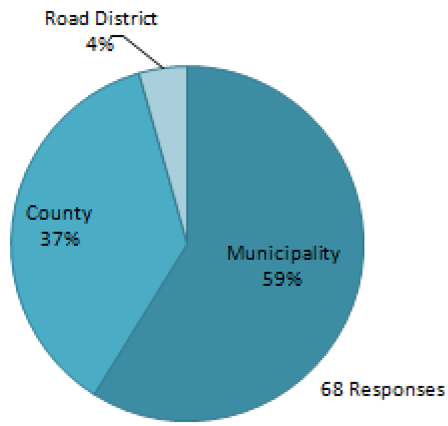


Figure 22. Responding agencies by agency type.

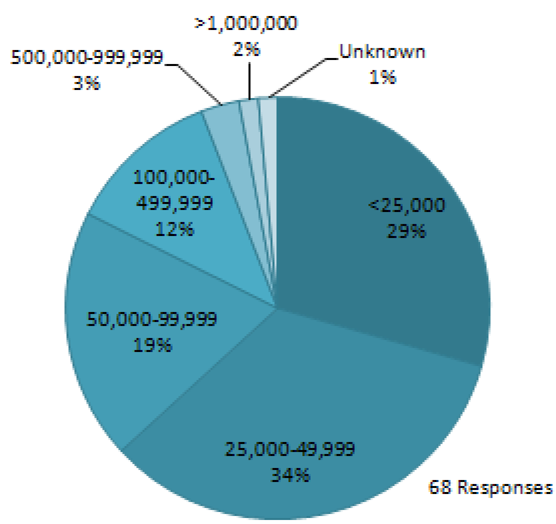


Figure 23. Responding agencies by population.

Figure 24 shows the distribution of responding agencies with a PMS by lane miles managed. This figure also illustrates the size of agencies involved in PMS initiatives. Seventy-one (71) percent of the responding agencies with a PMS manage lane miles of roadway from less than 100 lane miles up to 300 lane miles, with the largest proportion (34 percent) between 100 and 200 road lane miles.

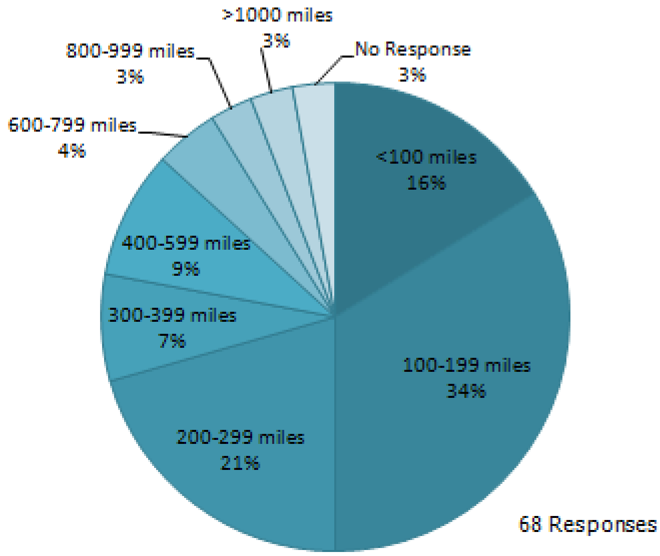


Figure 24. Responding agencies by lane miles of roadway managed.

Figure 25 shows the distribution of responding agencies with a PMS and their member participation with a Metropolitan Planning Organization. This figure shows that a majority (79 percent) of the responding agencies with a PMS are affiliated with the Metropolitan Planning Organizations in their jurisdictions. An MPO is a federally-mandated and federally-funded transportation policy-making organization that is made up of representatives from local government and governmental transportation authorities. They are used to channel federal funds and to ensure that existing and future expenditures of governmental funds for transportation projects are based on a continuing, cooperative, and comprehensive planning process. MPOs are required for urbanized areas with populations greater than 50,000.

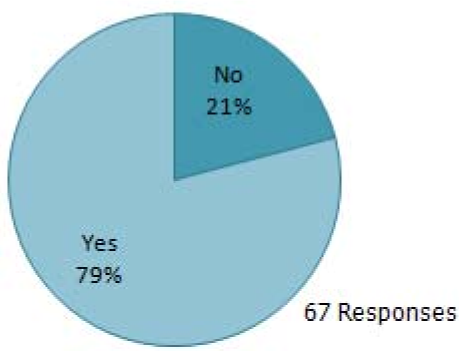


Figure 25. Responding agencies' involvement with an MPO.

5.3 RESPONSES OF AGENCIES WITH PMS – PMS CHARACTERISTICS

Agencies were asked to provide details on their PMS characteristics as per the following survey questions:

- How long has your agency's pavement management system been in place?
- What type(s) of PMS software programs are used at your agency?
- Approximately what proportion of your agency's total road miles are recorded in your PMS?
- What procedure does your agency use to collect condition data?

- Who collects the condition data?
- How often does your agency conduct pavement condition inspections?
- Approximately what proportion of your agency's total road miles is inspected each time you conduct pavement condition inspections?
- What type(s) of pavement condition data are incorporated into your agency's PMS?
- What type of condition rating does your agency use to evaluate pavement condition?
- How often does your agency use data from the PMS to help make investment decisions?
- What is your agency's annual pavement management budget?

The following section provides details of the survey responses directly as well as cross-classified by agency population and other demographics to identify trends among the agency implementations.

Figure 26 shows the distribution of the age of the responding agencies' PMS. These results not only helped in selecting representative case study agencies, but also demonstrated that pavement management systems are not a new concept to local agencies in Illinois. This figure shows that nearly half (48 percent) of agencies with a PMS have had them implemented for more than ten years. Seventy-two (72) percent of the responding agencies had their PMS implemented for more than five years.

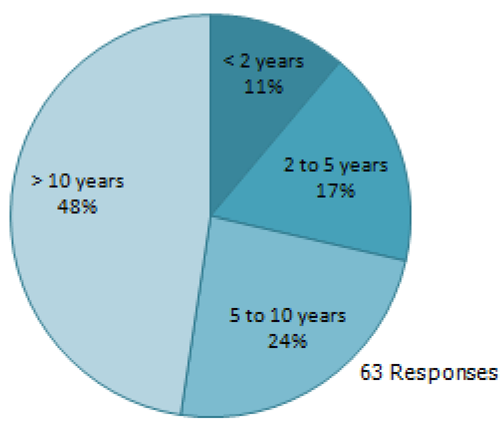


Figure 26. Age of responding agencies' PMS.

There are several different types of PMS software products available on the market. The most common PMS software programs used in Illinois are MicroPAVER, PAVEMENTview, PubWorks, RoadCare, and PavePro (figure 27). Some agencies have internally developed their own paper or electronic spreadsheets or have had an external consultant develop a management system for them. Other common PMS software products available to agencies in Illinois include RoadSoft, Utah LTAP TAMS, and Visual IMS. These programs were included as options in the survey; however, they were excluded from this and further analysis due to a lack of responses and use by survey respondents. Figure 27 shows the distribution of agencies with a PMS by software type. Note that the frequency of responses for each of the PMS software types is listed on the top of each bar, in addition to the relative frequencies (percent) on the vertical axis.

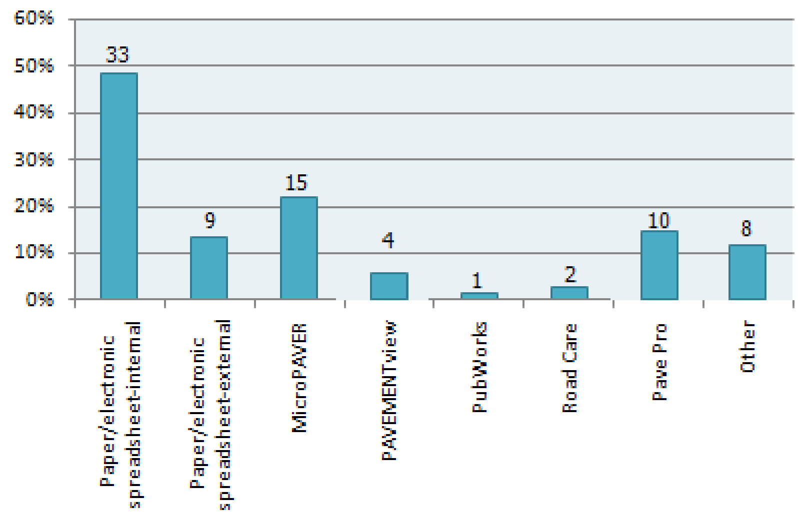


Figure 27. Responding agencies by PMS software used.

It should be noted that agencies were allowed to select more than one type of software. Nearly half of responding agencies (49 percent) use paper or electronic spreadsheets. Agencies in Illinois are also widely using MicroPAVER.

In order to further investigate patterns and trends of PMS software programs used by the respondents, a cross-classification analysis was conducted by population, as depicted in figure 28. This chart was created by categorizing the responses to each of the software types by population of the agencies that use it.

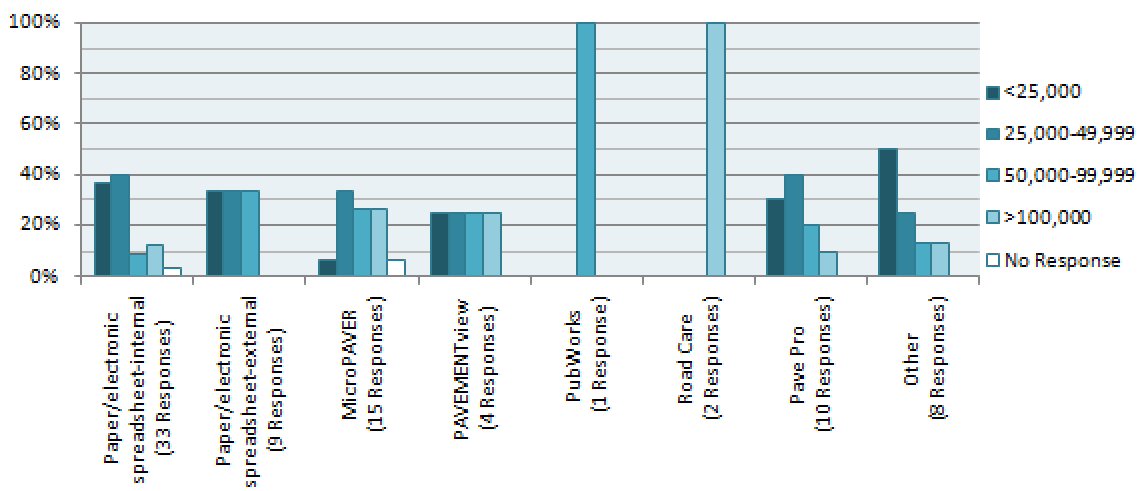


Figure 28. Responding agencies by pavement management software versus population.

For those responding agencies using paper or electronic spreadsheets developed internally, 75 percent of the agencies have populations up to 50,000. Agencies using a paper or electronic spreadsheet developed externally have populations ranging up to 100,000 with equal distribution (25 percent). Of the agencies that responded using MicroPAVER, 33 percent have populations between 25,000 and 49,999. There are also a substantial number of agencies using MicroPAVER with populations greater than 50,000. Agencies among all populations equally responded to have used PAVEMENTview (four agencies). The responding agency using PubWorks has a population between 50,000 and 99,999, while both agencies using RoadCare have populations above 100,000. Of the agencies using PavePro, 70 percent have populations up to 50,000. Within all population limits, agencies were found to have created their own PMS or used some other type of software not listed.

The results were also categorized by software type versus lane miles managed and are shown in figure 29.

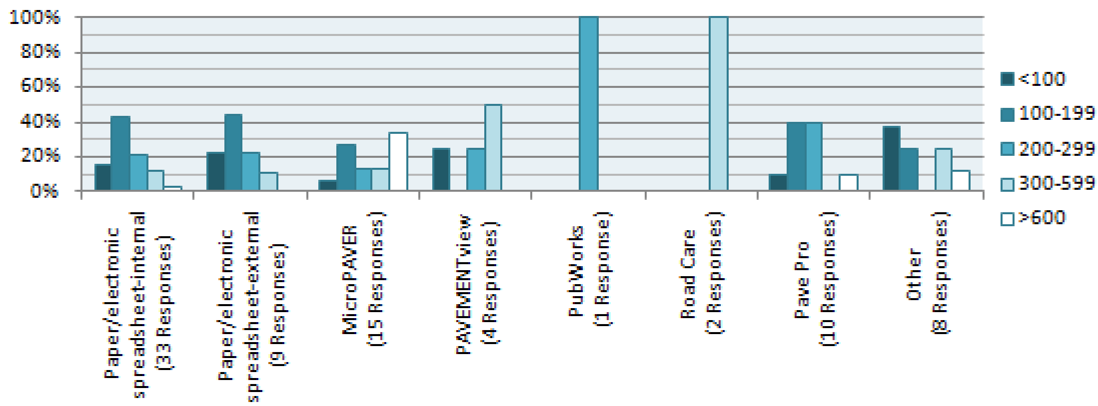


Figure 29. Responding agencies by pavement management software versus lane miles managed.

Figure 29 shows that of the responding agencies, 42 percent of those using paper or electronic spreadsheets developed internally and 44 percent of those using spreadsheets developed externally manage between 100 and 200 lane miles of roadway. Of the agencies using MicroPAVER, 27 percent manage between 100 and 200 lane miles, while 33 percent manage above 600 lane miles of road. A majority of those agencies using PAVEMENTview and RoadCare manage between 300 and 600 lane miles of roadway. The responding agency that uses PubWorks manages between 200 and 300 lane miles of roadway. For those agencies using PavePro, 80 percent manage between 100 and 300 lane miles of roadway. Agencies that are using other forms of pavement management manage a wide range of road lane miles.

Figure 30 shows the distribution of the responding agencies with a PMS by percent of road lane miles recorded in their system. The figure shows that 89 percent of the responding agencies are recording and using their pavement management system for 75 percent to 100 percent of the lane miles in their jurisdiction.

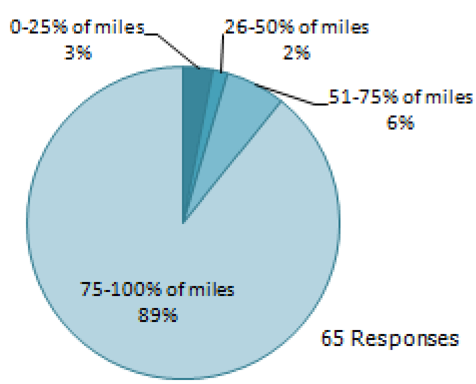


Figure 30. Responding agencies by percent of lane miles recorded in their PMS.

Agencies were also asked to specify the procedures they use to collect pavement condition data. Agencies were given the option to select any method that applies ranging from windshield surveys, detailed walking surveys, automated vans, or other with explanation. The agencies were allowed to select multiple responses. Of the 68 agencies with PMS, 65 responded to this question. Figure 31 shows the distribution the responding agencies by pavement condition data collection methodology, with the frequency of the responses shown on the top of the bars. Nearly 70 percent of the responding agencies perform windshield surveys to collect pavement condition data. However, agencies were allowed to select more than one response to this question. When analyzing the results, it was observed that a majority of agencies were using more than one strategy of collecting condition data.

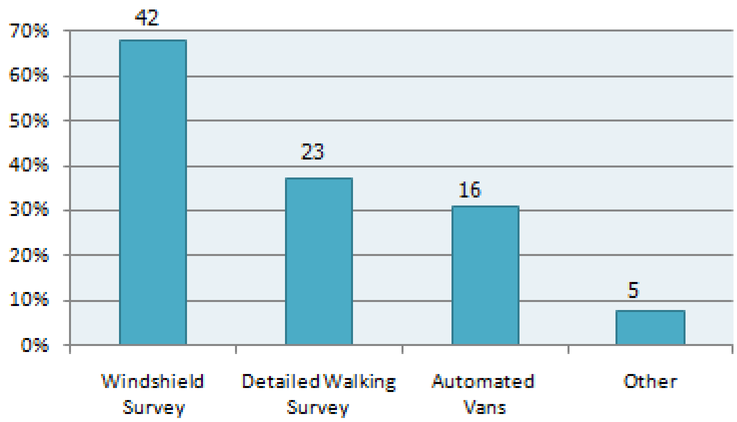


Figure 31. Responding agency pavement condition data collection methods.

Agencies were asked to provide details on who was responsible for collecting the pavement condition data (in-house staff or consultant/vendor). Agencies were allowed to select more than one answer or choose 'other'. Of the 68 responding agencies with a PMS, 64 responded to this question. Figure 32 shows the distribution of responding agencies as to who collects their pavement condition data. Just over 80 percent of the responding agencies collect condition data using in-house staff. Since agencies were allowed to select more than one response to this question, it was observed that some agencies are using both in-house staff and consultants/vendors to collect condition data.

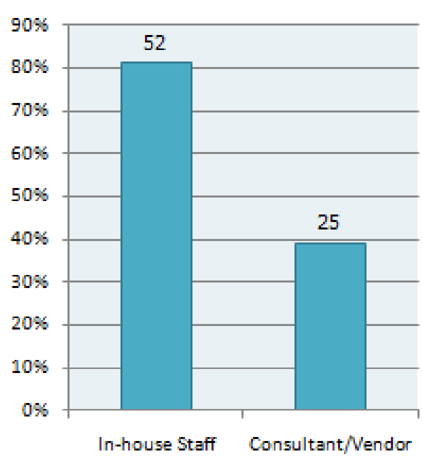


Figure 32. Agencies' responses to who collects condition data.

Agencies were asked how often they conduct pavement condition inspections. Of the 68 responding agencies with a PMS, 65 responded to this question. Figure 33 shows the distribution of agencies by frequency of pavement condition inspections. This figure shows that 45 percent of responding agencies conduct pavement condition inspections every year. Also, nine percent of agencies conduct pavement inspections every two years, while 18 percent conduct inspections every three years.

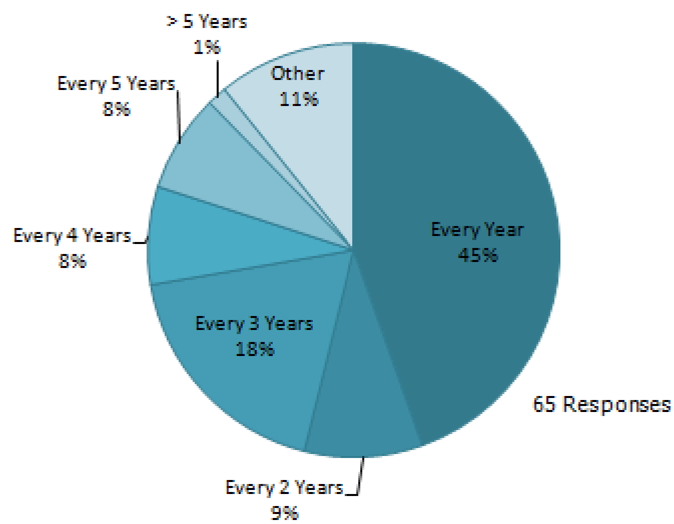


Figure 33. Responding agencies by frequency of pavement condition inspections.

Agencies were asked to specify what proportion of their total road miles is inspected each time they conduct pavement condition inspections; 65 agencies responded to this question. Figure 34 shows the distribution of agencies by percent of the network road miles inspected each time a pavement condition inspection is conducted. This figure shows that 45 percent of the responding agencies collect data on all their road miles during each inspection. Also, 42 percent of agencies only collect between 0 and 50 percent of the road miles they manage.

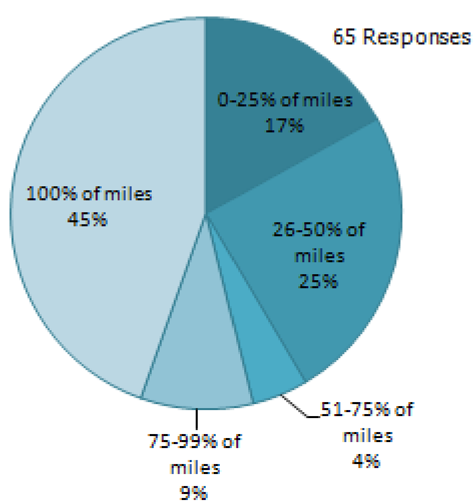


Figure 34. Responding agencies by percent of road miles inspected per pavement condition inspection.

Agencies were asked what type(s) of pavement condition data are incorporated in the agency's PMS. Four general types were listed: pavement surface distress, roughness data, structural capacity, and friction data. Pavement surface distress is the measure of the road's surface deterioration. Roughness data is the measure of the ride quality. The structural capacity is the ability of the pavement to support traffic with little or no structural damage. Friction data is the measure of pavement skid resistance. Of the agencies who responded with a PMS, 65 responded to this question and were allowed to select more than one answer. Figure 35 shows the distribution of responses by data type(s) incorporated into their pavement management system. As the figure shows, nearly 100 percent of the respondents use pavement surface distress data in their pavement management systems. Approximately 50 percent incorporate roughness data into their PMS, and nearly 40 percent use structural capacity data when evaluating their pavements.

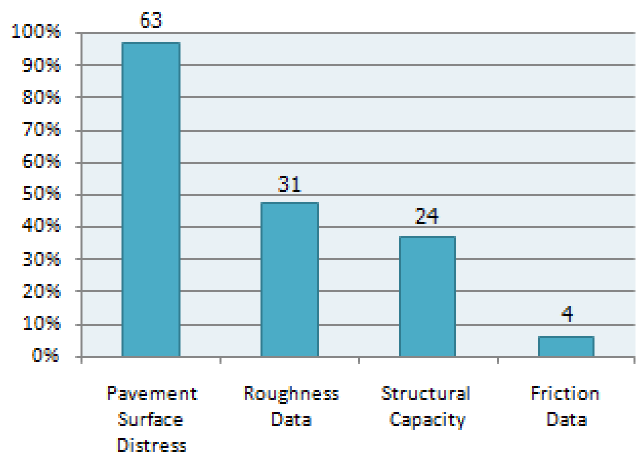


Figure 35. Responding agencies by PMS data type(s).

Agencies were asked what type of condition rating their agency uses to evaluate pavement condition. There are several different types of ratings including a general rating (good, fair, poor), PCI, PASER, Present Serviceability Index (PSI), Overall Pavement Index (OPI), Condition Rating Survey, and other with explanation. Of the 68 agencies with a PMS, 64 responded to this question (figure 36). The agencies were allowed to select multiple responses. When analyzing the survey results, it was observed that some agencies use several different types of rating systems in their PMS. Over 50 percent of responding agencies use PCI, while over 20 percent use a general good, fair, poor rating.

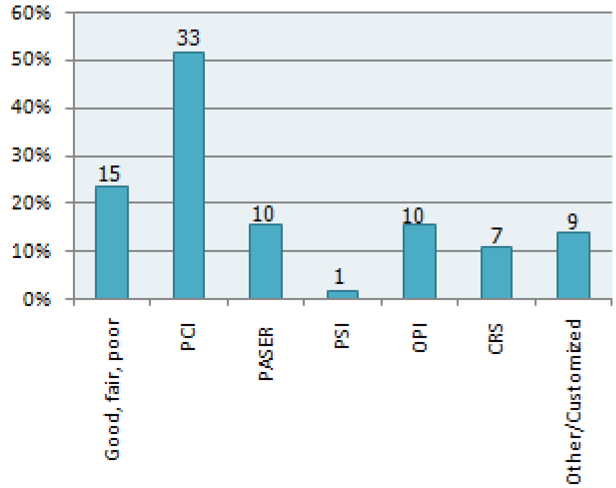


Figure 36. Responding agencies by rating system(s) used.

Further examination of pavement rating system by population was performed and is shown in figure 37.

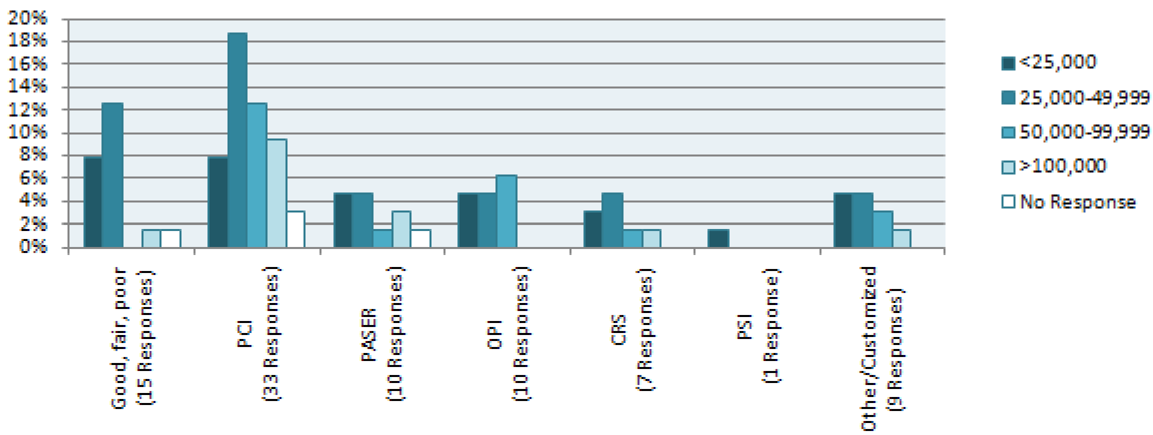


Figure 37. Responding agencies by rating system used and population.

The responses indicate that agencies with populations less than 25,000 mostly use the good, fair, poor rating and the PCI rating. The results show that agencies serving populations between 25,000 and 50,000 mostly use PCI followed by the good, fair, poor rating. Agencies with populations more than 50,000 mostly responded to using the PCI. .

Another cross-classification of PMS rating system by agency lane miles managed was performed and is presented in figure 38.

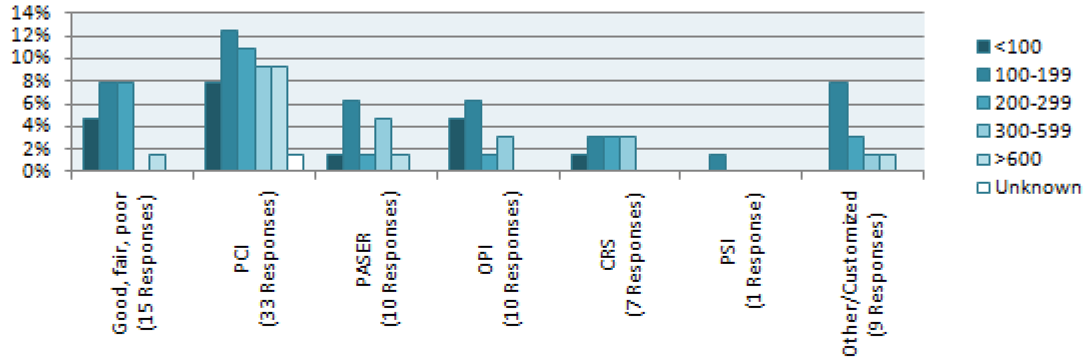


Figure 38. Responding agencies by rating system used and lane miles managed.

For those agencies managing less than 100 lane miles, PCI was the predominant rating method used. Agencies managing between 100 and 300 lane miles indicated that they mostly use the PCI rating followed by the good, fair, poor rating system. The agencies that manage more than 300 lane miles of road mostly use the PCI rating system.

Agencies were asked how often they use data from their PMS to help make investment decisions. Of the 68 responding agencies with a PMS, 64 responded to this question. Figure 39 shows the distribution of agencies based on how often they make investment decisions using data from their PMS. Figure 39 show that 65 percent of the responding agencies use data from the PMS to make investment decisions once a year. The vast majority (87percent) responded that they are using their PMS at least annually (or more often) to make investment decisions.

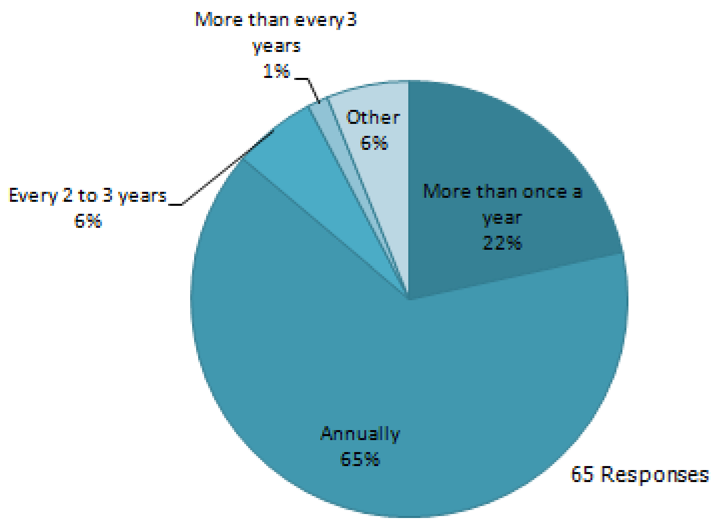


Figure 39. Responding agencies by frequency of use of PMS to make investment decisions.

Agencies were asked to specify their annual pavement management budget on a dollar per year basis. Only 51 agencies provided a response to this question. Figure 40 shows the distribution of agencies by their annual budget. This figure shows that 25 percent of the agencies who responded to this question do not have a specified budget for their PMS. For those agencies that do have a budget, 53 percent of responding agencies have up to $30,000 budgeted for their PMS. Of the responding agencies, 12 percent spend over $100,000 annually on their PMS.

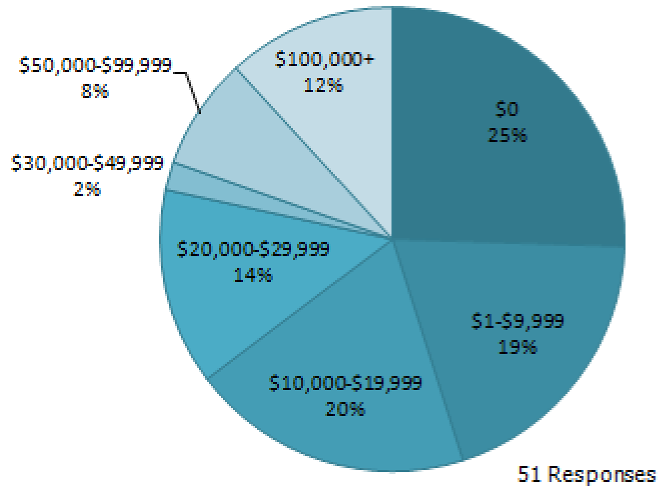


Figure 40. Responding agencies by annual budget for pavement management.

CHAPTER 6 CASE STUDIES

As a part of this project, seven local agencies were selected as case study agencies to obtain details and insights on their PMS implementation and practices so they could be shared in the creation of the *Implementation Guide*. The agencies selected represent a range of types/sizes along with pavement management practices used including pavement management software programs, data collection strategies, and analysis methodologies.

In October and November of 2010, the research team conducted on-site interviews with representatives from the selected local agencies: Champaign County, Edgar County, McHenry County, Stark County, City of Macomb, City of Naperville, and the Village of Villa Park. The interview guide that describes the process and provides sample questions asked during the interviews is included in Appendix C.

This chapter provides a detailed illustration of the agency-wide experience in the implementation efforts undertaken. For each of the agencies interviewed, a summary of the agency profile, implementation efforts, PMS characteristics, and successes and challenges related to the PMS are provided. This information can be used by other local agencies to identify effective implementation strategies specific to their needs.

6.1 CHAMPAIGN COUNTY

Champaign County is a rural county located in central Illinois with a population of approximately 195,000 as of the 2009 U.S. census estimates. The county is responsible for maintaining over 400 lane miles of county roads. Currently, the county spends five-sixths of their total budget on rehabilitation and the remainder on maintenance. To help maintain their road network in an efficient and economic manner, the county began implementing a PMS in 2004.

6.1.1 Implementation Efforts

Prior to the implementation of the county's PMS, there were differences of opinion between Champaign County and the Cities of Champaign and Urbana on how Champaign County's Motor Fuel Tax (MFT) funds should be spent. The cities expressed interest in having the county focus the use of the MFT funds on the fringe roadways that support travel around the cities instead of the rural roads. However, the county had no way of showing where the funds were truly needed on their road system and what treatments were truly the best options for these roadways. Up to that time, the county had focused on the use of overlays and had not investigated other maintenance treatment options. During this same time, the Champaign County Board was requesting that the various departments within the county begin using performance indicators to show the condition of the road network. Given all these factors, the county engineer and staff decided to implement a PMS.

Prior to moving forward with the implementation, the county engineer arranged for a consultant to give a PowerPoint presentation to the County Board to describe the benefits of pavement management systems. The presentation helped the board better understand what a PMS is and what it would do for Champaign County and the management of the road network. With buy-in from the County Board, the county hired an outside consultant, Applied Research Associates, to develop their customized pavement management system using the RoadCare software program.

Through the use of the output data of the PMS, the county has been able to "reduce political pressure" when making pavement management decisions. Also, their maintenance program now consists of several different maintenance strategies that will better serve their network needs and help minimize costs.

6.1.2 Pavement Management System Characteristics

The county's consultant handles all the data collection, input, and reporting output for Champaign County's PMS. Every other year, the consultant surveys the county's road network. Using automated vans, the consultant collects pavement images and uses those to determine the pavement surface distress, roughness data, and the structural capacity of the network. One reason Champaign County selected its consultant is due to their use of the Rolling Wheel Deflectometer to assess the structural capacity of the network. The county uses this data for project selection purposes as shown in figure 41. The county sends updates of construction and maintenance projects completed each year to the consultant and the information is updated in the pavement management system. All inventory and conditions are updated and reported to the county by August of each year.

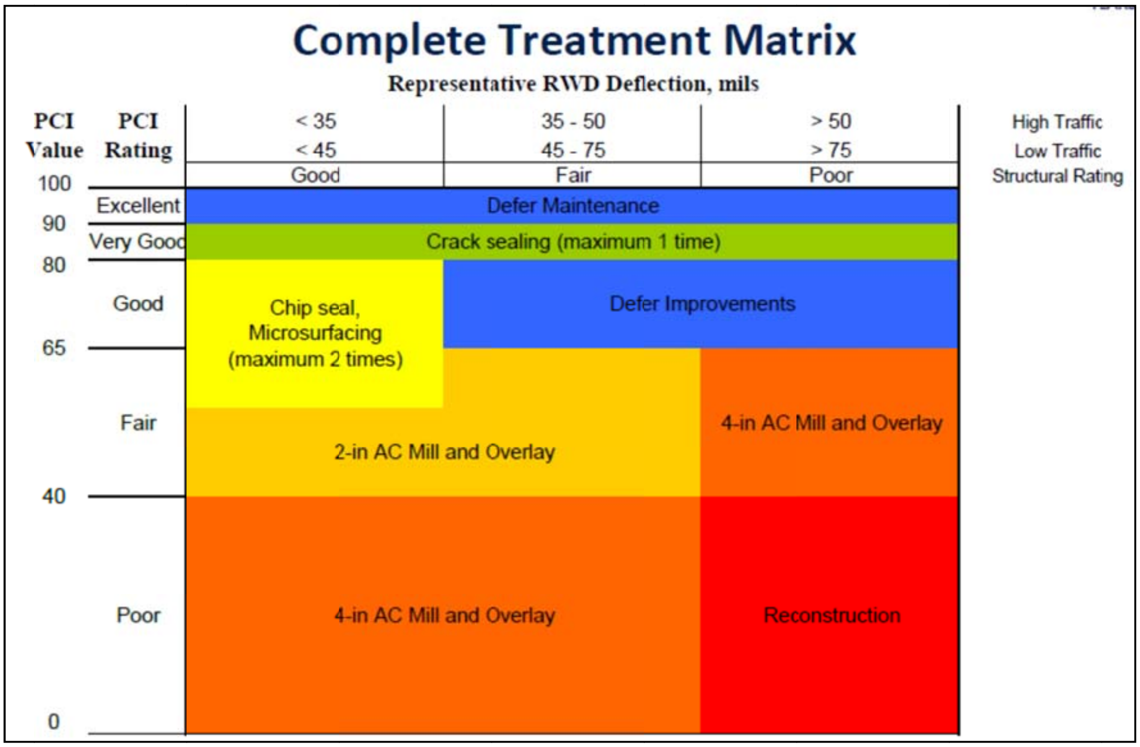


Figure 41. Treatment selection matrix (ARA 2009).

Once the network has a rating, the consultant provides the county with a prioritized list of pavement projects. County staff then holds a meeting to decide which roads will be selected for improvement and develops a five-year pavement plan, which is updated annually and presented to the board for funding. Figure 42 provides an example of a candidate projects list over a five-year period that is updated every year by the county engineer.

Year	Road	From Mile	To Mile	Length, mi	Treatment	Cost, $
2007	CH 9	0.00	7.31	7.31	Rubblization & overlay	1,250,000
2007	CH 22	0.00	6.52	6.52	2" Mill & AC overlay	1,600,000
2007	CH 1	4.45	4.88	0.43	4" Mill & overlay	319,117
2007	CH 32	4.04	5.05	1.01	Chip seal	70,393
2007	CH 11	6.38	15.08	8.70	Microsurface	729,870
2007	CH 17	1.37	1.94	0.57	Microsurface	47,819
2007	CH 20	16.83	17.83	1.00	Microsurface	83,893
2007	CH 25	0.00	2.03	2.03	Microsurface	170,304
2007	CH 13	2.25	6.02	3.77	Seal cracks	87,585
2007	CH 15	5.04	5.67	0.63	Seal cracks	14,636
2007	CH 15	12.15	12.71	0.56	Seal cracks	13,010
2008	CH 24	0.00	2.45	2.45	2" Mill & AC overlay	1,018,210
2008	CH 55	1.13	1.59	0.46	4" Mill & AC overlay	341,381

Figure 42. Candidate projects list for Champaign County (ARA 2009).

In developing the five-year plan, the impacts of various funding scenarios are also examined. Figure 43 displays the effect of the funding on the overall pavement condition prediction for Champaign County.

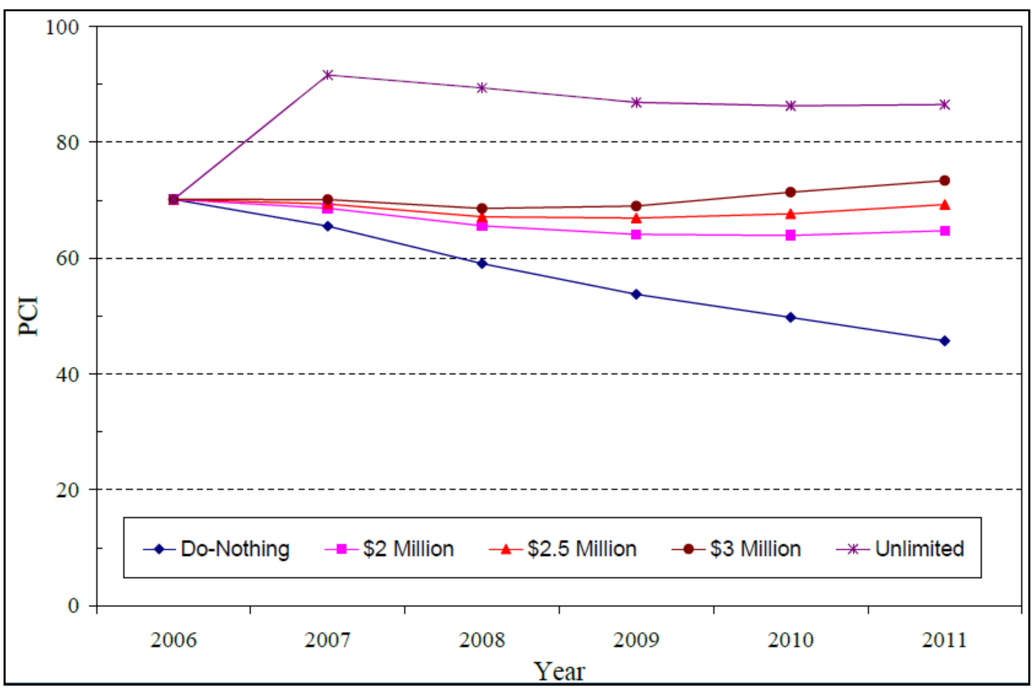


Figure 43. Overall pavement condition prediction.

The county engineer is currently using the RoadCare software via the web since the program is web-based. The county engineer not only has access to condition data and inventory data, but is also able to access videos of the whole pavement network and the right-of-ways.

The pavement management activities and software currently meet the county's needs. Future enhancements to the system include condensing long stretches of roads into one baseline so that construction is performed on a larger segment all at once instead of having multiple projects in one to two mile stretches.

6.1.3 Successes and Challenges

Champaign County's PMS has been in place and fully implemented since 2007. When the network was first surveyed, the network PCI was 70 out of a scale of 100. The results of the 2010 survey indicated that the network PCI had risen to 71. With available funding, the county is able to achieve their goal of maintaining an average network PCI above 70.

One of the main challenges the county faced in implementing the system was gaining access and compiling the necessary history data, as the collection of that information is a rigorous process. Another challenge Champaign is facing is compiling their signs and culvert inventories and integrating them into the PMS so all assets can be housed in one system. Currently, the county uses Simple Signs for their sign inventory and management. The county feels that they would have saved time and money if only one program was used to handle their multiple assets.

6.2 EDGAR COUNTY

Edgar County is a rural county located in eastern Illinois with a population of approximately 18,000 people as of the 2009 U.S. census estimates. The county maintains and rehabilitates over 150 lane miles of roadways. In 2009, the county determined there was a major need to implement an asset management program which would include a pavement management component. The need for the program was recognized as Edgar County wanted to have a systematic process in place for completing the "right work at the right time for the right reasons."

6.2.1 Implementation Efforts

There were several reasons the county wanted to implement an asset management system. They specifically wanted to manage county assets more effectively with the available taxpayers' dollars. The county also required a methodology to identify candidate pavement maintenance, resurfacing, and reconstruction projects and to support requests for federal dollars for road maintenance activities.

To ensure that asset management was a priority in Edgar County, the county engineer served as a "champion" of the project and acquired several expert staff and consultants to assist with the implementation process. One of the first steps was communicating to all stakeholders (i.e., staff, county board members, and constituents) the change in the way business would be done as the agency moved from a worst-first approach to more cost-effective maintenance strategies. Many stakeholders were somewhat apprehensive about the new business approach and the accompanying methodology using PMS. There was also concern with spending federal money on maintenance projects instead of new construction projects. The county overcame this challenge through a series of formal presentations and public open house meetings where they presented the methodology and results in the form of GIS maps and executive summaries based on results from the PMS. This allowed any unknown information to be addressed, which helped reduce concerns over the expected changes. Also, the county staff gained accountability as they shared information about the new processes and demonstrated how they were going to more proactively manage the infrastructure and become better caretakers of the county's assets.

The implementation of the PMS occurred in three phases. Phase I consisted of the pilot study of the PMS and lasted from April 2009 to December 2009. Phase II was the full development of the PMS and lasted from December 2009 to June 2010. Phase III was the approval and implementation of the PMS which began in June 2010 and was still in progress at the time of interview in October 2010.

The first steps taken by Edgar County in the development and implementation of their PMS were to (1) identify and inventory their assets and (2) assess the condition of their assets. To accomplish these goals, the county set up planning tools – an integrated GIS system with a pavement management component. The county used existing maps, paper records, and electronic data to identify their roadway asset inventory for inclusion in the system. Once the assets were identified, they could assess the condition of their roadway sections.

Edgar County determined that they would assess the condition of the network using a customized PASER rating (one to five) obtained during windshield surveys. The PASER ratings were used to define a desired level of service for each segment using ADT and grouped roadway characteristics on a scale of one to five. For example, oil and chip surfaces on lower ADT roadways are separated from full depth asphalt roads with high ADT levels. Additional research is being conducted to consider the use of roadway width, maintenance history, and other factors in setting the levels of service.

The next step was to determine how the county's assets would be prioritized. Edgar County decided to use a prioritization equation that took "time until failure of an asset" into consideration along with the consequence of that failure. The county represents the time until failure as an asset priority number (APN) and equates it as follows:

Asset Priority Number (APN) = risk of failure x PASER score

Once the priority scores are identified, the county needed to identify the optimum strategy for the "mix of fixes." In the past, the county used a cyclical approach for scheduling maintenance activities, such as sealing every "oil and chip" highway every "x" number of years. Since the implementation of its PMS, the county is taking on a segmental approach that moves away from the worst-first mentality. Edgar County is currently managing its pavements based on the 80/20 rule: "80 percent of your efforts are aimed at 20 percent of your system."

Finally, the county needed to determine how they were going to budget both preventive maintenance and reconstruct/rehabilitation projects. To assist with this activity, they first classified their projects into three categories: preventive maintenance, minor reconstruct/rehabilitation, and major reconstruct/rehabilitation projects. The county decided to heavily skew (85/15) their budget towards preventive maintenance, which differed from the past. The county is in the process of creating a Master Plan and a 20-year Capital Improvement Plan in which all major expenditures for all projects are weighed and assessed every year.

6.2.2 Pavement Management System Characteristics

Edgar County partnered with Eastern Illinois University and Francis Associates to create a custom-designed management system application that was suitable for the county's needs. The application includes an ESRI File-Based Geodatabase, which incorporates the county's custom PASER rating, distress types, and descriptions of each segment. The network is further broken up into four different surface types: seal coat, asphalt, concrete, and gravel. The program uses a visual basic code and Edgar County Highway Department's pavement calculator tool to store and display the corresponding final PASER value for each segment. The program also incorporates the annual daily traffic, probability of failure, consequence of failure, and the asset priority number into its calculations. The program is geospatially tied to ESRI's ArcView GIS which captures, stores, analyzes, manages, and displays all data linked with a specific segment. ArcView GIS was easily learned by the staff through training seminars at Eastern Illinois University.

In addition, the PMS software for Edgar County was developed so that it can easily be customized and expanded as the agency and the agency's asset management practices grow. The software is multi-variable and attributes can easily be updated while out in the field. The county is able to save previous field surveys and perform time deterioration comparisons to analyze how the system is performing over time. The program also instantly analyzes and performs short-term assessments of the overall pavement network condition.

The county's PMS utilizes a customized PASER rating for assessing the pavement network condition. The rating is on a scale of 1 (failed) to 5 (excellent). The ratings are coded into the software as a drop-down menu where the user has only five different choices, each of which has its own weighting factor built in. In order to get the PASER rating, windshield surveys of the whole pavement network are conducted by interns. The county has two interns and a consultant, who performs quality control and quality assurance over the interns. The county also uses a GPS unit in the vehicle to collect data for further analysis and documentation. They were able to survey approximately 20 miles per day with a full survey completed in less than three weeks.

The total cost for the pavement management pilot, design, and implementation was under $30,000. The cost of each phase of the design is as follows:

- Phase I—$5,000
- Phase II—$10,000
- Phase III—$11,500

The PMS was funded using county-appropriated funds.

6.2.3 Successes and Challenges

Edgar County successfully implemented their pavement management software through a partnership with academic professionals and local expertise. The county was challenged by the cultural shift of business as usual to the preservation approach needed to accomplish this work. Convincing all stakeholders that moving to the preservation approach required significant effort but the end result was a staff that was very supportive of the PMS and is continually learning more to expand the work into all county assets.

One major success the county had related to its PMS was customizing the use of seal coating application rates to meet its preventive maintenance needs. The county piloted a "reduced oil application with smaller, all-same size stone" program in an attempt to maintain more lane miles of road as oil prices increased. The county uses their personnel and equipment to complete the work, which allows them to easily adjust stone size and application rate depending on the condition of the segment. The performance of the piloted projects is being tracked in the management system and the county will be able to use the performance data to make informed decisions on how to proceed with future preservation work to make the best use of limited funds. Other assets the county has begun to manage include traffic counts, traffic crash reports, and sign inventory. Edgar County has accomplished portions of this work with the help of research students from Eastern Illinois University.

6.3 MCHENRY COUNTY

McHenry County is a suburban county located in northern Illinois with a population of approximately 321,000 as of the 2009 U.S. census estimate. The county maintains and rehabilitates 502 lane miles of county roads. The county's budget is approximately $9,500,000 per year. In 2001, the county engineer decided to "champion" the implementation of a PMS as part of an asset management system. After researching different management software products, having various vendors demonstrate software and consultants bid on assisting with the implementation, the county decided to use Cartegraph's PAVEMENTview along with internal spreadsheets to track various attributes of their system.

6.3.1 Implementation Efforts

In McHenry County, they were faced with the challenge that major reconstruction on a roadway was only an option when an increase in the number of lanes was needed to improve capacity. Therefore, the county needed guidance on how to maintain the road network in good condition until reconstruction was needed. In 2001, the county engineer decided to invest time in implementing a PMS to help maintain the network in good condition with the available funds. The PMS would also make it easier for the county engineer to present yearly programs to management and the transportation County Board for budget approvals, since it helps present what the money will be used for and the effects of the investment.

McHenry County decided to get everyone in the department knowledgeable and involved in the implementation of the PMS. A GIS steering committee of approximately ten people was created to discuss the needs and opportunities of the combination of the GIS and asset management system implementation. Discussions within and outside the committee were shared with all personnel in the department. Slowly, the whole department became comfortable with the idea of implementing an asset management system.

The GIS committee contacted ten software vendors throughout the course of a year in search of a program that would best suit the needs of the department. All ten software vendors sent information about their software to the county. Of these ten, three were found to best suit the McHenry County's needs. The county set up interviews with the three vendors, which the department participated in and filled out evaluation surveys to rate each of the vendors' systems. The department was not just looking for a PMS, but also for software that encompassed other assets. The evaluation surveys concluded that Cartegraph's PAVEMENTview best suited the department's needs because it was a full-spectrum software, well-tested, and had a work order module.

6.3.2 Pavement Management System Characteristics

McHenry County decided to use Cartegraph's PAVEMENTview software for their PMS. However, the county uses the software as a guide to provide options for maintenance and rehabilitation decisions and the recommended treatments are used to guide treatment selection.

Some of PAVEMENTview's benefits utilized by the department are the ability to lock the records for a certain segment(s) and then analyze the rest of the network without that segment(s). The user is also able to input and keep track of patch work in the program. The user can create work orders for pavement, as well as for many other assets. This allows county staff to visually see where there are multiple occurrences of a problem. The user is also able to obtain a cost estimate based on costs per square foot, using costs input into the software by the county.

Initial data for the system was collected by a consultant. The condition of the pavement is rated using two analysis methods: PASER and CRS. The PASER survey is conducted every year and takes about a week's time for two staff members to complete. The rating is done individually by each crew member so that the ratings can be compared and checked for quality. The PASER surveys are completed through a windshield survey where raters drive along the shoulder of the road at about ten miles per hour or use digital survey vans when available. Every two years, the county has the consultant perform a complete

CRS using the same formula as IDOT. All ratings are entered into their Excel spreadsheet in order for the county to check the CRS rating. When work is completed on a segment, the county does not use the software's default updated rating. An optimistic increased rating is used instead, which is currently an assumed 12 percent increase in condition when micro-resurfacing is applied and a three percent increase in condition for the placement of crack sealing. Other data the county collects is the Equivalent Single Axle Load (ESAL) information. The ESALs are broken out by class and categorized as high, moderate, or low and used to investigate the effects of traffic on the pavement.

There are several other features of the county's PMS. Currently, McHenry County has only one deterioration curve for the network but is in the process of creating one for each of the three major surface types. No further deterioration curves were developed due to uncertainty in the composition of the pavement base layer and the county's inability to further differentiate pavement segments based on pavement structure. When more data is collected, the curves will be further updated and expanded. The county places their preventive maintenance activities on a time schedule (i.e. crack sealing is done every three to five years). They also switched from doing work on several small projects to doing long segments of roads at once. They currently have 24 segments which they identified through the construction history of the roadways.

Only one staff member is needed to do all the work with PAVEMENTview and the internal spreadsheet. When implementing the PMS, the agency wanted to also focus on an overall asset management program. Therefore, the county used additional modules in the Cartegraph software including: Signview, Stormview, Bridgeview, Custom Guardrails, Signalview, Markingview, and Work Orders. The total cost of the asset management software was $43,000, which included ten licenses for each module, four days of training, and converting existing electronic records into the software database. It cost an additional $7,000 for the ArcInfo/ ArcView GIS software and $13,000 for annual maintenance. Any additional customization was at an additional cost.

6.3.3 Successes and Challenges

The main challenge McHenry County had to overcome was the time-consuming nature of implementation. Since history data are filed in multiple locations (electronically and paper files), it became complicated and time consuming to compile all data necessary to develop the deterioration curves. One of the main issues was in creating the initial scatter plot for the deterioration curves, as the data was inconsistent when dividing it into pavement families based upon pavement surface and base types. This therefore, made it difficult to distinguish patterns within the deterioration curves.

Even though it is too early in the investment stage of the PMS to see any cost savings, McHenry County feels their PMS has been successfully implemented due to several steps the county took during the process. They made sure to educate and involve as many people in the department as possible in the implementation process. The county simplified and customized the PMS by:

- Analyzing roads in longer segments that were more likely to be constructed all at once.
- Taking cores of the pavement before repaving to have a record of the base material.
- Narrowing their focus to only concentrate on visual distresses.

The county advises other agencies to customize software programs to meet their needs and not just accept the industry norms. They also suggest that local agencies implement their PMS slowly and integrate the system over time, since it can be an overwhelming and time consuming process. "Don't try to implement all at once, slowly integrate the program into your routine."

6.4 STARK COUNTY

Stark County is a rural county located in central Illinois with a population of approximately 6,100, per the 2009 U.S. census estimates. To help maintain their network of approximately 98 miles of road in an efficient and economic manner, the county decided to implement an internally developed PMS.

6.4.1 Implementation Efforts

Stark County decided to implement a PMS because the county engineer at the time wanted to "have more *engineering* behind decisions being made." They were also looking for documentation to justify their decisions to the County Board.

To get the PMS under way, the county used information collected through web searches to aid in choosing a rating system. PCR, PCI, and PASER ratings were investigated. They chose to use the PCR but further modified it to better suit their needs. They wanted to create a rating system that was more than just a field survey.

6.4.2 Pavement Management System Characteristics

For data collection, the county decided to use a modified version of the PCR. A form for the PCR field survey that is used by the Ohio Department of Transportation (ODOT) was found on the internet. Using ODOT's forms as a basis, some changes were made to incorporate distresses that were more important to Stark County. For example, adverse crown was added into the survey for oil and chip roads with a heavier weight than other distress types since it is a critical issue to Stark County. The three versions of the survey form that were used as a basis for the development of Stark County's forms included:

- Type I – Concrete (which is not used to a great extent by Stark County because there are only a few concrete pavements in the county's system).
- Type II – Hot mix (crack sealing deficiency is the main contributing distress).
- Type III – Oil and Chip (more attention is paid to the base and adverse crown as the main contributing distresses).

Figures 44 and 45 are examples of the base rating forms for flexible pavements.

Section:__________________ **KEY** Date: ____________________

Log Mile: _______ to _______ **FLEXIBLE PAVEMENT CONDITION** Rated by: ________________

Sta:____________ to_______ **RATING FORM** ________________________

DISTRESS	Distress Weight	SEVERITY*			EXTENT**			STR ***
		L	M	H	O	F	E	
RAVELING	10	Slight Loss of Sand	Open Texture	Rough or pitted	<20%	20-50%	>50%	
BLEEDING	5	not rated	Bit and Agg visible	Black Surface	<10%	10-30%	>30%	
PATCHING	5	<1 ft².	<1 yd²	>1 yd²	<10/mile	10-20/mile	>20/mile	
POTHOLES/DEBONDING	10	depth <1" area <1 yd²	<1", >1 yd² >1",<1 yd²	>1" and >1 yd²	<5/mile	5-10/mile	>10/mile	✔
CRACK SEALING DEFIC.	5	Not considered			<20%	20-50%	>50%	
RUTTING	10	<1/4"	1/4-1"	>1"	<20%	20-50%	>50%	✔

Figure 44. Portion of key rating form for flexible pavement conditions.

Section: ________________ Date: ________________

Log mile: ______ to________ Rated by: ______________

Sta: __________ to________ ______________________

FLEXIBLE

PAVEMENT CONDITION RATING FORM

DISTRESS	DISTRESS WEIGHT	SEVERITY WT.*			EXTENT WT.**			DEDUCT POINTS***
		L	M	H	O	F	E	
RAVELING	10	0.3	0.6	1	0.5	0.8	1	
BLEEDING	5	0.8	0.8	1	0.6	0.9	1	
PATCHING	5	0.3	0.6	1	0.6	0.8	1	
POTHOLES/DEBONDING	10	0.4	0.7	1	0.5	0.8	1 ✓	
CRACK SEALING DEFICIENCY	5	1	1	1	0.5	0.8	1	
RUTTING	10	0.3	0.7	1	0.6	0.8	1 ✓	
SETTLEMENT	10	0.5	0.7	1	0.5	0.8	1	
CORRUGATIONS	5	0.4	0.8	1	0.5	0.8	1	
WHEEL TRACK CRACKING	15	0.4	0.7	1	0.5	0.7	1 ✓	
BLOCK AND TRANSVERSE CRACKING	10	0.4	0.7	1	0.5	0.7	1 ✓	
LONGITUDINAL JOINT CRACKING	5	0.4	0.7	1	0.5	0.7	1	
EDGE CRACKING	5	0.4	0.7	1	0.5	0.7	1	
RANDOM CRACKING	5	0.4	0.7	1	0.5	0.7	1 ✓	

*L = LOW **O = OCCASIONAL TOTAL DEDUCT =

M = MEDIUM F = FREQUENT SUM OF STRUCTURAL DEDUCT (✓) =

H = HIGH E = EXTENSIVE **100 - TOTAL DEDUCT = PCR =**

*** DEDUCT POINTS = DISTRESS WEIGHT X SEVERITY WT. X EXTENT WT.

REMARKS:

Figure 45. Flexible pavement condition rating form example.

The rating is subjective for each element except for adverse crown and rutting, which are physically measured in the field. Each distress is described by its severity (low, medium, high) and its extent (occasional, frequent, extensive). The distress then has a correlated weighting factor applied depending on the importance of that distress.

The 98 lane-miles of road in Stark County were broken down into segments that were approximately three to four miles in length for pavement management purposes based on the construction history of the pavement. For each of these segments, windshield surveys were taken three times per mile to ensure a large enough sample for an accurate rating. It took the engineer approximately five to ten minutes per survey sample to collect all the necessary data and take photographs of the section. Data were collected by the same person to ensure consistency in the results. The photographs and data collected in the field were later linked with the GIS system.

After the surveys are completed, the information is entered into an Excel spreadsheet where equations automatically calculate the PCR. Also within Excel, maintenance and preservation options are programmed according to the resulting PCR rating. Along with rehabilitation options, maintenance options currently being used are Cold In-Place Recycling, crack sealing, 1 ½ inch hot-mix asphalt overlay, microsurfacing, spray patching, and cold patching. Previously, the preservation efforts focused on seal cracking, but currently the county is placing more focus on hot-mix asphalt.

All collected data was stored in a spreadsheet and linked to the GIS. Stark County worked with the Illinois GIS Transportation Coalition and NAVTEQ to set up their GIS base map.

The county only invested money into a GIS system, which cost approximately $1,500 and has a $1,000 maintenance fee each year. No money was spent directly on the PMS since it was developed in-house. The county has found their investment to be worth the effort as it has assisted them in making the right pavement maintenance decisions.

6.4.3 Successes and Challenges

The county found the GIS system easy to learn. They advise that for a small agency, it was very easy and cost-effective to get started with pavement management using GIS.

6.5 CITY OF MACOMB

The City of Macomb is a municipality located in McDonough County in midwestern Illinois. As per the 2009 U.S. census estimates, the city's population is approximately 19,700. The city maintains approximately 84 lane miles of local roadways. The Public Works Director manages a staff of 34 employees within all departments of public works. The Public Works Director spends approximately 35 to 40 percent of his time working on street-related projects, with about ten percent working on pavement management related activities.

6.5.1 Implementation Efforts

In the past, the City of Macomb used consulting firms to develop short-term pavement maintenance plans. In 2004, the city hired a consultant to perform an evaluation of all city streets to determine what pavement types were present throughout the city, and establish baseline conditions. The city uses the spreadsheet developed by the consultant as a basis for their PMS.

6.5.2 Pavement Management System Characteristics

The Public Works Director conducted research and developed a rating system for use in assessing the network condition. The rating is subjective and is based on a "good, fair, poor, and failed" scale. The Public Works Director and one other staff member (or more if needed) perform windshield surveys of the pavement network to obtain a rating for each segment based on ride performance and cracking. The surveys are completed each year for the whole pavement network and usually take two weeks to complete.

This rating system is acceptable for the city's current needs and is simple to use with judgment and past experience. In conjunction with the rating system, the city developed possible treatment strategies based upon each rating, which are as follows:

- Good – Minor maintenance needed such as crack seal.
- Fair – Maintenance needed such as cape seal, Microsurface, or spot repairs.
- Poor – Major repairs needed such as mill and overlay.
- Failed – Reconstruction.

The city further categorized treatments into a selection matrix that is coded into an Excel worksheet using if/then statements that include decisions based upon roadway classification (collector, minor arterial, local street, or residential), condition (good, fair, poor or failed), surface type (asphalt, concrete, asphalt over concrete or asphalt over brick), and the drainage system of the road (curb and gutter or open ditches). With treatment selection rules developed, the city could determine triggered work types and create maps of work type need, similar to that shown in figure 45.

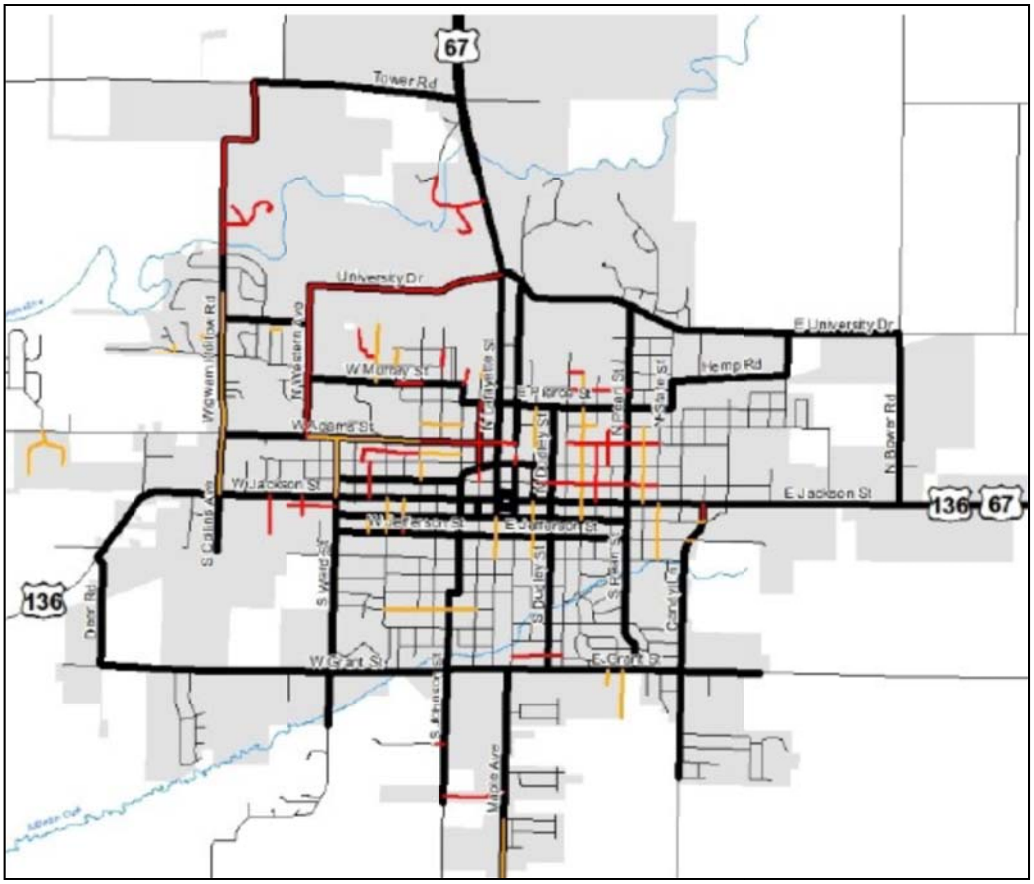


Figure 45. Sample map of roads in need of major rehabilitation or reconstruction. (City of Macomb 2011).

Each year the budget for road work must be approved by City Council. In 2010, the Public Works group proposed a half percent increase in the sales tax to support roadway needs. To gain support for the increased funding, the Public Works group developed a presentation showing how the pavement network will react with and without the proposed increase in funds. The city also had Western Illinois University use their GIS center to create maps for the presentation to City Council and the public. Currently, Western Illinois University staff and students are working along with the City of Macomb in linking their database with GIS. Once this stage is completed, the City Director is looking to expand the PMS further.

6.5.3 Successes and Challenges

During the pavement management implementation, one challenge the city faced was collecting the construction history of the pavement before 1995. The city moved forward using the available data and is updating the information as new construction records are acquired.

In terms of successful use of the pavement management system, the city was able to obtain approval for the half percent sales tax increase to support transportation funding for maintenance and rehabilitation by using the pavement management system to show the need for additional funds to preserve the road network. They accomplished this funding increase by projecting what the condition of pavement network would be in ten years with and without the funding increase and sharing the information with decision makers and constituents. The noted improvements with the additional funds were enough to convince constituents to vote for the sales tax increase.

6.6 CITY OF NAPERVILLE

The City of Naperville, Illinois is an urban municipality located in DuPage and Will counties with a population of approximately 143,000 as of the 2010 U.S. Census Bureau. The City of Naperville maintains approximately 450 centerline miles of local roadways with a current budget of about $11.6 million. In the early 1990's, the city decided to start implementing a PMS, which took more than two years to get approved and implemented.

6.6.1 Implementation Efforts

In the early 1990's, the city started conducting research on different PMS software available, with the help of other agencies using PMS. The city decided to conduct a pilot study with MicroPAVER where staff were trained on the software and implemented the system on 40 miles of roadway. The city was deterred by the cost of the pilot implementation since the option of using falling weight deflectometer testing along with the manual surveys was costly. The lack of other features, such as the ability to easily account for other assets such as driveways, sidewalks, and drainage, was also considered a limitation of the software. For these reasons, the city decided to create their own database in Microsoft Access using the structural backbone of the MicroPAVER software as a guide.

Using data from past projects, a hybrid database was created with fields to account for different street types, inventory information, and work history information. To develop the databases, the city assessed the availability of data since there was no prior documented inventory. Where needed, initial components of the database were based on estimates by the staff. These estimated values were updated to measured values as work was performed on that segment. It took approximately two years for the city to compile a complete database using quantifiable data measured from the field.

The city also developed a maintenance strategy scheme to help select appropriate work types. Naperville's maintenance strategies consist of mill and overlay, reconstruction, heat scarification and overlay, and a variety of overlay thicknesses depending on condition, as well as several different preventive maintenance strategies. The city worked specifically to incorporate preventive maintenance into their system. The database that was established by 1992 was used for years in the database form, but in 2010, the city decided to switch to MicroPAVER since the software became more affordable and more desirable to the agency needs. Information was loaded into MicroPAVER and performance prediction models were created by a consultant for use in projecting funding needs.

6.6.2 Pavement Management System Characteristics

The city uses the PASER system to rate the condition of the roadways. PASER ratings are collected for 450 centerline miles of roadway using a visual windshield survey. The initial project rating is a rough estimate made by the surveyor and is collected toward the end of summer or early fall. The city's goal is to perform inspections of the whole pavement network every three years, or one-third of the pavement network each year. The surveys are conducted by a specific group of trained technicians including one lead inspector with years of experience in surveying. It takes approximately 80 hours to collect the PASER rating for one-third of the network. When performing the current survey, the results of previous surveys are not reviewed in the field; however, they are used for comparison purposes when the surveyor returns to the office.

The database is easy to filter so that streets that have already been inventoried, or have been recently maintained, are excluded from being surveyed unnecessarily. Once a segment is maintained, the city assumes the rating reverts back to 10 (best condition). Currently, the road network in Naperville has an overall average PASER rating of 6.6.

GIS was introduced to the city in the late 1990's, at which time they linked the street network information into GIS so that all roadway segments were dynamically connected, allowing for easy mapping of information. Since GIS was introduced, it has been used heavily by the city to support pavement management activities.

Prediction models used by the city were built in Microsoft Excel and consist of models for asphalt, PCC, and asphalt over PCC (i.e. composite). Almost 40 percent of the city's network has been built since the early 1990's, resulting in full historical data for those segments. The remaining 60 percent of the network's historical data may not have been readily available, making base material composition unknown. However, with the network history data on file, the city has high confidence in forecasting three to four years in the future.

Over the years, the city continued to consider PAVER and then MicroPAVER, but neither software had all the features the agency was seeking. As MicroPAVER improved, the use of the software became more desirable to the agency, and the city decided to convert their system to MicroPAVER. The PASER ratings were converted over to PCI ratings for use in the software. With all data entered into the software, the city completed the development of a work plan and a long-term budget forecast within MicroPAVER.

In terms of staffing to support the pavement management process, there is one employee working with the PMS who spends approximately 30 to 40 percent of his time working with the system.

6.6.3 Successes and Challenges

The city produces pavement maintenance schedules yearly. The city's maintenance and rehabilitation plan consists of patching, resurfacing, microsurfacing, and crack sealing. Patching is usually done early in the pavement life so that the distresses are corrected immediately, because the city has a high expectation for its pavement network condition. Thoroughfares are resurfaced every 15 years and cul-de-sacs are resurfaced every 25 years. Generally, the network gets resurfaced on an average of every 17 years. Micro-resurfacing is performed every year on the network for those segments that are 12 to 15 years of age, except for arterials. In some cases, micro-resurfacing is applied twice on the same street in five year intervals. The city feels that micro-resurfacing treatment can extend the life of the pavement by six to ten years. With this approach, some segments may be treated too early and others too late, but the result is a better life-cycle cost. The department of public works coordinates construction activities with other city departments and clusters the maintenance activities so that customer service can be improved. As a result, the city has seen improvements in efficiency with contract management.

Previously the city was funded at $6 million to $7 million annually for the pavement program. In 2010, the city presented their analysis of the network condition to City Council to show the funding levels needed to keep the network in good condition (figure 46). The city approved additional funding for a total of $11.6 million primarily because new streets were added in the last 15 years which needed maintenance, and because of escalating construction costs between the years 2003 and 2010. The City noted that "…due to the economy, the pavement management system has become more important …" Internal staff analysis showed that a funding level of $12 million was needed; however the city felt that this should be verified by a third party. As a result, the city retained a consultant to confirm their budget needs. They also felt that hiring a consultant provided an opportune time to convert their PMS data to MicroPAVER.

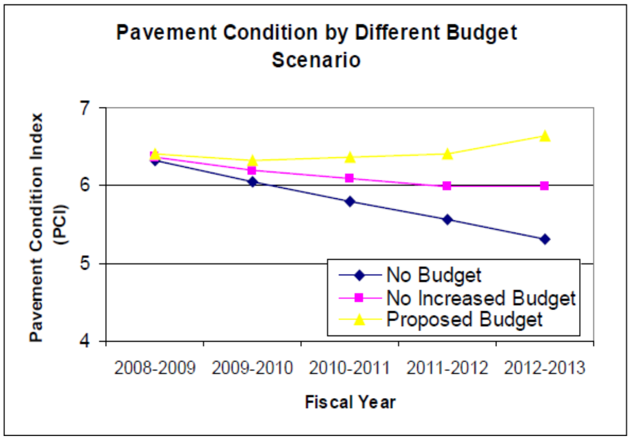


Figure 46. Analysis presented to Naperville city board for additional funding.

The Transportation, Engineering, and Development Departments are not only using a pavement management system, but have also implemented a full asset management program and are working toward integration with other city departments. The city uses an in-house program for sidewalk management, SASSIE. The Naperville Public Works Department uses *CityWorks* to manage its non-pavement assets and the Engineering and Transportation Department is looking to implement *CityWorks* as well so that all city departments can be fully integrated with one another.

6.7 VILLAGE OF VILLA PARK

Villa Park is a small village with a population of approximately 22,200 people according to the 2009 U.S. Census Bureau estimates. It is a suburb of Chicago, Illinois, and the village manages approximately 140 miles of roads.

6.7.1 Implementation Efforts

The village looked into implementing a PMS because they felt that it would be beneficial in presenting pavement needs to the Village Board for funding approvals.

6.7.2 Pavement Management System Characteristics

Villa Park chose to use IMS PavePro software with their PMS. Before deciding on the software, they investigated other software, but decided that the PavePro software meets their needs of obtaining a list of prioritized projects from which to select. The village also uses a Microsoft Excel spreadsheet for data manipulation and exporting. On each segment of the pavement network, cracking is checked and measured, and other tests are performed including the use of a Dynaflect for assessing pavement structural condition.

A consultant creates reports and prioritizes segments for the village based on a benefit ratio. The reports provided are on a five-year basis, but the village manipulates the data and provides the board with a ten-year pavement program. The system is being expanded by the consultant to include pavement preservation techniques. Preventive maintenance treatments that are applied by the village are also entered into the pavement management software by village staff.

6.7.3 Successes and Challenges

The Village of Villa Park has found significant success in sharing the recommendations of their pavement management system with decision makers and constituents through the use of GIS mapping. However, they have experienced some issues with limited ability to customize their pavement management software.

CHAPTER 7 SUMMARY & CONCLUSIONS

Pavement management systems are used by agencies to assist in identifying cost-effective strategies for preserving the pavement network and for determining the level of funding required to meet agency goals for desired levels of service. When it comes to implementing a PMS, there are several different approaches available to local agencies. Pavement management systems are flexible and can be easily tailored to meet specific agency needs and available resources.

The purpose of their research project is to develop a set of guidelines and recommendations that can be used by local agencies in appropriately implementing PMS. In order to establish a set of guidelines that will provide the best assistance in the implementation process, agencies should first be aware of the processes followed by other local agencies who have successfully implemented PMS. This synthesis was used to help craft the *Implementation Guide* and provides information on the state-of-the-art and state-of-the-practice regarding local agency PMS implementation, and includes a summary of information collected during the following:

- Literature search focused on PMS data collection methodologies, rating systems, pavement management software programs, and pavement management processes implemented by local agencies throughout the U.S.
- Current practice survey distributed to local agencies in Illinois.
- Case study interviews of selected local Illinois agencies regarding the details of their pavement management practices.

7.1 LITERATURE REVIEW

A literature review was performed to collect information regarding data collection methodologies, pavement management software programs, and pavement management processes implemented by local agencies throughout the U.S. The search revealed that there are various approaches for collecting pavement condition data. Since the collection of pavement condition data can be an expensive and time consuming process, it is important that the survey approach and methodology selected suits individual agency needs and available resources. There are several different approaches an agency can choose. The assessment of pavement condition can be estimated, where the distress quantities are based on the rater's judgment. Assessment can also be measurable where pavement condition is rated based on actual measurements of various types and severities of distresses. Using either approach, an agency can choose to either collect data via manual methods (windshield surveys, detailed walking surveys) or automated methods. The literature review details three rating systems to cover a range of complexities in terms of the procedures and methods, including PCI, PASER, and the CRS.

There are also various PMS software programs available on the market by public and private vendors. A few of the more commonly used public software programs available are MicroPAVER, RoadSoft GIS, StreetSaver, and the Utah LTAP TAMS. A variety of commonly used private software programs were also investigated. These include PAVEMENTview/PAVEMENTview Plus, PavePro Manager, PubWorks, and RoadCare. Another option available to agencies is to develop their own in-house PMS software program. Some local agencies simply use a spreadsheet or GIS application to manage their roads.

In order to assist local agencies in Illinois identify which type of PMS would best suit their needs, 24 sample local city or county agency PMS throughout the U.S. were obtained, reviewed, and documented. Detailed characteristics of the pavement management systems for the selected agencies were provided as part of the literature review. Documentation on agency size, implementation efforts, pavement condition data procedures, and pavement management software used is provided.

Through this research, institutional issues that may hinder implementation of PMS by local agencies were also identified. One issue recognized was that there may be limited technical and financial resources available at the local agency level. There may also be some perceived complexities of pavement management software and tools that will reduce the likelihood of adoption and continued use of a PMS. The implementation guide developed for this project, which is provided under a separate cover, provides recommendations for addressing these and other issues during the implementation process.

7.2 CURRENT PRACTICE SURVEY

A current practice survey was distributed to 347 local agencies in Illinois to gain an understanding of the types of pavement management systems implemented at the local level. A total of 115 responses were received from city and village municipalities, county highway departments, and local road districts. This resulted in a 33 percent response rate. Of those responding, 68 agencies (59 percent) indicated that they are involved in pavement management initiatives and have a system in place, whereas 41 percent do not.

The key findings from this current practice survey on local agency pavement management systems in Illinois are as follows:

- Of the agencies that do not have a PMS, 85 percent are interested in learning more about them.
- Most of the responding agencies with PMS are located in jurisdictions with populations of 49,999 or less, with the highest percentage (35 percent) in the 25,000 to 49,999 range. This reveals that not all pavement management systems are implemented by large agencies.
- Of the responding agencies with PMS, 71 percent manage lane miles of roadway from less than 100 miles up to 300 miles, with the largest proportion (34 percent) between 100 and 200 road miles.
- Of the responding agencies with a PMS, 79 percent are affiliated with Metropolitan Planning Organizations in their jurisdictions.
- Nearly half (48 percent) of agencies with a PMS have had them implemented for over ten years, and 72 percent of the responding agencies had their PMS implemented for more than five years.
- Nearly half of responding agencies (49 percent) use paper or electronic spreadsheets. Agencies are also widely using MicroPAVER for their pavement management software program.
- Nearly 70 percent of the responding agencies with PMS indicated that they perform windshield surveys to collect their pavement condition data. 37 percent indicated that detailed walking surveys are conducted, while 30 percent of responding agencies use automated vans. When analyzing the results, it was observed that a majority of agencies use more than one strategy of collecting condition data.
- In terms of the pavement conditions ratings used by agencies with PMS, it was observed that some use several different types of rating systems in their PMS. Over 50 percent of responding agencies use PCI; over 20 percent use a general good, fair, poor rating; 15 percent use PASER; and 15 percent of responding agencies use OPI as their rating systems.
- Of the responding agencies, 65 percent use data from the PMS to make investment decisions once a year. The vast majority (87 percent) responded that they are using their PMS at least annually to make investment decisions.

- Of the 51 agencies who answered the question about budget amounts, 25 percent do not have a specified budget for their PMS. For those agencies that do have a budget, 53 percent of responding agencies have up to $30,000 budgeted for the PMS, and 12 percent spend over $100,000 annually on their PMS.

7.3 CASE STUDIES

As a part of this project, case studies of local agencies that responded to the online survey, and that have implemented a PMS, were selected and highlighted. The agencies selected include a range of agency types/sizes, pavement management software programs, data collection strategies, and analysis methodologies. The research team conducted on-site interviews of representative local agencies willing to participate in this project to obtain details and insights on their PMS implementation and practices. The case study agencies interviewed were Champaign County, Edgar County, McHenry County, Stark County, City of Macomb, City of Naperville, and the Village of Villa Park. The case studies included assessment and implementation overviews of the PMS used by each agency. A few key quotes from the interview process include:

- The City of Naperville feels that “due to the state of the economy, the pavement management system has become more important.”
- Since Champaign County implemented their PMS, they are “now able to reduce political pressure,” when making pavement management decisions.
- The need for Edgar County’s PMS was recognized as the county wanted to have a systematic process in place for completing the “right work at the right time for the right reasons.”
- McHenry County encourages other agencies, “Don’t try to implement a PMS all at once, slowly integrate the program into your routine.”
- Stark County decided to implement a PMS because they “wanted to have more *engineering* behind decisions.”

7.4 SUMMARY

This report provides a synthesis of the literature search, the current practice survey of local agency pavement management systems, and the case study interviews that were conducted as part of this study. This document is a supplement to the *Implementation Guide* also developed in a separate document as a part of this research study.

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APPENDIX A

SUMMARY OF U.S. LOCAL AGENCY PMS IMPLEMENTATIONS

No.	County/City	Agency Type	State	Miles of Road in PMS	County/City Population as per 2009 Census Estimates	No.	County/City	Agency Type	State	Miles of Road in PMS	County/City Population as per 2009 Census Estimates
1	Bowling Green	City	Kentucky	470	56,598	13	Merced	County	California	1,727	245,321
2	Chittenden	County	Vermont	N/A	152,313	14	Modesto	City	California	1,130	211,156
3	Delhi	City	Ohio	55	30,100	15	Philadelphia	City	Pennsylvania	>2,000	1,547,297
4	Dublin	City	Ohio	419	39,297	16	Pierce	County	Washington	1,400-1,600	796,836
5	Folsom	City	California	237	67,807	17	Sacramento	County	California	N/A	1,400,949
6	Genesee	County	Michigan	1203	424,043	18	Seal Beach	City	California	N/A	24,238
7	Hillsborough	County	Florida	6,200 (lane miles)	1,195,317	19	Sonoma	County	California	1,387	472,102
8	Iowa Counties, cities and statewide	County & City	Iowa	23,500	2,982,085	20	Southeast Region	County & City	Michigan	12,450	Varies
9	Jackson	County	Missouri	500	705,708	21	Tinley Park	City	Illinois	240	59,000
10	Kansas	City	Missouri	2200	482,299	22	Tooele	City	Utah	144	30,708
11	Los Angeles	City	California	7200	3,831,868	23	Travis	County	Texas	1,220	1,026,158
12	Marion	County	Florida	2,300 (paved) and 500 (unpaved)	328,547	24	Buckley, Burlington, Langley, Prosser & Steilacoom	City	Washington	Varies	1,806-8,704

*N/A indicates information not documented in the publications

No.	Pavement Management System Description							
	Data Collection Techniques	Frequency of surveys	Distress Survey(s) Conducted	Who Collects the data?	Management Software Used	PMS Rating System	No. Years PMS in Place/ Year PMS was Implemented	PMS Annual Budget
1	Automated Vans	Every 3 years	Physical and Roughness Distress	Consultant	Pavement Management Application (PMA)	Surface Distress Index, Ride Comfort Index, Structural Adequacy Index, and Pavement Quality Index	1997	≈$650,000
2	N/A	N/A	Physical Distress	N/A	MicroPAVER	Pavement Condition Index (PCI)	N/A	N/A
3	Windshield Survey	Every 2 years	Physical Distress	In-house staff	Customized developed by consultant	Pavement Condition Index (PCI)	1988	N/A
4	N/A	Every year	Physical Distress	N/A	N/A	Distress point deduct system for three distress types, based on severity	N/A	N/A
5	Walking survey	Every 5 years	Physical Distress & Structural capacity	In-house staff	MicroPAVER transition into GBA Street Master	Pavement Condition Index (PCI)	1999	≈$1,100,000
6	Windshield Survey	Every year	Physical distress	In-house staff	RoadSoft	PASER rating system	2003	≈$7,400,000
7	Automated Vans	N/A	N/A	Consultant	Hansen Infrastructure Management System	Rated good, fair, or poor	N/A	N/A
8	Automated video images collected by an ARAN van	N/A	Physical Distress	N/A	IMPM GIS-based database	N/A	N/A	N/A
9	N/A	N/A	Physical Distress, Roughness, Structural Capacity, Friction	N/A	Accela Government Software	Pavement Condition Index (PCI)	N/A	N/A
10	Walking Survey	Every 3 years	N/A	In-house staff	Spreadsheet w/ ArcView	Pavement Condition Index (PCI)	2000	N/A
11	Automated Vans	N/A	Physical Distress	In-house staff	MicroPAVER	Pavement Condition Index (PCI)	1998	N/A
12	Manual Field Collection and Automated Satellite Imaging	N/A	Physical Distress	N/A	ArcPad	N/A	N/A	N/A

*N/A indicates information not documented in the publications

No.	Pavement Management System Description							
	Data Collection Techniques	Frequency of surveys	Distress Survey(s) Conducted	Who Collects the data?	Management Software Used	PMS Rating System	Year PMS was Implemented	PMS Annual Budget
13	Manual Windshield Surveys	N/A	Physical Distress	In-house staff	Customized Simplistic System	Overall Condition Index (OCI) or good/fair/poor	N/A	≈$7,700,000
14	N/A	Every 2 years	N/A	N/A	StreetSaver	Pavement Condition Index (PCI)	N/A	N/A
15	Walking or Windshield survey	N/A	Physical Distress	In-house staff	Spreadsheet w/ GIS	Pavement Condition Index (PCI)	2001	N/A
16	Manual Visual Surveys	Half the county every year	Physical Distress	N/A	ArcPad	Roads are assigned a score of 0 (poor) to 100 (good); achieve Lowest Life Cycle (LLC) Cost	N/A	$15 million
17	N/A	Every 1 to 3 years	Physical Distress	N/A	StreetSaver	Pavement Condition Index (PCI)	N/A	N/A
18	Manual Visual Surveys	N/A	Physical Distress	Consultant	In-house developed PMS	Pavement Condition Index (PCI)	2002	N/A
19	Manual Visual Surveys	N/A	N/A	N/A	StreetSaver	N/A	N/A	N/A
20	N/A	N/A	N/A	N/A	Customized by Consultant	N/A	N/A	N/A
21	N/A	Every 4 years	N/A	In-house staff	In-house database and deterioration curves	Overall Condition Index (OCI)	Late 1990's	N/A
22	N/A	N/A	Physical Distress	Utah LTAP	Utah LTAP	Low, medium, high rating of extent and severity of governing distress	N/A	N/A
23	Automated Digital Imaging Survey	Every few years	Physical Distress	Consultant	Cartegraph PAVEMENTview Plus	N/A	N/A	N/A
24	Manual Surveys	N/A	Physical Distress	In-house staff	Customized Simplistic System	Pavement Condition Rating with deduct values	N/A	N/A

*N/A indicates information not documented in the publications

APPENDIX B

STATE-OF-THE-PRACTICE SURVEY INSTRUMENT

A-1

1. Please provide the following contact information.

Name:

Title:

Agency:

Address:

Telephone:

Email:

2. Please indicate your agency type.

- Municipality
- County
- Road District
- Other, please specify

3. How many lane miles of roads does your agency maintain?

4. The majority of your agency's road miles are located in what area type?

- Rural
- Suburban
- Urban

5. Is your agency a part of a Metropolitan Planning Organization (MPO)?

- No
- Yes, please list

6. What is the approximate population of your jurisdiction?

7. Does your agency currently maintain an active pavement management system (e.g., paper, electronic spreadsheets, or software program)?

Pavement management systems are used by agencies to assist in identifying cost-effective strategies for preserving the pavement network and for determining the level of funding required to meet agency goals for desired levels of service. An agency can use its pavement management system to evaluate various pavement rehabilitation, maintenance, and preservation strategies on the future condition of the pavement network for various budget levels.

- ○ Yes
- ○ No, but I am interested in knowing more about pavement management
- ○ No, and I am not interested in knowing more about pavement management

8. How long has your agency's pavement management system been in place?

- ○ < 2 years
- ○ 2 to 5 years
- ○ 5 to 10 years
- ○ > 10 years

9. Please describe the type of PMS software program used at your agency. Select all that apply.

- ☐ Paper or electronic spreadsheets developed internally by agency staff
- ☐ Paper or electronic spreadsheets developed by an outside consultant
- ☐ MicroPAVER
- ☐ RoadSoft
- ☐ Utah LTAP Transportation Asset Management Software (TAMS)
- ☐ Cartegraph's PAVEMENTview
- ☐ PubWorks
- ☐ Road Care
- ☐ Visual RB IMS
- ☐ Other, please specify

10. Approximately what proportion of your agency's total road miles are recorded in your PMS?

- 0 to 25 percent
- 26 to 50 percent
- 51 to 75 percent
- 75 to 100 percent

11. What procedure does your agency use to collect condition data? Select all that apply.

- Windshield surveys
- Detailed walking surveys
- Automated vans
- Combination/other, please specify

12. Who collects the condition data? Select all that apply.

- In-house staff
- Consultant/vendors
- Combination/other, please specify

13. How often does your agency conduct pavement condition inspections?

- Every year
- Once every two years
- Once every three years
- Other, please specify

14. Approximately what proportion of your agency's total road miles is inspected each time you conduct pavement condition inspections?

- 0 to 25 percent
- 26 to 50 percent
- 51 to 75 percent
- 75 to 99 percent
- 100 percent

15. Please indicate what type(s) of pavement condition data are incorporated into your agency's PMS. Select all that apply.

- ☐ Pavement surface distress - measure of road surface deterioration
- ☐ Roughness data - measure of ride quality
- ☐ Structural capacity - ability of pavement to support traffic with little or no structural damage
- ☐ Friction data - measure the skid resistance of the pavement

16. What type of condition rating does your agency use to evaluate pavement condition. Select all that apply.

- ☐ General ratings of good, fair, poor
- ☐ Pavement Condition Index (PCI)
- ☐ PASER rating (1 to 10)
- ☐ Present Serviceability Index (PSI)
- ☐ Overall Pavement Index
- ☐ Condition Rating Survey (CRS)
- ☐ Other, please specify

17. How often does your agency use data from the PMS to help make investment decisions?

- ○ More than once a year
- ○ Annually
- ○ Every 2 to 3 years
- ○ More than every 3 years
- ○ Other, please specify

18. Please specify your agency's annual pavement management budget (e.g., cost of software, condition data collection, etc.)

Total budget ($/year):

Budget per mile ($/mile/year):

19. Would you/your agency be interested and able to participate further in this research project?

If you indicate "Yes", we may contact you about serving as a case study agency.

As a part of this project, case studies of local agencies that have implemented a PMS will be selected and highlighted. The study will include a range of agency types/sizes, pavement management software programs, data collection strategies, and analysis methodologies. The research team consisting of professionals from Applied Pavement Technology, Inc. and Bradley University will then conduct on-site interviews of representative local agencies willing to participate in this project to obtain details and insights on their PMS implementation and practices.

- ○ Yes
- ○ Not at this time

APPENDIX C

ON-SITE CASE STUDY INTERVIEW QUESTIONS

INTERVIEW PACKET

Introduction

Pavement management systems are used by agencies to assist in identifying cost-effective strategies for preserving the pavement network and determining the level of funding required to meet agency goals for desired levels of service. An agency can use its pavement management system to evaluate various pavement rehabilitation, maintenance, and preservation strategies and to estimate the impact of those strategies on the future condition of the pavement network for various budget levels.

Research Project R27-87, *Implementing Pavement Management Systems for Local Agencies*, is being conducted by Applied Pavement Technology, Inc. (APTech) and Bradley University through the Illinois Center for Transportation (ICT) at the University of Illinois with support from the Illinois Department of Transportation (IDOT) to develop guidelines to help local agencies interested in implementing a pavement management system (PMS). The results of this initiative will provide the information necessary for local agencies to learn more about pavement management and the steps involved in its implementation. Because of your agency's experiences with pavement management and your willingness to assist us with this project, members of the research team will conduct on-site interviews to obtain details and insights on your PMS implementation and practices. The information we receive will be used to help shape the guidelines being developed to support other local agencies' pavement management efforts.

Thank you in advance for agreeing to participate in the interviews. In an effort to streamline the process, the project team has created this interview packet containing information about the interviewers and examples of the types of questions that will be asked. If you have any questions prior to the interviews, please contact Ms. Angie Wolters of APTech at awolters@appliedpavement.com or 217-398-3977. Information about the research study can be obtained from Mr. Kevin Burke of IDOT at Kevin.BurkeIII@illinois.gov or 217-785-5048.

Meet the Interview Team

The pavement management interviews will be conducted by Ms. Angie Wolters, P.E., Mr. Brian Pfeifer, P.E., and Ms. Ashley Rietgraf. Ms. Wolters is a Pavement Engineer with APTech and is serving as the Principal Investigator for this study. Ms. Wolters earned her B.S. and M.S. in Civil Engineering from the University of Illinois and has been working in the area of pavement management since 2000. Mr. Pfeifer serves as the Asset Management Program Specialist for the Illinois Division of the Federal Highway Administration. He is currently a member of the Technical Review Panel for this research study and will serve as an instructor for *Transportation Asset Management for Local Agencies*, which was recently developed through the National Highway Institute. . Ms. Rietgraf is assisting with this research study as part of her graduate studies in the civil engineering department at Bradley University.

Sample Interview Questions

The following questions are provided to give you an indication of the interview topics that will be covered. These questions will be customized for each agency interviewed based on the specifics of your practices. Please note that we do not expect to go through the questions in the order in which they are listed. Rather, we will ask you to describe your practices and we will use the questions to help ensure that we have covered each topic sufficiently. Therefore, there is no reason for you to prepare written responses to these questions prior to the interview.

If you have suggestions for other topics that might be relevant to your pavement management practices, please bring them up at any time during the interview. *Also, if you have any documentation regarding your pavement management practices, the research team would appreciate a copy of the information, if possible.* The interview team expects to spend approximately 2 hours with your staff that is involved in your pavement management processes. We will begin by discussing the general outlined questions and proceed to the others as time permits.

General

1. What motivated your agency to start using a pavement management system? Was it difficult to build support for this activity? What hurdles did you have to overcome? Is there continued support for the agency's pavement management activities?
2. How did your agency select your current pavement management system? Once you selected your system, what other steps did you take to implement your process?
3. What have been the keys to your successful pavement management implementation? Have there been any specific challenges?
4. Are available resources (money, personnel, and so on) adequate to meet the level of effort needed to maintain your pavement management processes? What is the current allocation of personnel? Do you use vendor or consultant support to fulfill your staffing needs? If so, what does this additional assistance cost?
5. What has been your investment in implementing and maintaining your pavement management system (e.g., software costs, consultant fees, staffing costs, etc.)?
6. Has pavement management saved your agency money? Have pavement conditions improved since you started using pavement management? What other benefits has it provided to your agency? Explain your answer.
7. Describe your system in terms of how easy it is to implement and operate.
8. What are the biggest advantages and disadvantages to your particular pavement management software?
9. If you were to do it all over again, what would you do differently? What advice would you give your peers?
10. Please describe your pavement management practices in terms of your annual schedule (e.g., when are the surveys conducted, when is the data processed/analyzed, when are treatments selected, etc.).

Data Collection

1. What inventory data is currently stored in the pavement management system? *If possible, please provide the interview team with a data dictionary of the information you are storing or an electronic example of stored inventory information from the pavement management system.*
2. Is there inventory data that wish you had available? Is there information collected by other identities such as IDOT or regional transportation groups that would be beneficial for you to have?
3. What pavement condition information is currently being collected? How is it obtained? How often? How did you decide on this rating method?
4. What length of sample is inspected as part of the data collection process? Is this length adequate for the type of decisions being made? Does it work well for the raters? Are additional samples rated if sample conditions vary considerably?
5. Does your agency have adequate resources to continue monitoring pavement conditions? What level of resources is currently allocated to this activity (both internally and externally)? How many samples can be inspected per day?

Data Management

1. Are there other management systems used throughout your agency that share data with pavement management? Are there any known instances of duplicate data collection or data storage activities between the pavement management system and these other systems? Is the level of integration appropriate?
2. Who are the operators of the pavement management system? Do others need direct access to the pavement management information? Is access provided to those who need it? What format is used to provide access (e.g., GIS)?
3. Is there an interface between the pavement management system and your GIS?
4. What portions of data management and analysis are conducted internally and what parts are conducted by a consultant?

Data Reporting

1. What information from your pavement management processes is shared with decision makers and stakeholders and in what format? Is there a specific format that you present this data in? *Please share any example report documents or graphics you might have.*
2. How much confidence do stakeholders have in the information provided by the pavement management system? What is the basis for your answer?

Deterioration Prediction

1. Does your pavement management system include some type of pavement deterioration prediction? If so, how often do you update these performance models?
2. Do the models adequately take into consideration differences in pavement performance due to traffic factors, climatic conditions, material properties, and construction issues? What other factors should be considered in predicting pavement performance?

Analysis of Need

1. Does your pavement management system incorporate treatment selection rules and unit cost information to identify work types and calculate project costs within the system? *If so, please provide a copy of the treatment selection rules.* What factors differentiate the use of the various treatments?
2. Describe the process that is used to identify maintenance, resurfacing, and reconstruction needs within the agency.
3. What would you consider to be the strengths and weaknesses in the current process? How do you think the process can be improved?
4. Who receives information on pavement needs? How is it used?

Selection of Investment Decisions

1. Identify and prioritize the factors that influence the project selection process. In other words, what factors influence the projects that are eventually selected for maintenance and resurfacing? How do you incorporate the “importance” of the road in your selection process?
2. What percent of the recommendations from the pavement management system make it into the program?

Impact Analysis

1. Are the results of the condition analysis and their impact on the maintenance and rehabilitation plans effectively communicated to decision makers? To the public? To other stakeholders?

2. What format is the information provided in? When is it presented?
3. Are the results of the impact analysis linked to chosen funding levels?