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Understanding Asset Management Systems Utilized by Municipalities in Massachusetts

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16. Abstract

A MassDOT goal is to have an overall idea of the pavement condition of state and local roads in Massachusetts. This study cataloged the different pavement management systems (PMS) being used by municipalities, Metropolitan Planning Organizations (MPOs), and Regional Planning Agencies (RPAs) throughout Massachusetts.

A comprehensive literature review was performed. An internet-based survey was developed and administered to Massachusetts local/regional agencies. Some follow-up interviews were conducted. The potential for using a unified PMS software within the state was explored.

The study compared 13 different PMS software programs currently being used in Massachusetts. Each has unique approaches to condition data collection. Each calculates distress/condition indices differently, thus the same condition data could yield different results when calculated using different software programs.

The potential of using a unified PMS software for MPOs/RPAs in Massachusetts was explored. Vendors held virtual demonstrations of selected PMS software; there was no consensus on software preference reached.

Overall, this study helps outline the existing PMS state of practice at the local and regional level in Massachusetts and identifies obstacles that lay ahead in achieving MassDOT's goal to have an overall idea of the pavement condition in Massachusetts, for both state and local roads.

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Understanding Asset Management Systems Utilized by Municipalities in Massachusetts

Final Report

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Disclaimer

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Executive Summary

Massachusetts has approximately 36,700 centerline miles of roadways. About 3,000 miles are under Massachusetts Department of Transportation (MassDOT) jurisdiction and 33,700 miles are under municipal or other jurisdictions. Conditions on MassDOT's 3,000 miles are reported annually to the legislature and 3,361 miles of National Highway System (NHS) roadways are reported through the Highway Performance Monitoring System (HPMS). Combined, this represents only 11.4 percent of the Commonwealth's 36,700 roadway miles. Condition data on the remaining 32,500 (88 percent of the mileage) remains unreported. Many cities and towns in Massachusetts have implemented asset management systems utilizing differing approaches. Though municipalities and regions invest in pavement management systems, there is no process or infrastructure in place to assemble this data to achieve a state-wide perspective. The main goal of this study was to catalog the different pavement management systems being used by municipalities, Metropolitan Planning Organizations (MPOs), and Regional Planning Agencies (RPAs) throughout Massachusetts. Ultimately it is MassDOT's goal to have an overall idea of the pavement condition in Massachusetts for both state and local roads with corresponding backup data (and a means to report such data). This research represents the initial steps in attaining this goal.

The research methodology utilized for this study included

- Conducting a literature review to determine if other states within the United States have conducted any similar studies
- Developing and administering an internet-based survey to gather information related to local level asset management from each municipality, MPO, and RPA in Massachusetts
- Conducting interviews of selected online survey participants to obtain greater depth and insights into that agency's Pavement Management System (PMS) and how their PMS impacts their investment decisions.
- Exploring/investigating the idea of a unified PMS software to be used by the MPOs and/or RPAs in Massachusetts.

The literature review showed there were some research studies conducted regarding local agency PMS practices and data in the 1980s and 1990s. The focus of the majority of these studies was the development and establishment of PMS systems, condition surveys, the calculation of indices, prioritization, etc. None of the studies were directly related to cataloging the PMS systems being used within a state, how the data was reported, or how the data was included in the overall pavement condition reporting for the state. There was also no information on how local agency data was used in overall decision-making beyond local prioritization of priorities. Thus, the literature review indicated that the objectives of this study were unique and have not been attempted prior to the start of this study.

A 35-question internet-based survey was developed which consisted of the following sections: demographic information about the respondents, information related to the agency, general information about their PMS, specific details about their PMS, and information about investment decisions. The survey was distributed to a list of 2,000 contacts representing 320 municipalities and 14 MPOs/RPAs in Massachusetts for solicitation of responses. The survey response rate was 5.8 percent which consisted of responses from 109 municipalities (towns and cities) and 15 MPO/RPA representatives. Significant findings from the internet survey included

- Currently there are 13 different PMS software programs being used in Massachusetts.
- 93 percent of respondents indicated that they have an inventory for their roads.
- 81 percent of respondents currently maintain an active PMS.
- Many different procedures are used to collect condition data. Windshield surveys and detailed walking surveys were the most noted by respondents.
- Condition data is collected by in-house staff, consultants/vendors, or a combination of both.
- For the majority, 76 to 100 percent of all road miles are included in an agency's PMS.
- Condition inspection frequency varies, but annually and every three years were the most noted.
- Condition data collected consists primarily of pavement surface distress and roughness.
- Seven different condition rating systems (indices) are being utilized.
- For the majority of respondents, their PMS is used to make investment decisions annually or more than once in a year.
- Budgets for pavements are primary based on an annual budget as opposed to a lump sum for a period of time.

Interviews of selected online survey participants were conducted to gain greater depth and insights into the agency's PMS and how their PMS impacts their investment decisions. Fourteen interview questions were developed that focused on the following: data management, data reporting, deterioration prediction, if their PMS incorporates treatment selection rules and unit cost information, investment decisions, and the impact of implementing a PMS on maintenance and rehabilitation plans. Interview participants were drawn from both municipalities and MPOs/RPAs. Representatives of six municipalities and nine MPOs/RPAs were interviewed. Significant findings from the interviews included the following:

- For municipalities, PMS software selection was based on user friendliness, availability of open-source software (i.e. reduced cost), compatibility with existing condition survey practices, capability to include other municipal asset work (utilities), and recommendations from other municipal users. For MPOs, software selection was based on legacy (already in use at the agency), being part of a group-based purchase for multiple MPOs at the same time, initial setup and annual maintenance costs, and compatibility with existing GIS systems.

- Municipal investment decisions made with PMS data included recommendations of repair methods, cost-benefit analyses, planning decisions, and development of capital plans. MPOs generally did not make investment decisions with their PMS data.

- Treatment selection and unit costs were typically handled by the chosen PMS software for both municipalities and MPOs. Generally, municipalities have the option to include treatments that are not included in their PMS software.

- No municipalities or MPOs collected any structural condition data.

- Deterioration prediction was typically completed by the PMS software utilized by both municipalities and MPOs.

- Little information was available/known on exactly how condition indices were calculated. These calculations were generally made by the PMS software. No information was available on how distresses were weighted in a combined index like Pavement Condition Index (PCI) or Overall Condition index (OCI). It appears these calculations were left to the discretion of the PMS software supplier during initial setup. It should be noted that municipalities and MPOs/RPAs generally have the option of changing the types of distresses and their associated weights when calculating indices.

Finally, the potential of using a unified PMS software for MPOs/RPAs in Massachusetts was explored. Interviews conducted with MPOs and RPAs indicated that they would be willing to consider switching to a unified PMS software package if MassDOT would be willing to pay for and support it. Based on this positive response, a virtual demonstration day of selected PMS software vendors was held. The top three commercially available PMS software vendors identified by the internet survey and interviews were invited. During this day, these PMS software vendors showcased their software and answered related questions. Then a follow-up online survey was developed to determine feedback regarding the demonstration day. The survey indicated that there was no consensus among MPOs/RPAs as to which software was preferred. Various reasons were supplied by the MPOs/RPAs as to why each software was either selected or not selected. This suggests that implementing a unified PMS software for the MPOs/RPAs may be challenging.

Overall, this study helps outline the existing PMS state of practice at the local and regional level in Massachusetts. It also helps identifies obstacles that lay ahead in achieving MassDOT's goal to have an overall idea of pavement conditions in Massachusetts for both state and local roads.

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List of Acronyms

Acronym	Expansion
AADT	Annual Average Daily Traffic
AC	Asphalt Concrete
ADT	Average Daily Traffic
ALDOT	Alabama Department of Transportation
BMPO	Berkshire Region Metropolitan Planning Organization
BRMPO	Boston Region Metropolitan Planning Organization
BRPC	Berkshire Regional Planning Commission
CCC	Cape Cod Commission
CCMPO	Cape Cod Metropolitan Planning Organization
CMMPO	Central Massachusetts Metropolitan Planning Organization
CMRPC	Central Massachusetts Regional Planning Commission
CTPS	Central Transportation Planning Staff
CTRE	Center for Transportation Research and Education
FAE	Federal Aid Eligible
FCTPO	Franklin County Transportation Planning Organization
FHWA	Federal Highway Administration
FRCOG	Franklin Regional Council of Governments
GIS	Geographical Information System
HPMS	Highway Performance Monitoring System
IDOT	Illinois Department of Transportation
IPMP	Iowa Pavement Management Program
IRI	International Roughness Index
ISTEA	Intermodal Surface Transportation Efficiency Act
LTAP	Local Technical Assistance Program
MAPC	Metropolitan Area Planning Council
MassDOT	Massachusetts Department of Transportation
MMPO	Montachusett Metropolitan Planning Organization
MPO/MPOs	Metropolitan Planning Organizations
MRC	Measurement Research Corporation
MRPC	Montachusett Regional Planning Commission
MTO	Ministry of Transportation of Ontario
MTTC	Massachusetts Technology Transfer Center
MVC	Martha's Vineyard Commission
MVMPO	Merrimack Valley Metropolitan Planning Organization
MVPC	Merrimack Valley Planning Commission
NHS	National Highway System
NMCOG	Northern Middlesex Council of Governments
NMMPO	Northern Middlesex Metropolitan Planning Organization
NPEDC	Nantucket Planning and Economic Development Commission
NWPMA	Northwest Pavement Managers Association
NWPMUG	Northwest Pavement Management Users' Group

Acronym	Expansion
OCI	Overall Condition Index
OCMPO	Old Colony Metropolitan Planning Organization
OCPC	Old Colony Planning Council
PCC	Portland Cement Concrete
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PMS	Pavement Management System
PMUG	Pavement Management User Group
PSI	Present Serviceability Index
PVMPO	Pioneer Valley Metropolitan Planning Organization
PVPC	Pioneer Valley Planning Commission
RCR	Ride Condition Rating
RIDOA	Rhode Island Department of Administration
RIDOT	Rhode Island Department of Transportation
RPA/RPAs	Regional Planning Agency
RSL	Remaining Service Life
RSR	Roadway Surface Rating
SMMPO	Southeastern Massachusetts Metropolitan Planning Organization
SRPEDD	Southeastern Regional Planning and Economic Development District
SPR	State Planning and Research
TAMS	Transportation Asset Management System
TIP	Transportation Improvement Projects
TPOs	Transportation Planning Organizations
URI	University of Rhode Island
VDOT	Virginia Department of Transportation
VSR	Visual Inspection Rating
VTRC	Virginia Transportation Research Council
WSDOT	Washington State Department of Transportation
WSPMS	Washington State Pavement Management System

1.0 Background and Objectives

This study of Asset Management Systems Utilized by Municipalities in Massachusetts was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

1.1 Background

Massachusetts has approximately 36,700 centerline miles of roadways. About 3,000 miles are MassDOT jurisdiction and 33,700 miles are municipal or other jurisdictions. Conditions on MassDOT's 3,000 miles are reported annually to the legislature and 3,361 miles of NHS roadways are reported through the Highway Performance Monitoring System (HPMS). Combined, this represents only 11.4 percent of the Commonwealth's 36,700 roadway miles. Condition data on the remaining 32,500 (88.6 percent of the mileage) remains unreported. Many cities and towns have implemented asset management systems utilizing differing approaches including utilization of in-house staff, consultant contracts, universities, and contracts with Metropolitan Planning Organizations (MPOs). Though municipalities and regions invest in pavement management systems, there is no process or infrastructure in place to assemble this data to achieve a state-wide perspective. The main goal of this study is to catalog the different pavement management systems being used by municipalities, MPOs, and RPAs throughout Massachusetts.

Pavement management systems (PMS) have many uses. They begin with the most fundamental condition reporting and establish benchmarks from which to monitor performance trends. Pavement management systems also allow modeling that predicts future performance based on varied investment levels. At the highest level of maturity, pavement management systems can support optimized project selection through which the benefit of every dollar spent is maximized.

The Commonwealth of Massachusetts has 351 cities and towns within its jurisdiction. It also has ten MPOs and three other Transportation Planning Organizations (TPOs), each of which have a Regional Planning Agency (RPA) which conducts planning activities on behalf of the MPO or TPO:

1. Berkshire Region Metropolitan Planning Organization (BMPO)
    a. Berkshire Regional Planning Commission (BRPC)
2. Boston Region Metropolitan Planning Organization (BRMPO)
    a. Metropolitan Area Planning Council (MAPC)
        i. Central Transportation Planning Staff (CTPS)
3. Cape Cod Metropolitan Planning Organization (CCMPO)
    a. Cape Cod Commission (CCC)

4. Central Massachusetts Metropolitan Planning Organization (CMMPO)
    a. Central Massachusetts Regional Planning Commission (CMRPC)
5. Franklin County Transportation Planning Organization (FCTPO)
    a. Franklin Regional Council of Governments (FRCOG)
6. Martha's Vineyard Commission (MVC)
7. Merrimack Valley Metropolitan Planning Organization (MVMPO)
    a. Merrimack Valley Planning Commission (MVPC)
8. Montachusett Metropolitan Planning Organization (MMPO)
    a. Montachusett Regional Planning Commission (MRPC)
9. Nantucket Planning and Economic Development Commission (NPEDC)
10. Northern Middlesex Metropolitan Planning Organization (NMMPO)
    a. Northern Middlesex Council of Governments (NMCOG)
11. Old Colony Metropolitan Planning Organization (OCMPO)
    a. Old Colony Planning Council (OCPC)
12. Pioneer Valley Metropolitan Planning Organization (PVMPO)
    a. Pioneer Valley Planning Commission (PVPC)
13. Southeastern Massachusetts Metropolitan Planning Organization (SMMPO)
    a. Southeastern Regional Planning and Economic Development District (SRPEDD)

Eleven of these organizations have some form of pavement asset management. What is unclear is how much they do on behalf of the MPOs, how/what type of data they are collecting, and how they are using this to influence capital investment decision-making at the local/regional level. These same unknowns, along with what type of asset management is being used, exist for each of the individual towns/cities throughout the Commonwealth. MassDOT needs to identify what type of pavement asset data is being collected, who collects the data, and what these organizations then do with the data. Ultimately it is MassDOT's goal to have an overall idea of the pavement condition in Massachusetts for both state and local roads with corresponding backup data (and a means to report such data). This research represents the initial steps in attaining this goal.

1.2 Objectives

The objectives of this study were as follows:

1. Catalog the different asset management systems being used by cities, towns (municipalities), Metropolitan Planning Organizations (MPOs), and Regional Planning Agencies (RPAs) throughout Massachusetts.

2. Prepare a report describing the different asset management systems used, type of data collected, and how that data is being utilized in decision-making. The report would also include recommendations on how MassDOT can work with local and regional partners to assess pavement condition and future reporting.

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2.0 Literature Review

2.1 Introduction

The research team from UMass Dartmouth conducted a thorough literature review to determine if other states within the United States have conducted any similar studies. Effort was expended to find literature that outlines any state experience with cataloging pavement management systems being used throughout their state at the local level, means of incorporating and reporting local pavement conditions by a state agency, any methods being used to compile and harmonize the data from all these local agencies, and what the data is ultimately being used for in terms of decision-making. The sources for this literature review were research reports published by state agencies, other governmental agencies, and any papers published in journals by the Transportation Research Board and the American Society of Civil Engineers.

2.2 Overview of a Pavement Management System

The primary goal of a pavement management system is to provide information and guidance to road managers (or any member of the respective field) so that more cost-effective, justifiable, and reliable decisions can be made. The idea is to assist in creating a balance of minimizing the money spent while maximizing the lifecycle and desired performance of any roads within an agency's jurisdiction. Pavement management systems can aid managers or executive representatives in providing solid support and logistical evidence if the agency needs additional funds *(1).*

Pavement management systems can operate on two distinct levels of work, and an ideal one will be able to cover both levels. The first level of a pavement management system is the network level. This level is the core focus of this project as it will cover the entire pavement network within an agency, such as state, city, etc. This level will be capable of assisting with required budget estimations and performance predictions based on practices by the agency and historical records available. The other level of a pavement management system is known as the project level. Project level pavement management systems will operate on a smaller scale and have a greater focus on the details of specific roadways. This level is typically consulted during construction, maintenance or rehabilitation on a contractual basis, typically in a more privatized manner. As stated, this level would be significant when a section of a roadway requires preventative maintenance, some form of resurfacings and future treatments throughout the length of the project *(2).*

In addition to the two different levels of pavement management systems, there are a number of components that can be incorporated into the PMS, and the more components are utilized, the more the PMS will benefit in terms of accuracy and application. The primary component to any pavement management system is the actual data within the system. Whether at the

network or project level, each PMS will have an inventory of roads to be considered that can be further analyzed and categorized, based on characteristics such as length, functional class, location, route number or street name, etc. Each representative section of the roadway should have pavement condition information, which can also vary in terms of accuracy depending on the tests conducted. Any historical information for the PMS roadway should also be incorporated, such as construction, maintenance, rehabilitation and reconstruction records that would be relevant to any future work. Noting traffic conditions and expected volumes is a key aspect for accurately predicting deterioration, which will be mentioned shortly. Finally, one of the most significant pieces of PMS data that should be included is the cost of any actions for the road. Each aspect is significant, but without the cost, a pavement management system will realistically only be useful for seeing how quickly a road can deteriorate without any true guidance as to how to mitigate such issues *(2).*

The next key component to a pavement management system is the development of the models for analysis of the roadway. The models will be based on the information found from the aforementioned data within the system and then will be used to provide notable information to agencies. These models can provide performance predictions based on the data provided and then utilize different probabilistic and deterministic methodologies to predict the future performance of the roadway. This information can establish a hierarchy for prioritizing work to be done. Additionally, based on the costs of different treatments, the PMS can conduct different economic analyses for budgeting purposes to assist in determining the most fiscally feasible roadway treatments within the system to help maintain desired serviceability ratings *(2).*

The PMS data itself should be more than just information. Operating in tandem with the analysis conducted with the models, there should be a way to manage the data that can provide a deliverable as well. This could mean that the PMS will be capable of generating reports, and should be readily available to be updated with more information and data. The last aspect to the PMS in terms of components should be a type of reference system. This reference system can be paired with different databases of information based on the agencies' capabilities to keep track of the specific details in the PMS network. Such reference systems are often routed in geographic information for a region and enhanced by the data provided. The referencing system will help to differentiate the types of pavement within a roadway section or identify traffic flows that could vary by direction *(2).*

2.3 Agency Experience with Pavement Management for Localities

The following section will describe the lengths to which state agencies (or in the case of Canada, provincial agencies) have gone to assist local agencies, such as cities, towns, municipalities, MPOs and/or RPAs. It should be noted that due to the uniqueness and nuances of the projects, the involvement of the agencies will vary greatly from region to region, with only a few of the agencies performing a research project similar to what is being conducted here. The states that performed work most closely resembling the project will have significantly more detail as to assist the team with understanding procedures that were successful and those that were not.

2.3.1 Alabama *(3)*

To help document multiple approaches to pavement management on a local level, Christian Vasquez created a report focusing on a few instances of PMS integration for towns and cities *(3)*. One of the instances documented was the case where the Alabama Department of Transportation (ALDOT) and University of Alabama in Huntsville worked with local agencies to craft a uniform pavement management system that each agency would have access to. The system itself was developed with the use of Visual Basic and C++ as its primary programming languages.

Since the main purpose of the program was to assist the cities and counties, the software does not use Geographical Information System (GIS) data to note locations but instead uses defined, geographical locations. Because the main personnel using this program work for their respective agencies, this was decided to be the best course of action. This allows for engineers, contractors and all other workers to know exactly what they are working on. To map out the respective county, the engineer divides the county (or any local) map into segments based on intersections. The developers noted that adding GIS data to the software would assist all other non-local agencies; they hope to integrate such modifications in the future.

The three core aspects considered in the ALDOT model are the Pavement Condition Index (PCI), Average Daily Traffic (ADT) and tractor-trailer traffic. In addition to the aforementioned limitations of not using GIS data, during data collection, all relevant information still needs to be obtained by each agency. This information includes the length, start and end points, and date of data collection. The PCI data is obtained through a visual inspection rating (VSR) at 20 miles per hour, which ranks the road on a scale of one to ten (with ten being the highest) and includes photos of the road. All ADT and tractor-trailer traffic records are obtained from the historical records of each agency. With this data, the program will produce an input screen that allows the engineer to input all collected data, such as

- Start and end point
- Length of section
- Type of road
- Roadway classification
- District
- VSR
- ADT
- Percentage of Trucks
- Date of data collection
- Any additional comments
- Photograph of the road

After the data is entered, a maintenance screen allows the user to input more comments reflecting what has or has not been done to the respective road.

The software also has a database implemented to allow the use of queries imbedded into a route reports section. This allows for simpler navigation for users and less time spent looking for specific roads. In addition to the route reports, there are two more screens: road history and road inquiry. These screens mirror the input screen but will provide information about maintenance and will project the state of the PCI and the ADT for the following year using a linear regression statistical analysis.
The linear regression model operates under three key assumptions:

1. Statistical errors are assumed to have a normal distribution
2. Variance on the error is constant
3. Errors are independent

This linear regression model is applied to most of the collected data listed before and can form one equation consisting of the ADT, the percentage of trucks, and how long ago the road was resurfaced. This model achieved success as most agencies that needed had very limited funds and minimal programming knowledge. Its simplicity is its primary strength.

2.3.2 Illinois *(4)*

In 2011, the Illinois Department of Transportation (IDOT) and the FHWA began a cooperative effort to develop an approach process to creating a PMS that would be aimed at assisting local agencies throughout the state of Illinois, specifically *(4)*. The first process for completing such a task required the team to conduct a literature review to best understand how other localities and municipalities throughout the United States have had success or failure in their own respective PMS implementations. While looking at local agencies throughout the country, it was noted that a variety of different PMSs were being implemented and that there were a few notable trends and issues. These include the following:

- There was competition inherent in a pavement management system due to the other transportation related infrastructure asset management systems desired
- There were potential financial and technical limitations of the local agency
- There were inconsistent pavement rating systems in use
- The perceived complexity of these systems made agencies hesitant to attempt their implementation

This review not only focused on the localities' experiences but also noted the different types of PMS software currently available on a public or private level. Software packages noted within the report include

Public Use

- MicroPAVER
- RoadSoft
- GIS
- StreetSaver
- Utah Local Technical Assistance – Transportation Asset Management System (LTAP – TAMS)

Private Use

- PAVEMENTview
- PAVEMENTview Plus
- PavePRO Manager
- PubWorks
- RoadCare

Figure 2.1 describes and compares these PMS software packages *(4).*

The literature review provided IDOT and the FHWA some guidance in proceeding with the next step of conducting a current practice survey for Illinois. This survey asked a variety of questions to a total of 347 local agencies, with 115 total agencies providing responses. This represents approximately a third of the recipients providing responses, which is fairly sizeable compared to the typical average response rate for surveys of around 20 percent. The questions aimed to grant the team an understanding of the overall state of pavement management systems for the state's local agencies. These questions involved prior use of PMSs at the locality, involvement in metropolitan planning organizations, population of the county or municipality, method of data collection, frequency of inspection, available budget, etc. One of the most notable conclusions to be made from the results of the survey is that the majority of the respondents had populations of 49,999 or less, which indicates that not all PMSs are to be implemented by larger agencies. Additionally, about 50 percent of the respondents stated that they used the PCI in terms of pavement ratings.

The final step in the implementation of the local pavement management systems was to conduct a few case studies to determine whether the current attempts would be successful. The term "success" was considered in subjective terms and was determined at the discretion of the respective agency that was implementing the system, so a pure definition of such cannot be provided. The seven localities selected for the case studies were representative of variations in population sizes, pavement management practices, and locations. The local agencies chosen were Champaign County, Edgar County, McHenry County, Stark County, the City of Macomb, the City of Naperville and the Village of Villa Park. Each agency expressed that they were satisfied with the implementation of the PMS and considered it a success, briefly described below:

- Naperville City stated that "due to the state of the economy, the pavement management system has become more important."
- Champaign County noted that they are "now able to reduce political pressure" during pavement management decisions.
- Edgar County expressed that they are capable of "completing the right work at the right time for the right reasons" due to their PMS implementation.

- McHenry County felt their PMS project was successful, but warns other agencies, “Don’t try to implement a PMS all at once; slowly integrate the program into your routine.”
- Stark County felt that they were able to achieve their goal since they “wanted to have more engineering behind decisions.”
- Macomb City noted that despite the initial challenge of having to recover historical pavement data (pre-1995), they were able to effectively gain approval for a sales tax increase for the purpose of pavement management due to the budgeting models produced by the PMS.
- The Village of Villa Park mentioned they felt the use of GIS yielded significant success as their PMS.

Criterion Description	Pavement Management Software Programs								
	Public				Private				
	MicroPaver	Roadsoft GIS	Utah LTAP	StreetSaver	RoadCare	PAVEMENTview	PubWorks	PavePro Manager
Vendor	U.S. Army Corps of Engineers	Michigan Technological University -Center for Technology and 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	Inconclusive	Yes	Yes	Inconclusive
Ability to Analyze other Assets	No	Yes	Yes	Yes	Inconclusive	Yes	Yes	Inconclusive
Default Pavement Condition Rating Measure	PCI	PASER	RSL	PCI	PCI, IRI	OCI	PASER	Inconclusive
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	Inconclusive	Yes	Yes	Inconclusive
GIS Integration	Yes	Yes	Additional Software Needed	Additional Software Needed	Additional Software Needed	Additional Software Needed	Additional Software Needed	Additional Software Needed
Customization Capabilities	Yes	Limited	Yes	Yes	Inconclusive	Inconclusive	Additional Modules Needed	Additional Modules Needed
Cost (2011)	APWA Member: $995; non-member: $1095	Contact Vendor	Utah: Free, Other: $500	Contact Vendor	Contact Vendor	Contact Vendor	Contact Vendor	Contact Vendor
User's Manual	Yes	Yes	Yes	Yes	Inconclusive	Yes	Yes	Inconclusive
Technical Assistance	Training Courses/Four part web-based training	telephone/web-based training	free telephone/paid, on-site arrangements	4-day training class twice per year & custom on-site training	Inconclusive	On-site training/web-based training; technical help via phone	Formal training 1 day per module, free updates, software helpdesk	Inconclusive

Figure 2.1: Pavement management software features *(4)*

2.2.3 Iowa *(5)*

A report created by Smadi and Maze explains the process that the state of Iowa performed in 1998 to develop a PMS for the entire state, incorporating its municipalities and all adjacent localities *(5)*. This task involved covering 23,500 miles (or 38,000 kilometers) of the state's roads. The core idea behind the implementation of one centralized pavement management system for the entire state lies in the economic feasibility that the state will have access to, as opposed to individual counties and cities.

At the outset of the project, the Iowa Pavement Management Program (IPMP) was to be formed to meet the requirements of Intermodal Surface Transportation Efficiency Act (ISTEA), which mandated the development of seven different transportation management systems, one of which was to be a pavement management system. The ISTEA also required that any federal aid eligible (FAE) highways be covered by a pavement management system. As stated before, Iowa planned to replicate these core concepts, but on smaller governmental levels. As in most states, a large amount of the FAE highway network in Iowa is under the management of its respective department of transportation (Iowa DOT), while the rest of the roadways are left to be maintained and developed by the cities and counties. In the state of Iowa, there are eight MPOs and eighteen RPAs that all had the option to be incorporated into the statewide pavement management system. Most of these agencies decided to be participants in the development of the system.

It became apparent that there would be a few "non-technical" issues to consider during the creation of the statewide PMS. To ensure that local and regional governments would not feel as though the Iowa DOT would use this information in a way that could influence the funding dispersal, it was decided that an unbiased, third-party organization should develop and maintain the system. In the case of the IPMP, it was decided that the Center for Transportation Research and Education (CTRE) at Iowa State University would be in charge of this aspect of the project. Additionally, governmental representatives from each involved agency and members of the Federal Highway Administration formed a non-National Highway System (NHS) task force to direct the planning, development and implementation of the IPMP, while the aforementioned CTRE provided the staff necessary to perform the required tasks.

The IPMP project was divided into three phases: the design phase, the implementation phase, and the operation phase. The objective of the design phase was to provide guidelines for the development of the system. This objective consisted of understanding the data needs, database and management tools, information exchange, and governmental support. At this phase, the team pushed the idea of the project and as much information as possible to all local entities (cities, counties, agencies, etc.). Additionally, at this stage it was decided to move away from a legacy linear geo-referencing system to one using real-world coordinates.

The implementation phase's objectives were to develop the various components of the system, test and evaluate said components, and develop a plan for operating the system. As is the case for each phase, there were a number of tasks to be completed, such as to

- Establish the pavement management computer database
- Implement systems for the physical inventory of pavement
- Evaluate financial, institutional, and technological pavement condition data collection options
- Collect pavement construction costs and historical data from state and local agencies
- Evaluate and select pavement management analysis software
- Collect pavement condition baseline data
- Calibrate the pavement management analysis system and implement the database
- Develop a data exchange mechanism between the central database and state, regional, and local users
- Test and evaluate the system
- Evaluate the system at organization level, comparing the system with its original objectives

At this phase it was determined to collect the base pavement data over a two-year period, taking roughly half a year to collect the data for half of the state. The IPMP then proceeded to establish a GIS database for all pavement management data, a physical inventory system, an automated pavement condition data collection system, and baseline condition data. Since all agencies maintain their records differently, each agency would subsequently request the data be presented in a way that matched their current system (such as physical paper copies, processed through their respective PMS software, compatible with different GIS databases, etc.) and that due to this, the most challenging aspect of the project would be to provide feasible methods of data exchange. The option proposed by the IPMP was to try to develop the PMS information in a format compatible with an inexpensive GIS software that would have default queries programmed to allow for a more executive system for all parties.

The final phase was the operation phase which included the training and support of staff for all agencies involved. During this phase, constant testing and evaluation was performed to ensure the PMS was operating properly. It is most likely that this phase will consist of the maintenance for the system, as well as updating it when new records are introduced, or other historical records are to be included.

For the purpose of developing a database during the implementation of the project, the IPMP required the creation of a GIS database that would be supported by dynamic segmentation. The concept of dynamic segmentation involves designing the longitudinal view of a roadway with different element layers underneath. The layers that make the road include the highway network, the pavement management section, the test sections, and finally the inventory sections. With the roadway modeled using these layers, it is possible to manage, maintain and record all notable pavement characteristics that would be necessary for Iowa's PMS. Each layer was designed using a kilometer point referencing system which involves using fixed point segments of the roadway, each covering approximately 0.1 kilometers. During the

development of the GIS database, the following steps were followed in order to achieve the goals of the IPMP: developing a graphical linear framework, storing and managing the data, data maintenance, data access, and management systems data integration.

Following the development of the database, the pavement condition data needed to be collected. The IPMP task force was assigned this task and focused on a number of issues, such as

- Identifying categories of pavement types based on paving materials, where pavements in each category perform similarly, or similarly enough, to be included in the same pavement performance model. The categorization must be broad enough to allow its application across all three levels of jurisdictions (i.e., state, city, and county roadways).
- The requirements for pavement condition data elements (distress types) necessary to support network-level decision-making at each level of jurisdiction.
- The requirements for pavement condition data elements (distress types) necessary to support project-level decision-making at each level of jurisdiction.
- The coverage of the data collection (e.g., could data be collected for a representative sample, or was it necessary to have 100 percent coverage).
- The necessary frequency of data collection (e.g., collect pavement condition data every year or less frequently).
- The feasibility and effectiveness of using automated data collection equipment to collect condition data to support the data requirements for pavement management at each level of jurisdiction

With these issues considered, the state of Iowa decided to purchase a service agreement with a vendor, specifically Roadware Corporation, for pavement condition data collection, reduction and delivery. For the pavement condition data collection, the committee decided upon key distresses to focus on that would be present in asphalt concrete (AC) pavements and Portland cement concrete (PCC) pavements, as shown in Table 2.1.

Table 2.1: Key distresses based on pavement type

AC Pavements	**PCC Pavements**	**Both**
Longitudinal Cracking	D-Cracking	Patching
Block Cracking	Spalling	Transverse Cracking
Alligator Cracking		
Potholes		

Regardless of the pavement type, each distress is catalogued based on the extent of the deformation and the severity of said distress. At the time that the article was released, the IPMP had yet to decide on a pavement management software; however, they had outlined important characteristics they wished to have in the software. The software needs were

subdivided into two categories: needs for the software at a network level and needs for the software at a project level. For the network level, the software would need to

- Conduct network-level pavement management analysis that produces the following:
    - Resource allocation strategies for cost-effective pavement management (maintenance, rehabilitation, or reconstruction) decisions.
    - Provide current and future pavement network conditions based on
        - Funding levels
        - Performance constraints
        - Other user-defined variables
- Utilize mathematical programming techniques for the optimal allocation of resources based on user-defined optimization and analysis parameters.
- Initially utilize probabilistic performance prediction techniques to forecast the future condition of the pavement network.

The main focus of the IPMP is to assist all forms of government at the network level; however, the project level is still to be considered. The project level software needs include the following:

- Single-year prioritization
- Multi-year prioritization with performance trends
- Multi-year optimization (benefit cost, incremental benefit cost, or marginal cost
- analysis)
- Provision for short-term analysis (three to five years)
- Reporting (tabular and/or graphical), querying, and viewing capabilities

2.3.4 Massachusetts *(6)*

Paul Sachs, a pavement specialist employed by the Washington State Department of Transportation (WSDOT) worked with the FHWA to note any involvement that state agencies have had in assisting respective local agencies in crafting a pavement system *(6).* From this report, it was found that in Massachusetts, the current stage of pavement management at the statewide level involves the assistance of the thirteen regional planning agencies and MassDOT in working with local agencies for their pavement management systems. The MassDOT first noted that there existed a large network of roads that they were not directly responsible for (as is the case with most state agencies). The state's initial involvement began with helping the municipalities pay for a tool to better organize and document the condition of the roads to help persuade financial committees that the local agencies needed pavement management systems in the first place. Then, the RPAs, some local consultants, local agencies and the Massachusetts Technology Transfer Center (MTTC), and the MassDOT worked together to generate an in-depth evaluation of the current PMS software offered. They concluded the evaluation by recommending three systems, including a private sector option, a public domain option, and a university developed system, which each RPA would select for their respective municipalities. During this process, the RPAs also formed the Pavement-Management User Group (PMUG) which would help the RPAs assist agencies that were new to pavement management. The two most

common systems used by the RPAs are the Road Manager™ software and the Road Surface Management System™. MassDOT's goal at the time was not to create a statewide system for pavement management but to simply assist its municipalities in creating their own.

2.3.5 Mississippi *(7)*

George et al. recorded a particular instance where local agencies assisted the state in crafting a PMS, essentially working backwards from the scope of work for this project *(7)*. In 1994, after the successful implementation of a district road pavement management system, the Mississippi Department of Transportation (MDOT) decided to craft their own for the state's highways. The state-maintained highway network consists of over 12,000 miles, and the focus of the pavement management system was to properly minimize the costs to repair and maintain this network. The state of Mississippi identified what they referred to as "four basic building blocks" to design such a system. These building blocks are a database, an interface program, a pavement management system maintenance planning and budgeting program, and a priority ranking system.

For the development of the database, MDOT used a software known as FOXPRO. This database consisted of inventory, traffic, overlay, condition, and other databases. In order to do so, the software broke down areas of pavement into homogeneous sections where, based on the information and observations, they could conclude that these sections were about the same in whichever respective terms were being considered. As a way to keep these sections all linked, each section was provided with a unique section ID number, denoted by SECIDNUM in the software. This allows for all databases to be linked to one another for ease of access when using the software.

To obtain surface distresses on the roadways, high-speed automatic video cameras were mounted on top of MDOT's trucks. For the International Roughness Index (IRI), a South Dakota-type profiler was implemented to survey the area. The rutting or faulting information was surveyed via the use of ultrasonic sensors to gather height measurements. Once all of the information is collected, the program generates a form of composite measurement known as a Pavement Condition Rating (PCR), so that all of the data can be viewed in terms of a single variable.

From this point, an analysis can be performed based on the databases' information and the software will create a recommended repair strategy, as well as providing what the expected costs would be. The expected costs are be presented in a way that establishes a hierarchy of maintenance consisting of major maintenance, minor maintenance, lane widening or shoulder widening, routine maintenance and long-term costs. Finally, utilizing the other databases outlined prior, an index can be created to help create a priority ranking system based on traffic data, functionality, and type of pavement. Implementing each step outlined allowed for MDOT to successfully craft a PMS that incorporated each "building block" the agency required.

Despite the success in achieving its goals, at the time of the article's publishing, MDOT outlined a few other key items that they wished to look into, which included the following:

- Video interpretation of distress manifestations will need continued improvement
- Structural evaluations of pavements, both at the network level and at the project level, need to be incorporated into the system, as do the surface texture/skid resistances of pavements
- Prediction models for both distresses and PCR measures are needed
- A rational optimization/prioritization scheme for single-year as well as multi-year work planning is needed

2.3.6 Nebraska (*6*)

Another state that was included in Paul Sachs' national assessment of local pavement management was Nebraska *(6)*. Nebraska's method of assisting local agencies developing pavement management systems has been a relatively hands-off approach. The goal of Nebraska (similar to Massachusetts's) was simply to aid in the local agencies' understanding of the pavement management systems offered, not to establish a statewide, organized one. The state department of transportation worked with the metropolitan planning organizations and the T^2 center to sponsor a one-day training class on pavement management in the early 1990s. The training was based off of the FHWA's course "Pavement and Road Surface Management for Local Agencies." Following this lesson, the T^2 center plans on training workers from across the state in the use of the Road Surface Management System software as needed.

2.3.7 Ontario, Canada *(8)*

Outside of the United States, pavement management systems are just as significant and are gaining attention from the proper agencies. The case of local agency assistance was noted by Robert A. Douglas *(8)*. The province of Ontario, located in Canada, noticed that a sizeable amount of roadway maintenance and management is left up to the localities of provinces throughout the country. Specifically, Douglas noted that approximately 80 percent of the roadways in the province are left up to the local governments to manage while the remaining 20 percent are managed by the federal government. This imbalance prompted him to create a rudimentary set of pavement management guidelines with a minimalistic approach, detailing the very least that local governments would need to do to have some sort of strategy, regardless of budgetary limitations.

As far as data collection is concerned, the four primary types of performance output that pavement is judged by are structural capacity, riding comfort (roughness), safety (such as skid resistance) and distress. When municipalities are constructing their PMS, the most significant performance to note is the distress, as it often relates to the other performances and is also the most fiscally manageable by any government. Distress measurements can be performed without the use of expensive equipment, as visual inspections can often provide the agency with a large amount of information that is easy to manage and manipulate as needed. Additionally, most agencies that will be adopting a PMS will most likely not have

pavement engineering experts to conduct such management, so simplicity in approach is in the best interest when trying to establish a uniform approach for localities use.

Measuring the distress comes in two forms: severity and density. Severity details how bad the distress is and is typically rated on a scale mirroring the following (in terms of ascending severity, according to the Ministry of Transportation of Ontario): very slight, slight, moderate, severe, or very severe. The Ministry of Transportation of Ontario (MTO) has created a manual for public use with an abundance of photos for the local agencies to reference to determine what level of severity the distress should be rated at. Density details how much of the distress is present in terms of percentage, as shown in Table 2.2.

Table 2.2: Distress density percentages

Description	Percentage of Occurrence
Few	< 10
Intermittent	10-20
Frequent	20-50
Extensive	50-80
Throughout	80-100

These two terms collectively can be combined with the ride condition rating (RCR), which is a subjective measurement of pavement roughness determined by the smoothness of the ride when driving at the posted speed limit, to determine the PCI. The RCR rating system and equation to determine PCI are also available in a manual provided by the MTO.

Following the distress measurements and subsequent PCI ratings, the future states of the pavement are modeled using deterioration curves. Pavement deterioration curves are modeled with the PCI plotted against either time or traffic. If a roadway is low traffic, then the curve would be plotted against time since the environment is the most substantial contributor to the deterioration, and vice versa. Typically, due to scarcity of information on the local level, there are only a few data points to potentially construct the deterioration curve, so local agencies may need to rely on master curves instead. Master curves are used to track typical deterioration based on a few criteria, and since deterioration would be modeled within the next five years, it is acceptable to use these if necessary.

The final step in constructing a PMS would be considering the organization of the budget relative to the treatments necessary. Typical strategies for scheduling maintenance include the following: worst first, most expensive first, least expensive first, and in rank order when ranked for annual average daily traffic (AADT). As most local agencies are typically dealing with a backlog of deferred work, the most likely option would be the “worst first” approach, which as the name implies would first treat the pavements that are in the worst shape (i.e. having the lowest PCI). For all future work, the roadways would be monitored at a feasible frequency, depending on the agency, and when a segment of the road fell below a set PCI, treatment would begin. For a local government’s application, the budget would be modeled in three scenarios: unlimited, yearly budgets with fixed amounts, and yearly budgets to achieve a specified weighted average PCI for the agency. These three models would be used by those in charge of pavement management to rationally explain potential increases in

funding to the local governments that are in charge of establishing the budget. Often, the hands of those who will maintain the roads are tied and the final decision will be at the discretion of the city council. Ideally, these models would allow for some type of compromising, hybrid budget so that the local agency could achieve its pavement management goals.

2.3.8 Rhode Island *(9)*

Bowen and Lee recorded one of the earliest instances of the recognition of PMS requirements for local regions in the state of Rhode Island *(9)*. In September of 1987, then governor of Rhode Island Edward D. DiPrete proposed a 3-year, $8 million pavement management program that aimed to repair the local roads and streets throughout the state. This program required assistance from the Civil Engineering Department at the University of Rhode Island (URI) to implement a pavement management system that could correctly complete this task. This research team coordinated with the governor's office, the Rhode Island Department of Transportation (RIDOT), and the Rhode Island Department of Administration (RIDOA). The overall objective for this joint effort was to identify the best PMS for the locally maintained roads and then implement whichever PMS was chosen through proper trainings and support.

The first step for this process involved sending out a survey to the local communities (all 39 of them) to attempt to get a grasp on the state of their PMSs in place. The survey aimed to identify the existing pavement maintenance practices, identify the state of the agencies' computer networks and access, and to help create an interest in a computerized PMS. The results of the survey were varied but had some notable trends. Each municipality had an average of 130 miles of road to be maintained, and a majority of these roads were AC pavement roads. As far as cost effective responses were concerned, the state noted that the agencies used a number of different approaches. The approaches consisted of a type of inspection/ survey method, a condition ranking system, a priority/ available budget method, and one municipality mentioned that they used a comprehensive drainage and road plan. Additionally, 33 communities noted that they did have a regular maintenance plan, and these plans varied in frequency of treatments (every year, every two years, etc.). Every community expressed concerns about the state of their roads, while the majority also stated that they did not currently have a computerized PMS in use. The final conclusions of the survey were simple: the PMS must be cheap, microcomputer based, simple to maintain, and easy to use.

After the completion of the first step, the team focused their attention on evaluating the systems offered. This step was subdivided into two phases: the first phase involved a literature review on the PMSs available, while the second phase served to compare the PMS options outlined in the first phase. For this step, there were a few key characteristics outlined by the team:

- The implementation and operation of the PMS should be simple
- The initial cost and maintenance fees should be low
- It should be based on visual observations
- Any collected data should be capable of being converted into a single index to indicate the state of the pavement

- At a minimum, the PMS should be able to store the condition data, develop an objective pavement condition index, contain a rating system for the maintenance, perform a life cycle cost analysis, and provide budget requirements

The second phase used these characteristics to compare the PMS systems offered. After the conclusion of the second phase, Micro PAVER was chosen. Micro PAVER is nonproprietary and requires no development costs, as well as being capable of providing a practical design approach, balanced out with a cost-effective maintenance strategy for any roads designed.

Following this decision, the team proposed two test runs for the system, with one being aimed at the URI Kingstown campus and the other implemented for the town of South Kingstown. URI was chosen since it is a small-scale mock-up of a typical city and would have a similar municipal structure; applying the system to the town of South Kingstown would be a true attempt at a proper implementation. The test run at URI yielded a success for the program's effectiveness, and most importantly, the campus ended up having a PMS in place for any future maintenance. The town of South Kingstown required a bit more work. The team worked with the town in retrieving and recovering old records of the town's roads, as well as performing any research and additional data collection to help fill in any gaps. In South Kingstown, Micro PAVER was not applied to its fullest capabilities, but the town still expressed happiness with the progress made.

To properly collect data, the first step for each municipality was to create its network components. This involved subdividing the towns' geography into a hierarchy of zones, branches, sections, and samples. Each zone contained its own branches and sections, while each section required samples for data collection. The sections are defined as areas of the roadway that are considered uniform in terms of pavement structure composition, traffic, construction history, pavement rank, drainage facilities, and shoulders. The samples are the actual spaces within the sections that are inspected for data collection. Due to the enormous amount of man-power that is required, the state needed to extrapolate in certain circumstances to accurately reflect the network.

With the success of the trial runs, Rhode Island began to implement the system at the state level. This process required each municipality to obtain proper training through RIDOT sponsored workshops. In this situation, representatives from 26 of the 39 communities (or two-thirds) attended at least one of the workshops. In the future, the authors stated that enhancements to the program would incorporate any future software updates, addition of an unsurfaced road condition index, and an extended memory to increase the speed of report generation.

2.3.9 Virginia (*6*)

Paul Sachs recorded the involvement in local PMS assistance by the state of Virginia, as well *(6)*. Virginia, like some other states reported on by Sachs, had a very minimalistic approach to working with the cities and towns, but their assistance was still notable. Starting in the early 1990s, the Virginia Department of Transportation (VDOT), and the Virginia Transportation Research Council (VTRC) began to assist local agencies in their pavement

management systems practices. The first step involved teaching the agencies the basics of a pavement management system in 1992. Following these teachings, the state conducted a survey to assess the state of the municipalities in terms of their own PMSs, to which half of the agencies expressed that they did have one in place. These agencies would operate with the assistance of the VDOT, where the state would gather necessary data for the city or town in exchange for financial reimbursement from the locality. VDOT provided the interested agencies with what the state was currently using as a PMS, the Pavement Management Systems Inc. Super PMS 2.0 for Windows. Despite working with the local agencies, the VDOT stated that they did not cover the cost of any required associated hardware that any municipality needed should they wish to implement the aforementioned PMS, however, they did provide any required trainings.

2.3.10 Washington (*6*)

The final state Sachs addressed in his report was his state of employment, Washington *(6)*. In the mid-1980s, it was decided that the Washington State Pavement Management System (WSPMS), which was used by the Washington State Department of Transportation, could be modified to assist local agencies in their pavement management needs. To proceed, a committee consisting of representatives from cities, counties, and the State was formed, known as the North West Pavement-Management Users Group (NWPMUG). This group's sole responsibility was to refine the already existing PMS for local agency use. At the conclusion of the project, the software was taken over by the Measurement Research Corporation (MRC) and the meetings of the group became less frequent until the group decided to disband to establish five separate organizations localized in respective areas of the state (three of which are in the west and the other two in the east). These organizations became a key element to the Northwest Pavement Managers Association (NWPMA). This organization became the backbone of the collected effort of the municipalities to continue working with the state and, most importantly, each other in a continuing effort to improve the WSPMS for each associated party's use. Additionally, the group has assisted in a rewrite of the original *Pavement Condition Raters Manual*.

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3.0 Internet Survey

3.1 Purpose

An internet-based survey was developed to gather information related to local level asset management from each municipality, MPO, and RPA in the Commonwealth of Massachusetts. The purpose of the survey was to gather information about what types of pavement management systems are being used by local agencies, who collects the condition data, what type of data is collected and reported, how the data is used within their asset management system, and what investment decisions are made based upon said data.

3.2 Survey Questions & Distribution

The survey was divided into the following sections: demographic information about the respondents, information related to the agency, general information about their PMS, specific details about their PMS, and information about investment decisions. The survey questions were developed by the research team and the MassDOT project champions (PCs). In total there were 35 questions posed to each respondent. The final list of questions was reviewed and approved by the MassDOT PCs prior to solicitation of responses. The general format of the survey is shown in Figure 3.1.

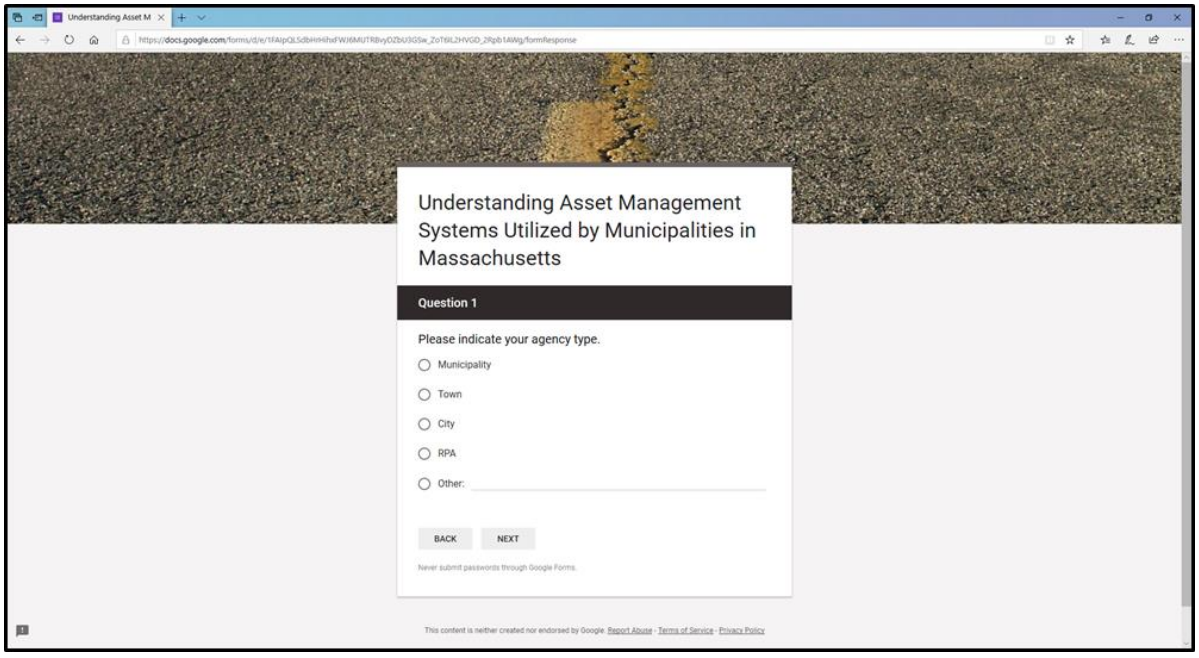


Figure 3.1: Format of internet-based survey

A copy of the survey questions is located in Appendix A of this report. The survey is also available at the following link:

https://forms.gle/h6X5FNFxrbFF3D9EA

The distribution list for the survey included local contacts obtained from the outreach list used by MassDOT for the federally required Local Highway Finance Report, contacts from MPOs and RPAs, Chapter 90 engineers, and Baystate Roads's contact lists. The final distribution was approved by MassDOT prior to solicitation of responses. The final distribution list had over 2,000 contacts representing 320 municipalities and 14 MPOs/RPAs. The survey was distributed in August 2020, and responses were received until Spring 2021.

3.3 Response Rate

In total, 125 responses were received for the internet survey resulting in a response rate of 5.8 percent (125 out of 2,161). There was a total of 109 municipal responses (towns and cities) and 15 MPO/RPA responses as shown in Figures 3.2 and 3.3 respectively. There was also one additional response from the MassDOT Pavement Management Section. In some cases there were multiple responses from the same municipality or MPO/RPA, and these are indicated in Figures 3.2 and 3.3.

Towns

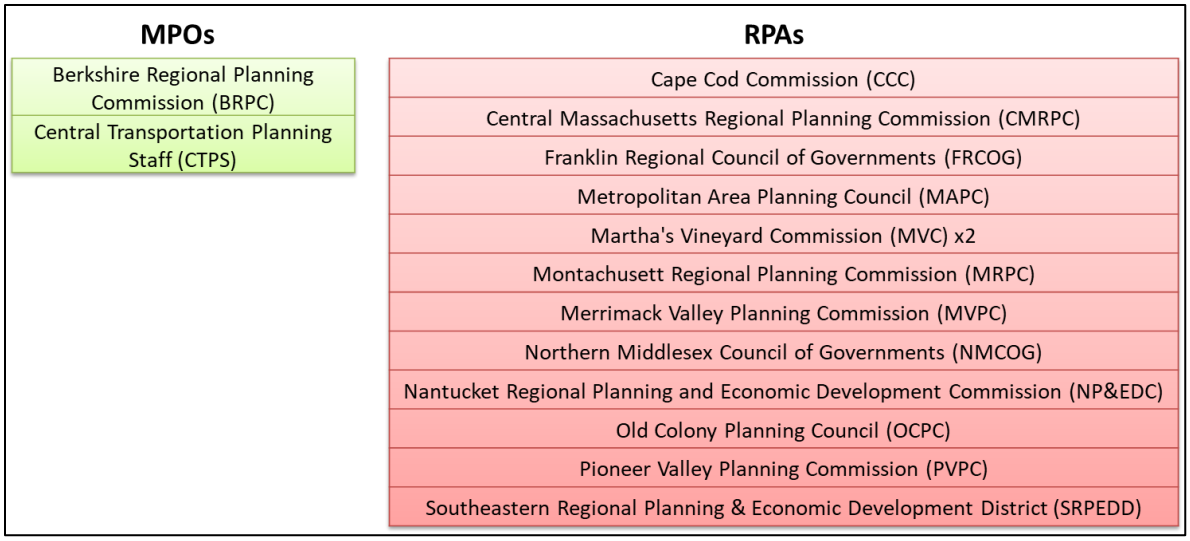
Abington	Dedham x2	Halifax	Norfolk	Salisbury
Agawam x2	Deerfield	Harwich	North Attleborough	Shrewsbury
Arlington	Dighton	Hatfield	North Reading	Southbridge
Ashburnham	Douglas x2	Heath	Northborough	Southwick
Athol	Dracut	Hinsdale x2	Northbridge	Stoughton
Avon	Dudley	Holland	Orange	Sutton
Becket	East Bridgewater x3	Ipswich	Oxford	Tewksbury
Bedford	Eastham	Lee	Paxton	Uxbridge
Belchertown x2	Easton	Lexington	Plainville	West Bridgewater
Brewster	Egremont	Longmeadow	Plympton	West Brookfield
Burlington x3	Fairhaven	Lynnfield	Raynham	Westborough
Carver	Foxboro	Mansfield	Rehoboth	Westport
Chatham	Freetown	Maynard	Rochester	Yarmouth
Dudley	Georgetown	Medway	Rockport	
Dalton	Gill	Middleborough x2	Rowley	
Dartmouth x3	Granby x2	Monson	Russell	

Cities

Amesbury	Medford
Boston x3	Melrose
Brockton	New Bedford x2
Cambridge x2	Northampton x2
Chelsea	Taunton
Framingham	Waltham
Greenfield	Woburn
Lawrence	

Note: Multiple responses from the same agency are indicated by "x number," where the numbers represent the number of responses from that agency.

Figure 3.2: Towns & cities responding to internet survey



Note: Multiple responses from the same agency are indicated by "x number," where the numbers represent the number of responses from that agency.

Figure 3.3:MPOs & RPAs responding to internet survey

3.4 Survey Results

The final tabulated survey results are presented in this section.

3.4.1 Agency Information

This section shows the survey results related to agency information.

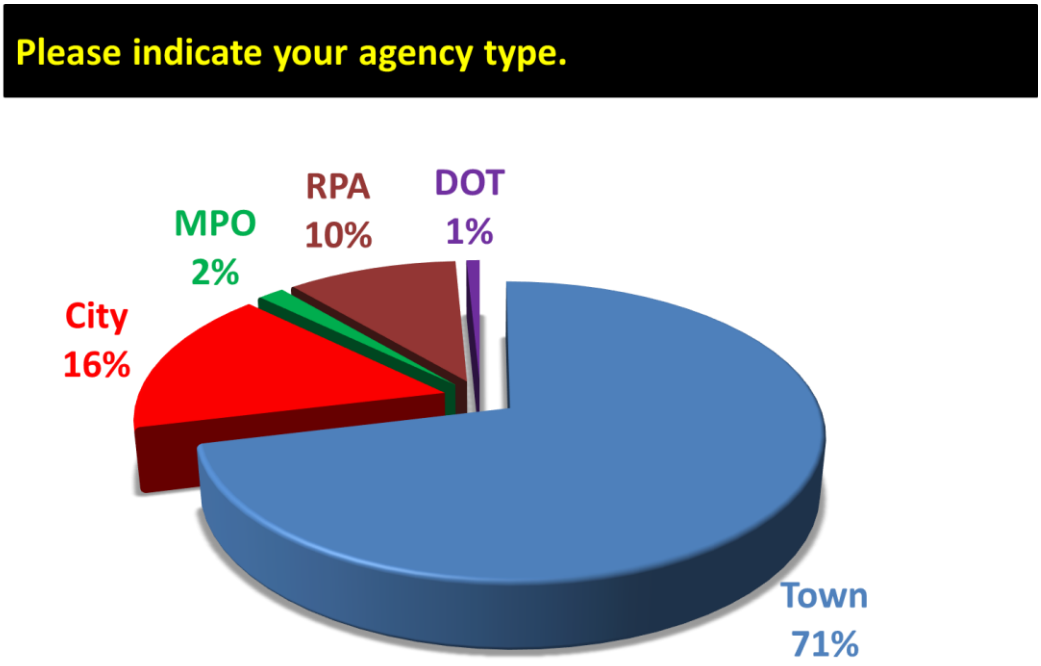


Figure 3.4: Survey result—agency type

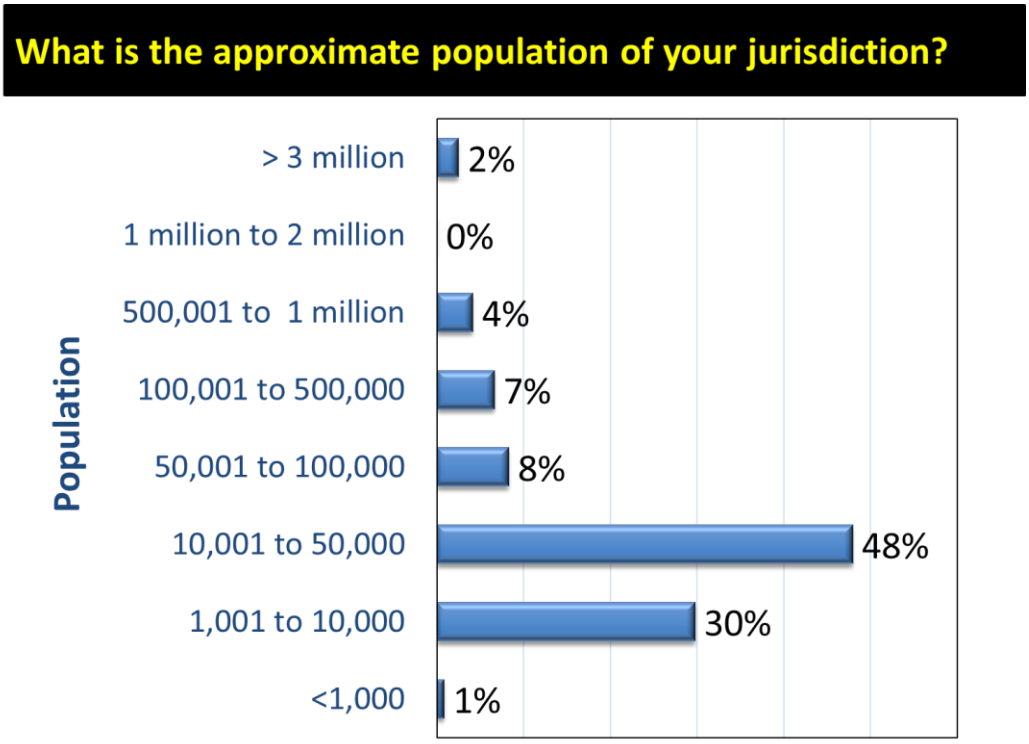


Figure 3.5: Survey result—population

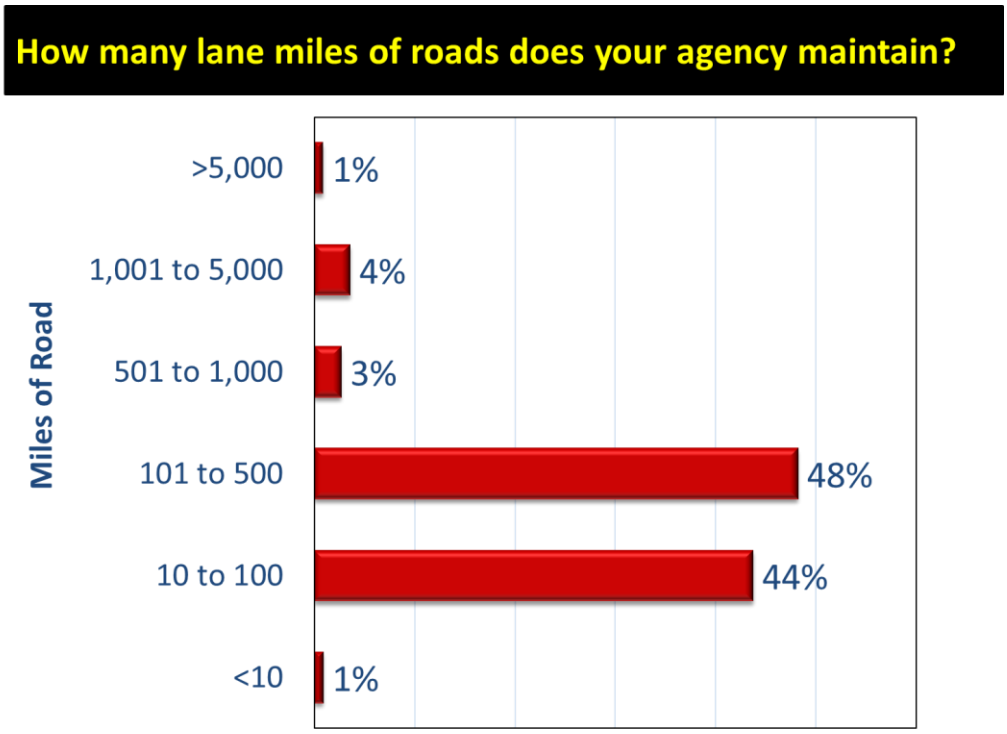


Figure 3.6: Survey result—miles of roads

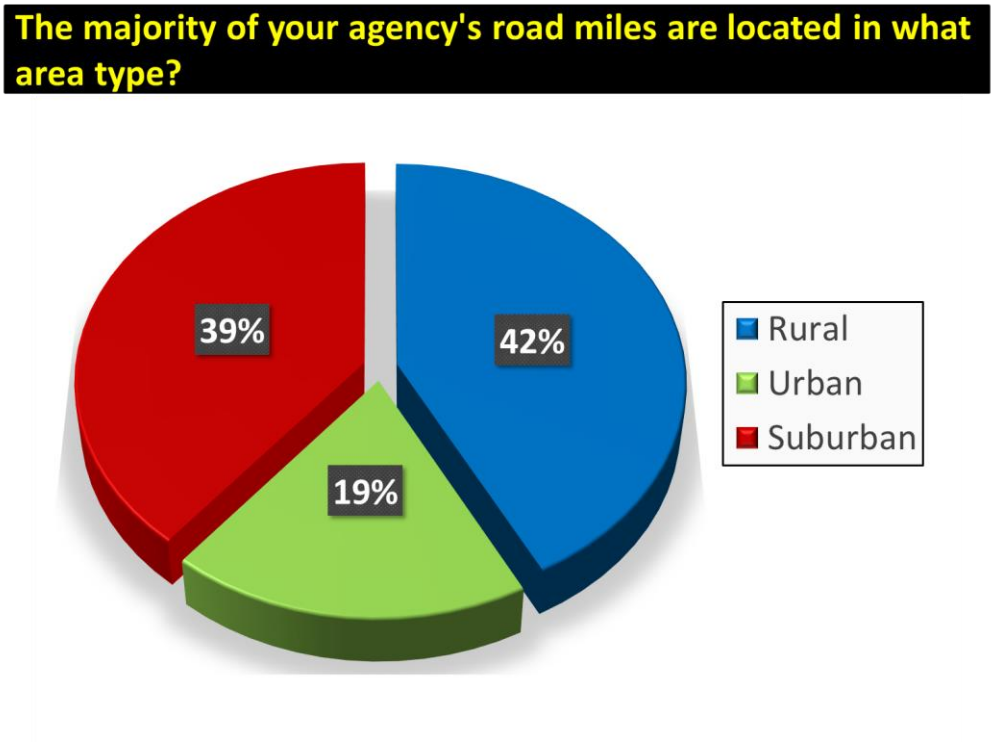


Figure 3.7: Survey result—type of area

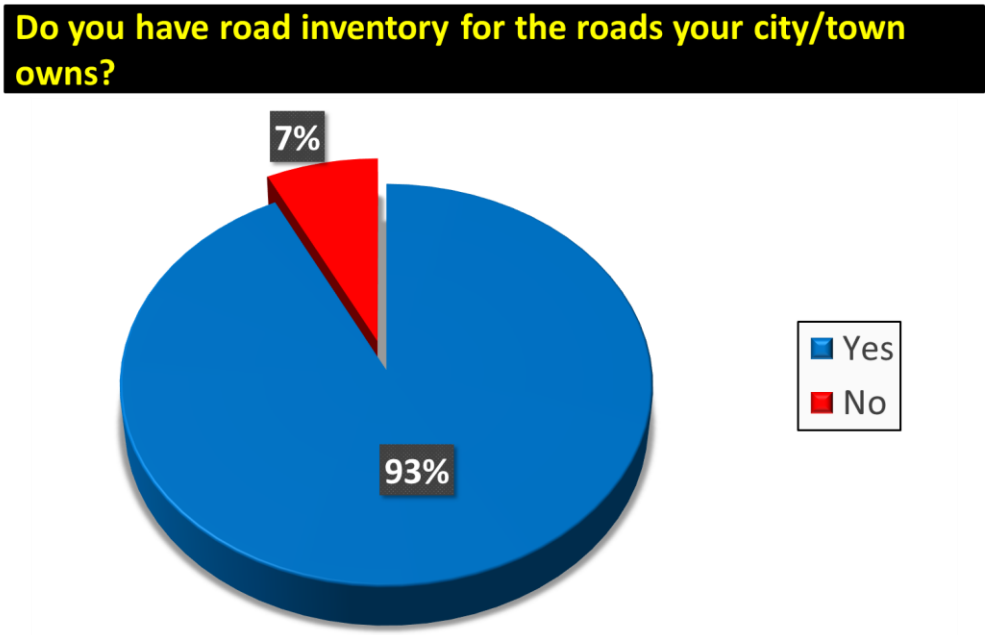


Figure 3.8: Survey result—road inventory

If you selected No, please describe what are the obstacles to obtaining/conducting a road inventory.

The CMRPC does not own any roads however we monitor the condition of the region's Fed-aid system (1,278 centerline miles). To do this we have an inventory of roads in our region built to work with the MassDOT RIF.
Unknown
Cost
Funding
I have the tools to do a road inventory just no time to put it together.
Have old inventory needs updating.
Boston Region MPO staff rely on MassDOT's Road Inventory for analysis purposes (the MPO does not maintain roadways, and so does not use the inventory for asset management purposes). Several MPO staff members work with MassDOT staff on an ongoing basis to maintain and update data in the road inventory.
MAPC does not conduct road inventories.
Workload priorities

Figure 3.9: Survey result—road inventory obstacles

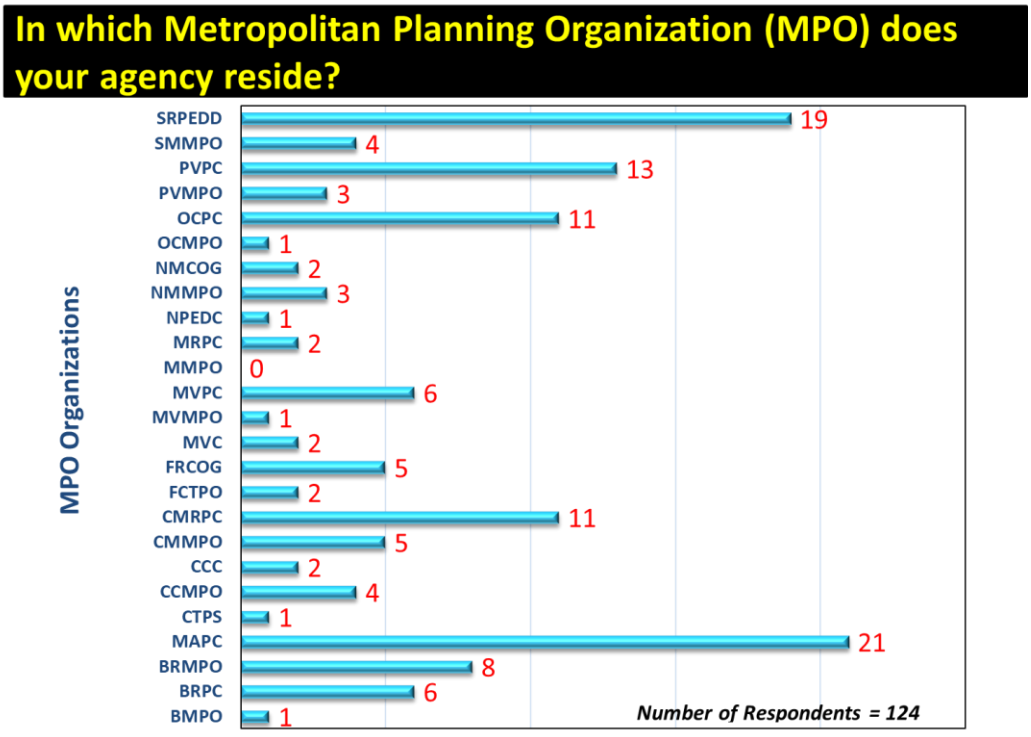


Figure 3.10: Survey result—Metropolitan Planning Organization (MPO)

3.4.2 Pavement Management System

This section shows the survey results related to an agency's pavement management system.

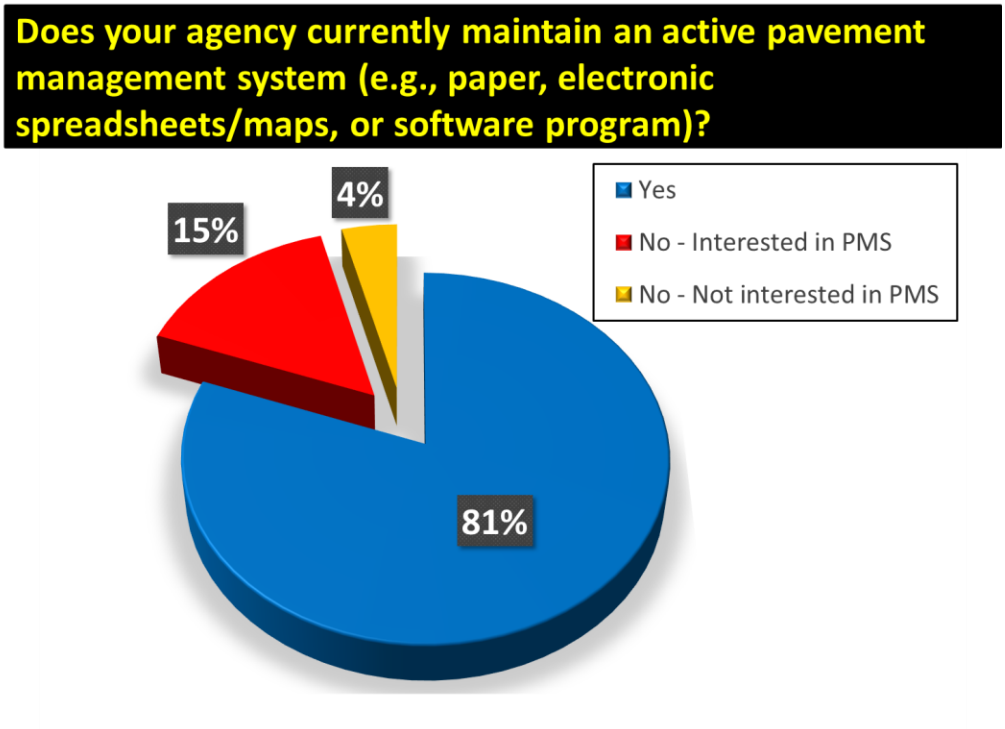


Figure 3.11: Survey result—active pavement management system

If you selected No PMS, please describe how you make investment decisions for your road network.

Local Decisions
We are working on developing one through the Complete Streets program
Annual assessment by DPW & P&D management
I look at all roads and figure out which roads need attention
Town Manager / Highway Supt. decide
Identify key areas of need by visual inspection and plan accordingly
Would coordinate with Highway Dept and IT
Pavement condition, Traffic volume, Geographic Location, Funding
The Highway Superintendents makes those calls
Consultant updating plan
Visual Inspection, Yearly funding, Traffic volumes, Geographic location
I ride all roads and grade them 1-5 one being the best. Then I determine the cost of repairing 5-1 with treatment comparison network approach.
By order of need, usage, condition
Utility work & complaints
In 2011 the Boston Region MPO considered a pavement management system but ultimately decided not to fund the development of one. The MPO maintains a policy of not funding resurfacing-only roadway projects. When evaluating more extensive roadway improvement projects for potential inclusion in the Transportation Improvement Program, the MPO does award some points to projects that will bring pavement considered to be in fair or poor condition into good condition. The MPO uses International Roughness Index (IRI) information from the Massachusetts Road Inventory and/or information provided in project functional design reports (FDRs) to make this assessment.
We look to CTPS and MassDOT
Based on historical pavement age and visual overall condition, as well as traffic loads.
Inspection
Highway Surveyor makes that determination based on local knowledge
With the limited funding we have we currently are working on the worst roads and with any funding left goes toward pavement preservation
We see what Chapter 90 allotments will pay for
Visual Observations, Future utility work and stakeholder requests

Figure 3.12: Survey result—investment decisions

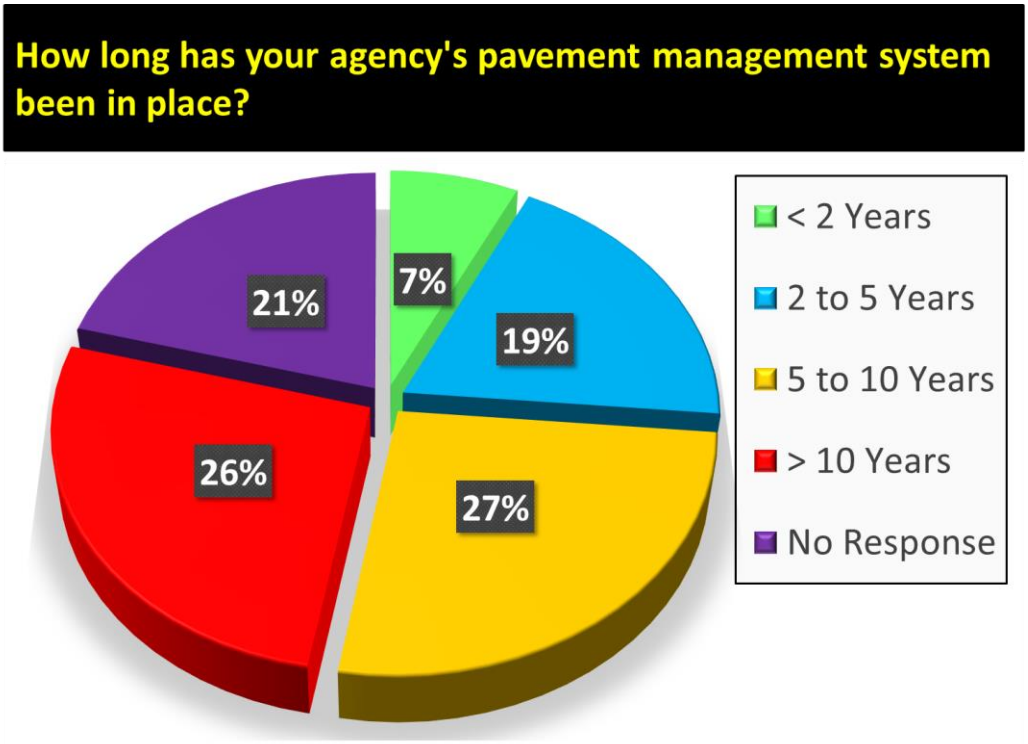


Figure 3.13: Survey result—PMS for how long

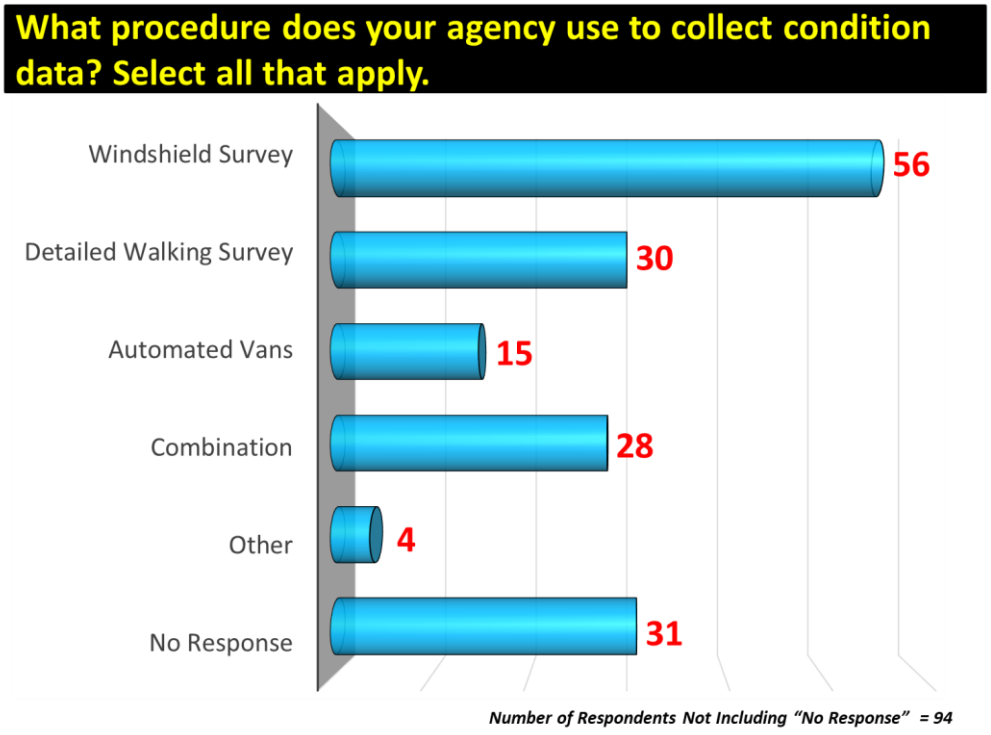


Figure 3.14: Survey result—data collection procedure

What procedure does your agency use to collect condition data?

Other/Comments

We contract VHB, Inc to collect pavement condition data.
PAVEMENTView through PVPC.
Resident input.
Performing automated survey in near future.

Figure 3.15: Survey result—data colletion other procedures

If your agency collects condition data using windshield survey and/or detailed walking survey, which of the following tools you use to conduct the survey.

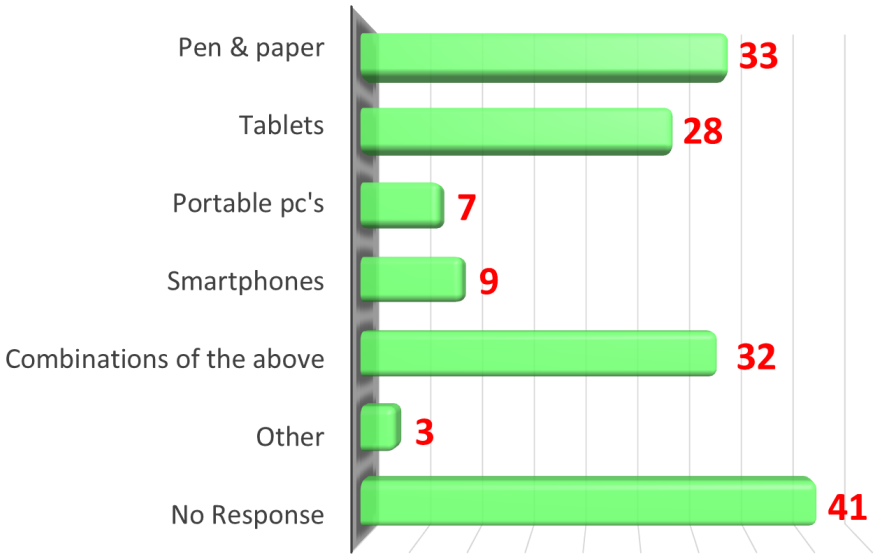


Figure 3.16: Survey result—survey tools

If your agency collects condition data using windshield survey and/or detailed walking survey, which of the following tools you use to conduct the survey.

Other/Comments

VHB, Inc collects the condition data. I believe they use combinations of the above.
Done by third party. BETA Group, Inc.
Services provided under contract with VHB. Don't know what tools they use.
I would have to ask the consultant. Probably tablets or laptops.
Performed by consultant
Email

Figure 3.17: Survey result—other survey tools

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

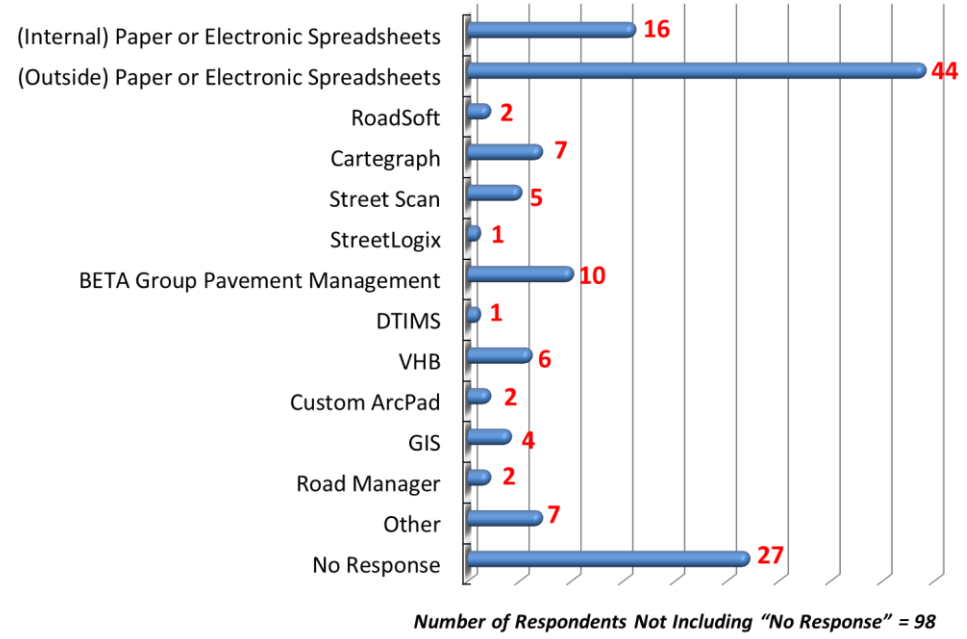


Figure 3.18: Survey result— PMS software programs

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

Other/Comments

Consultant's Proprietary Software
RoadManager GPMS
Don't know
Access Database
IWorQ software
Paser Asphalt Management (University of Wisconsin-Madison)
Not sure of the software, our consultant performs this task for us.

Figure 3.19: Survey result—other PMS software programs

Approximately what proportion of your agency's total road miles are included in your PMS?

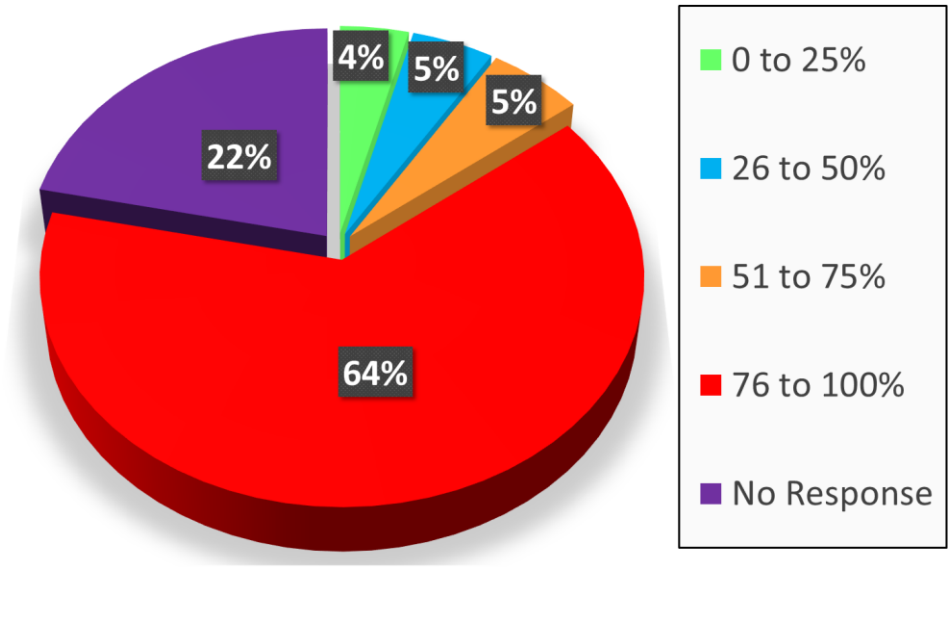


Figure 3.20: Survey result—road miles in PMS

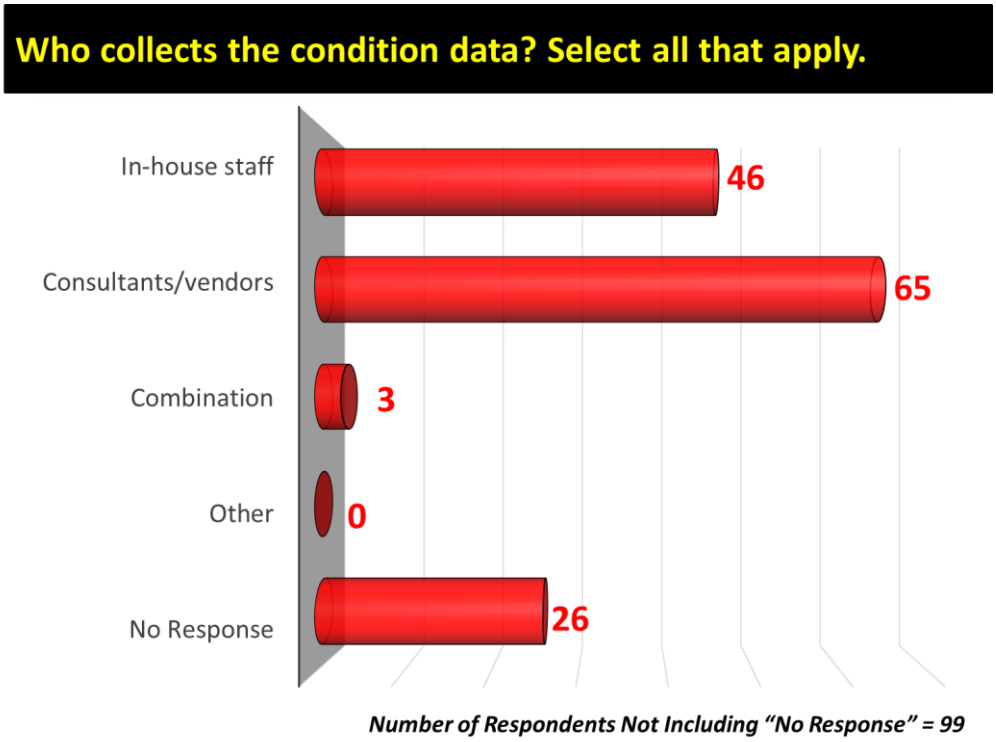


Figure 3.21: Survey result—who collects condition data

PAVEMENTview Plus
Don't know
ESRI ArcPad, window tablet

Figure 3.22: Survey result—other tools

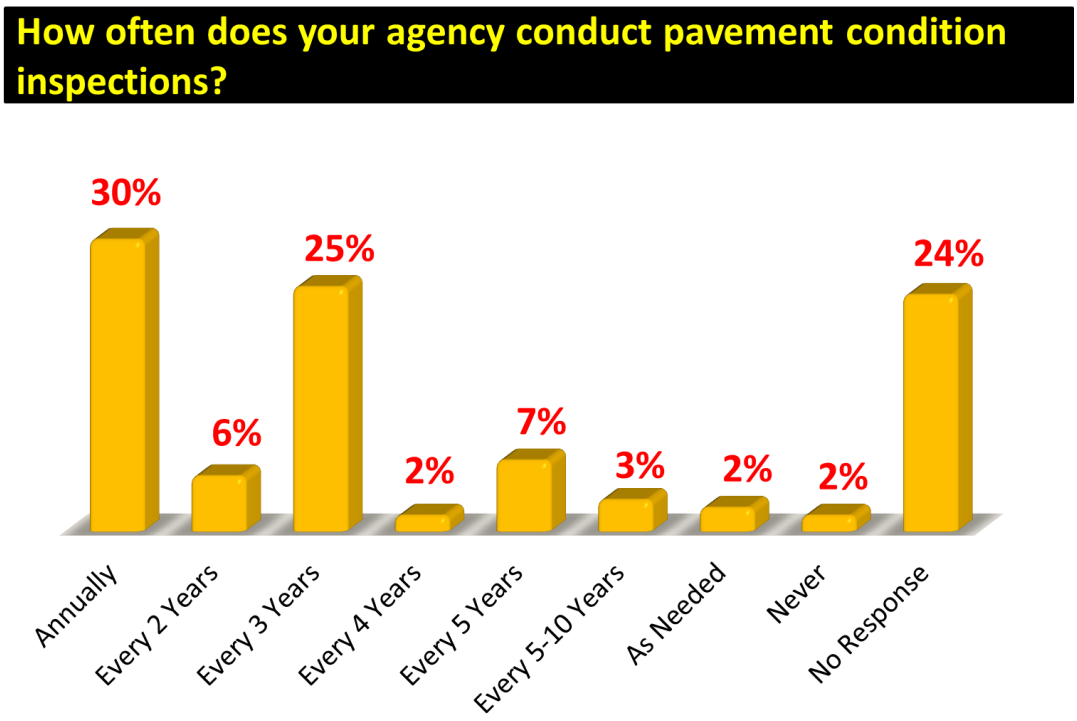


Figure 3.23: Survey result—frequency of inspections

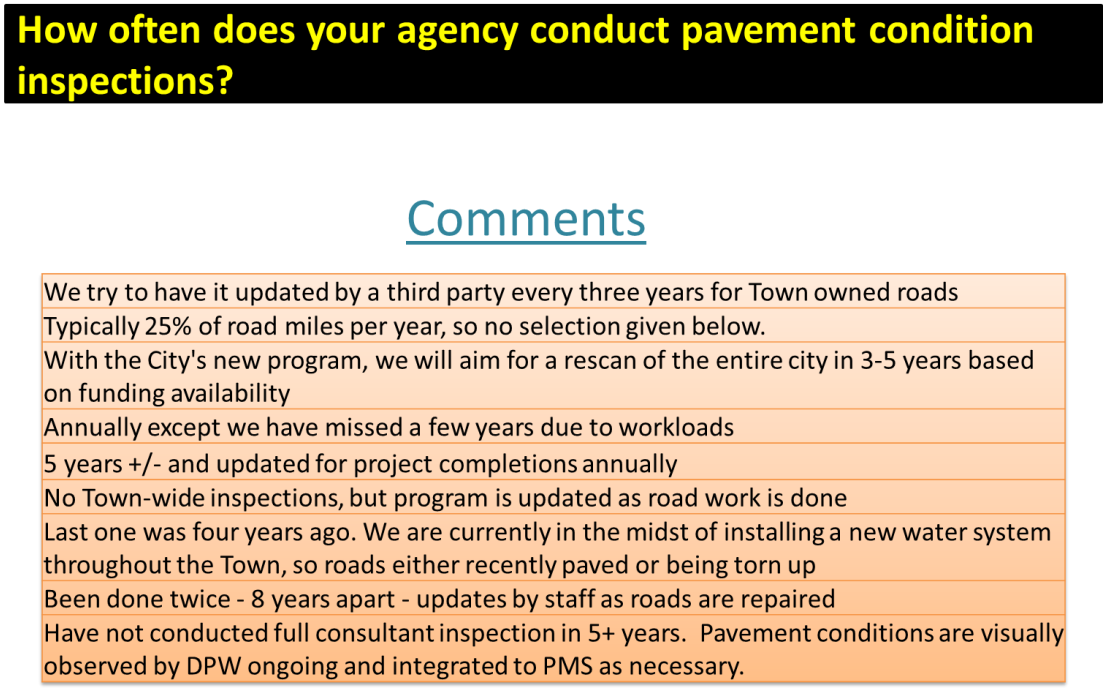


Figure 3.24: Survey result—inspection comments

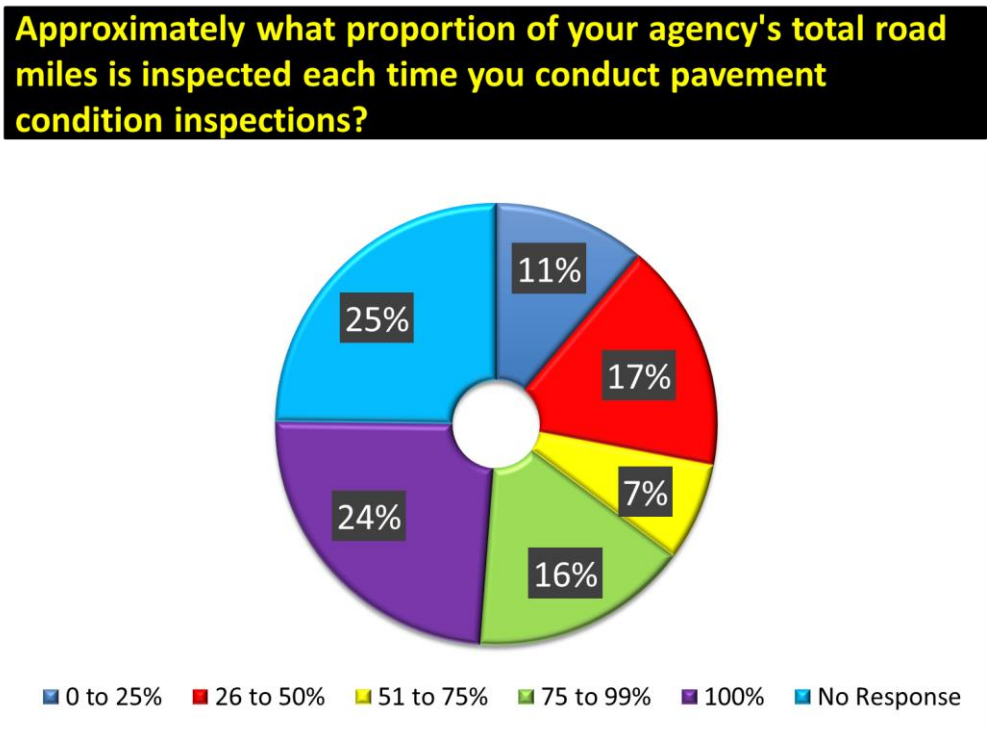


Figure 3.25: Survey result—percent inspected

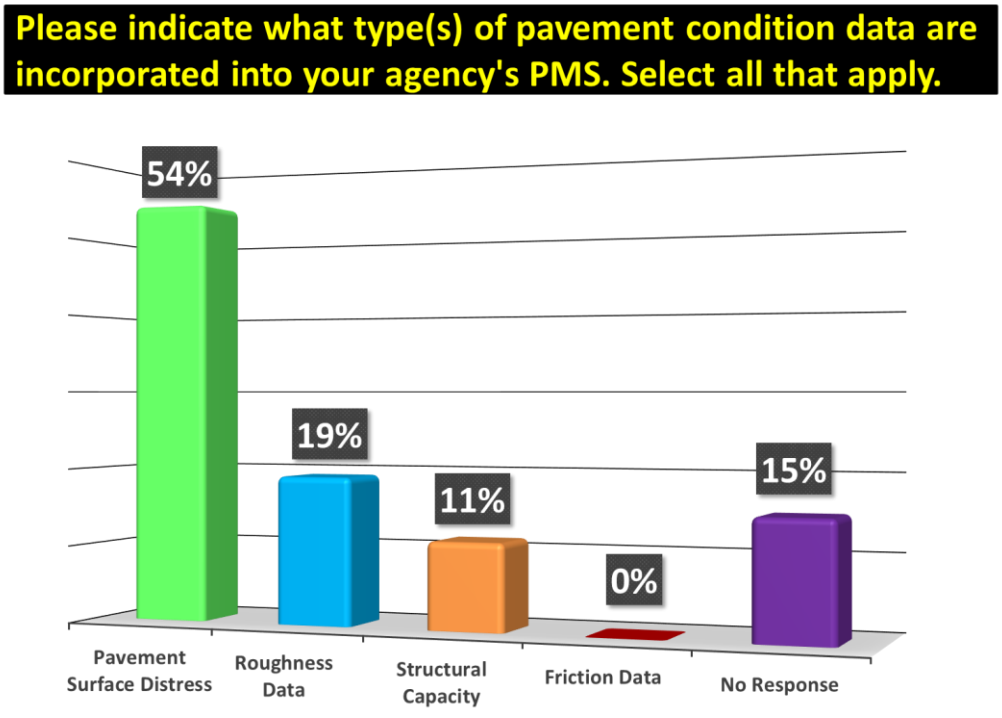


Figure 3.26: Survey result—types of condition data

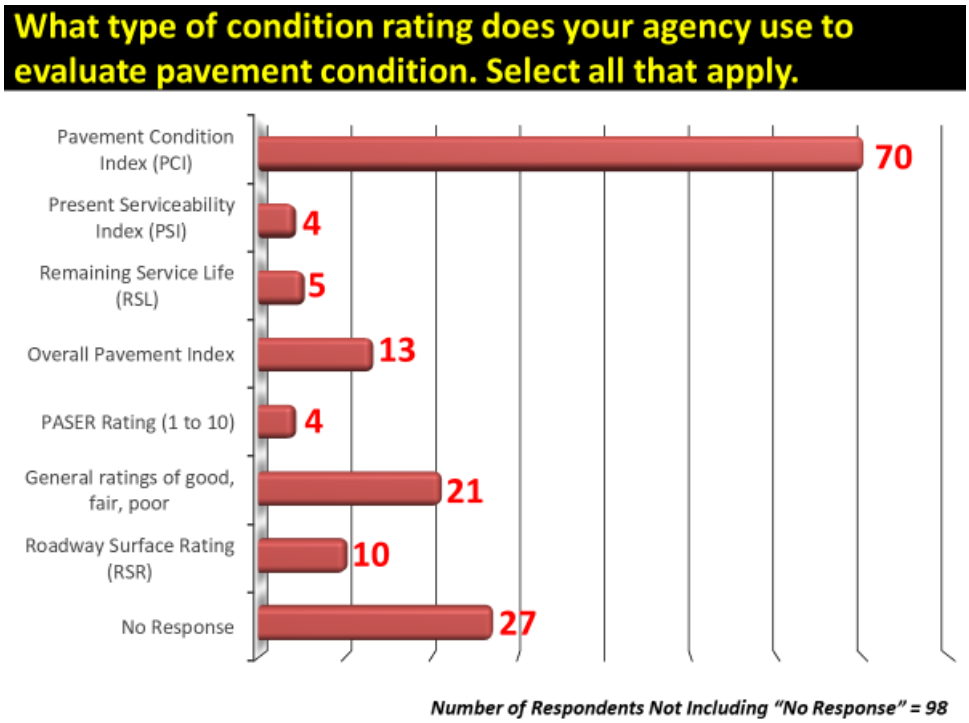


Figure 3.27: Survey result—condition rating types

3.4.3 Investment Decisions

This section shows the survey results related to an agency's investment decisions.

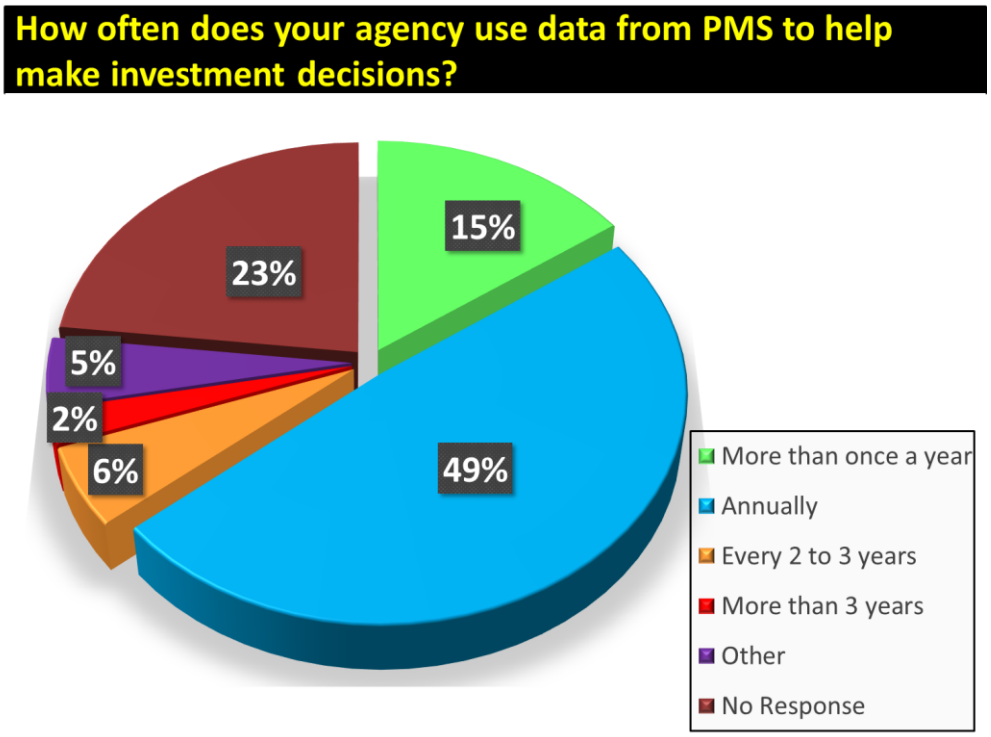


Figure 3.28: Survey result—investment decision frequency

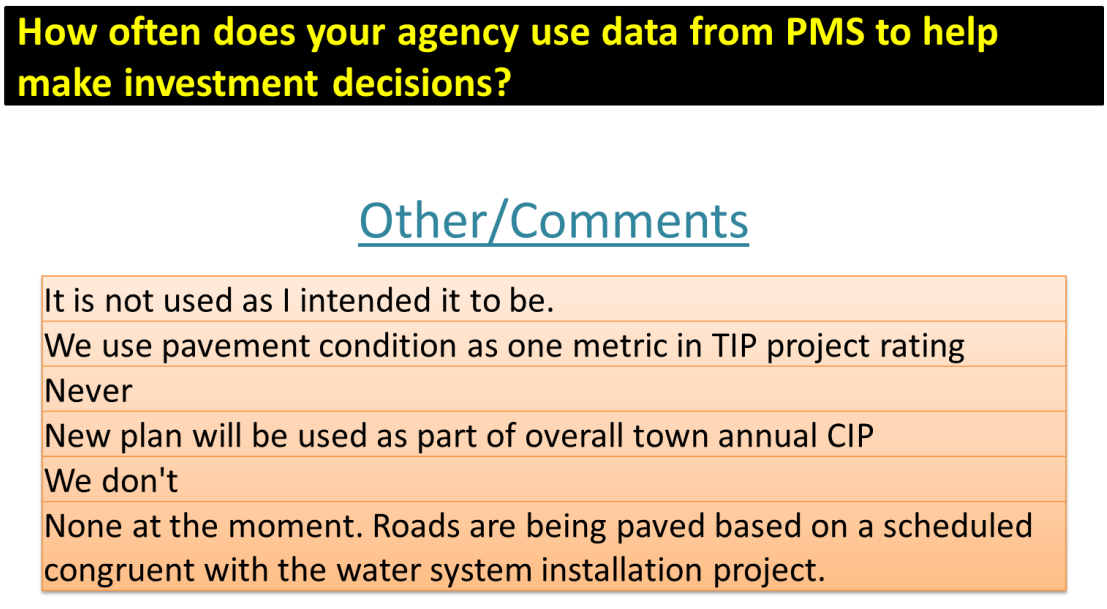


Figure 3.29: Survey result—investment frequency comments

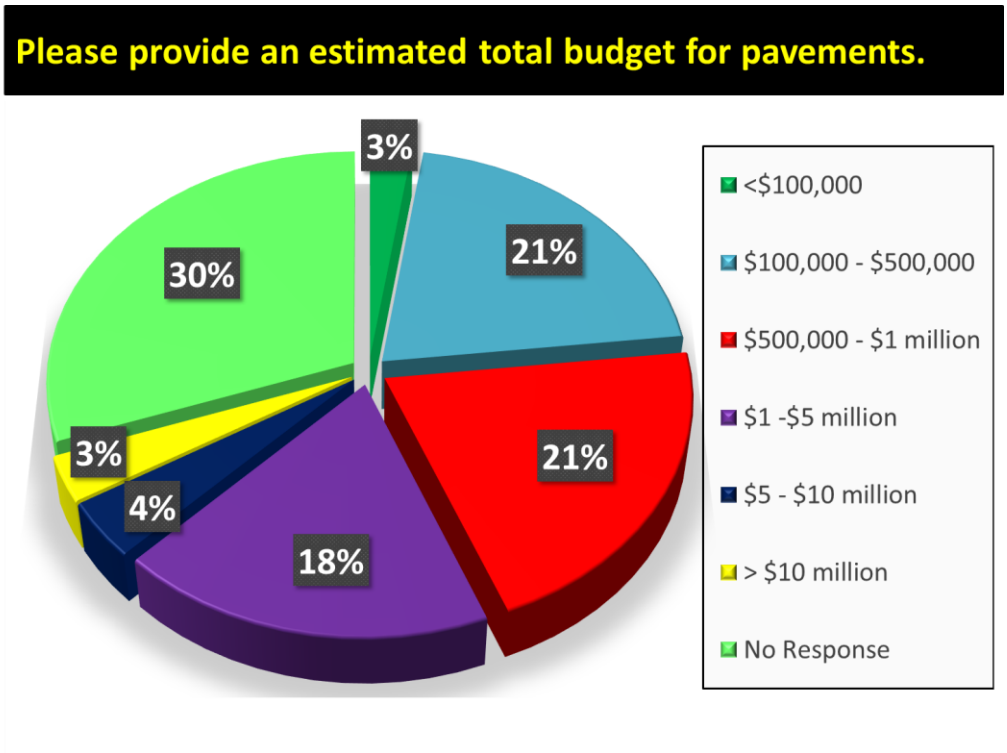


Figure 3.30: Survey result—estimated pavement budget

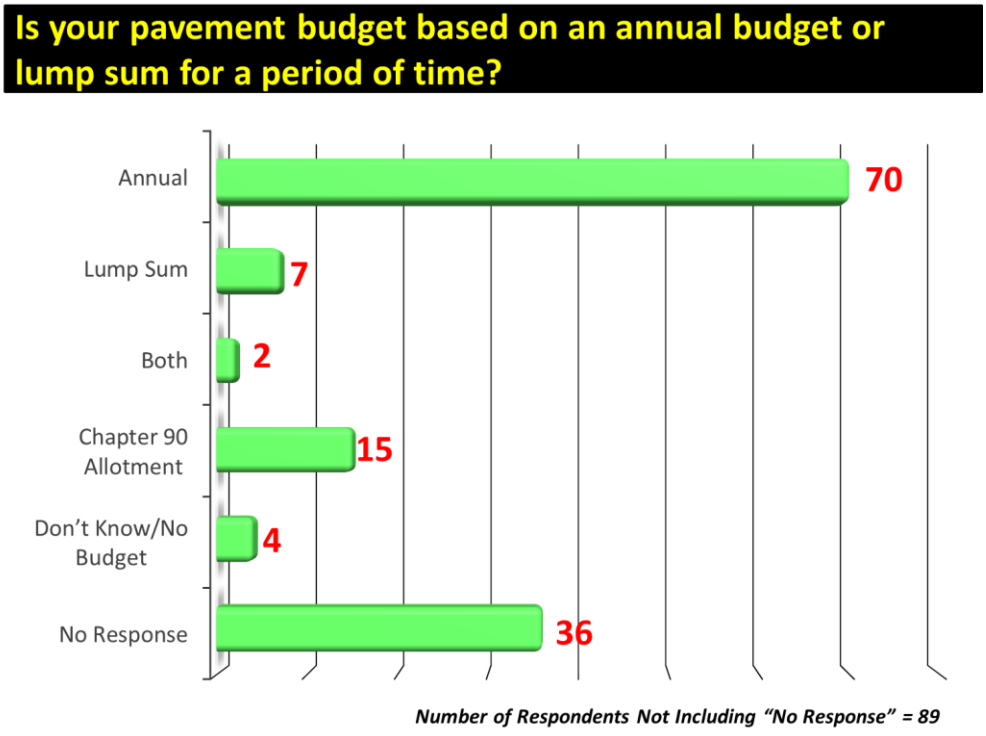


Figure 3.31: Survey result—pavement budget type

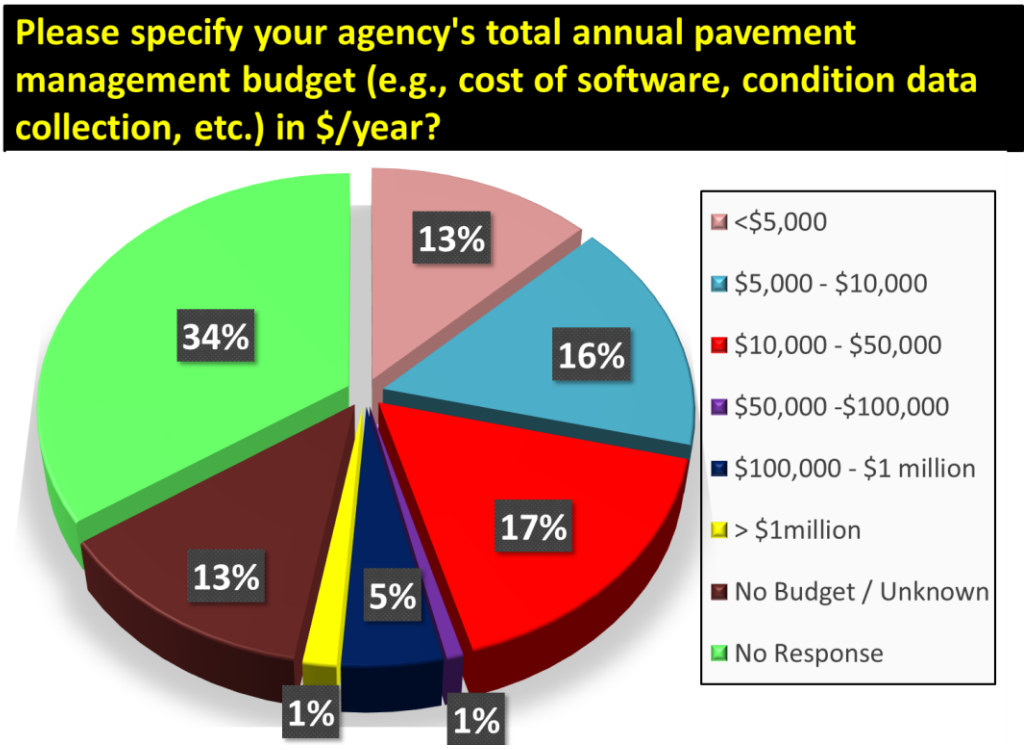


Figure 3.32: Survey result—annual pavement management budget

Table 3.1: Survey result—investment decisions

Results from survey question "Please describe how you make investment decisions. How does the PMS assist in your decision-making?"
Using the rating system we are able to analyze the entire city instead of 1 sample road
Road work prioritization
PCI rating
We use benefit value calculation to determine which roads to pave/maintain
We use the PMS to help score projects for funding. We have several other criteria that come into play.
The PMS is a piece of the decision-making process. There are other factors considered, such as budget, utility projects, continuity with previous resurfacing projects, and school impacts if within the area.
Provides detail on road conditions to help us determine preservation roads and rehab roadways and helps to develop budgeting and projections as well as a snapshot of network health (i.e. RSR and backlog)
A combination of factors enter into the decision-making process
PMS & utility upgrades warranting full reconstruction or cold plane/overlay
Ratings are used to prioritize/rank projects
PMS gives the decision-makers a good starting off point. This is combined with other information such as geographical location, combining multiple years of paving in similar areas, neighborhood complaints, decades of experience of paving and road conditions, and any necessary political considerations.
PMS info provides guidance and helps develop the 5-year plan.
Cost benefit equation that is built into the software program
Priorities and surface treatment based on PCI. Adjusted annually as needed.
Pavement preservation decisions are made based on several factors. PMS is one.
Sorting right-of-ways into five repair levels of escalating invasiveness and expense, and then focusing repair on the candidates at largest risk of falling into a more invasive/expensive level most quickly.
PMS assists with annual selection of streets to be resurfaced.
The PMS listed our roads in priority order of need
Look at current conditions, developments, utilities, etc.
Yes
Cost-Benefit Ratio
This is a loaded question. Need to consider condition of roadway and asset management priorities for all underlying city utilities and limited budgets while maintaining roadways in best possible condition with least costly maintenance option. Unfortunately, many roadways are in need of reclaimation.
PMS is used to identify roads that need various types of restoration: full depth, grind and overlay, patch paving, crack sealing
We are tracking our roads and targeting those in the worst condition. We also have many unpaved and unaccepted dirt roads in our town. Residents are always asking for more to be done with those.
The City's PM tool is maximizing the engineering's department's initiative to utilize various preventative maintenance methods. In the past, the city has spent the majority of the annual funds on full depth road reconstruction. The PM tool helps the city analyze how to better spread the funds while also moving forward to preserve its roadways to the best extent possible.
Review pavement management prioritizations and personal knowledge
Helps public understand pavement management
The utilization of multiple evaluation criteria including PMS to assess conditions and determine magnitude of improvement.
?
5 years

Table 3.1: Survey result—investment decisions, cont.

Results from survey question "Please describe how you make investment decisions. How does the PMS assist in your decision-making?"
Shows which roads are in most need of paving
PMS data is part of a rating matrix for TIP projects that establish priorities
Incremental Benefit Cost for preservation and optimized project selection. Worst first to identify locations in need of immediate repairs.
We generally make decisions on a case-by-case basis, sometimes using PMS but more often looking at budget amounts, roadway conditions, utility work needs, etc.
From past assessment of road conditions based on the worst roads that need to be resurfaced
We prioritize investment in main roads that are in good condition while delaying roads that are poor or failed as long as possible.
Compare data collected to make a decision
Use of software as a general guideline of work/cost to be done after current year roads repair program is established by the Commissioners/DPW discussions.
Programming roads in annual CIP
Try to pave the worst first.
Try to take care of worst roads first and biggest gain for dollars spent
Provides estimates for repair costs as well as a rating for worst roads to best
We reevaluate the roadways and determine which roads will be included in the next fiscal year appropriations.
PMS weighs heavily in selecting higher volume roads but we also try to do a little work each year on the lower volume roads with a much lower benefit value.
It doesn't
We utilize PCI, Functional Classification and general condition along with resident feedback and general knowledge
We utilize the pavement condition to help choose the correct repair method at the correct time.
We take the PMS into consideration and also amount of traffic that uses a certain road.
Through our pavement management and inspection efforts, the Town is able to determine which roads are in the worst condition and need repair in a given construction season and also which roads are in good to fair condition that we can use techniques such as crack sealing and fog sealing to maintain. Sidewalk repair is given priority to streets that have recently been paved. We use our pavement management program to prioritize road related projects funded through grants such as the Complete Street and Safe Routes to School programs.
Determine worst streets and value them based on street classification
We repair and resurface roads based on the PCI
PCI
Try to prioritize projects based on PMS Cost Benefit Analysis
Use PCI reports as a starting point and assess with institutional knowledge to fine tune
N/A
Target roads with low scores
PMS is part of the decision process but equally important is our Capital Plan for other infrastructure improvements such as water, sewer and drainage.
We mainly report condition of NHS roadways per Federal requirements. We do not have direct responsibility for maintenance of roadways.

Table 3.1: Survey result—investment decisions, cont.

Results from survey question "Please describe how you make investment decisions. How does the PMS assist in your decision-making?"
We use our PMS as one tool in determining whether there are adequate federal and state road maintenance funds to maintain our region's federal aid roadways over the 20-year period covered in the MVMPO's Regional Transportation Plan.
quarterly discussions with DPW, Mayor, etc. regarding condition of roads and available funding.
PMS is performed by in-house staff
Not Much. No funding.
The RSR ratings and cost benefit analysis portion of the reports helps to make decisions
Aids in identifying treatment type and regional needs as well as capital planning
Identifies long term maintenance required so a plan and estimates of cost can be developed for Public Works CIP
Provided lists of road by conditions and repair type to be considered to treatment—how best to invest the funding
With cost benefit value
Determines which roads to crack seal, mill and overlay or reconstruct.
we resurface the roads in the worst shape, with priority roads taking precedence.
The Paser system allows us to justify, to residents and other stakeholders, which roads will be rehabilitated.
PMS informs decision making.
We use the PMS every year as tool to determine our paving priorities.
Streets receiving the lowest PCI score are prioritized
Heavily rely on the pavement management.
Yes
PMS provides priority streets based on roadway classification and PCI. Oxford prioritizes its arterial and collector streets more heavily than low volume-local roads due to budget constraints.
Review Pavement Management Report and updates from Utility Construction
Utilize PMS system for cost/benefit of improvements and integrate priority roadway improvement projects.
they describe what roads should be done every year but it's up to the Assistant Director and money
We use the Road Surface Rating to help decide which roadways to maintain and/or reconstruct and how to maintain or reconstruct the roadways.

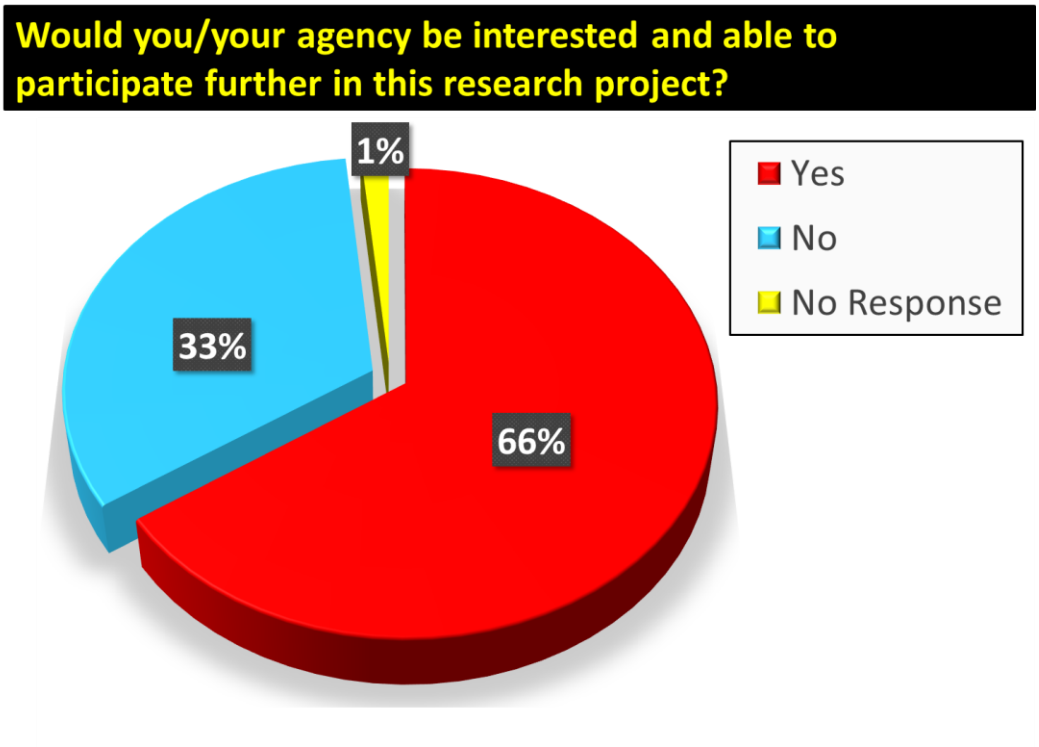


Figure 3.33: Survey result—further participation

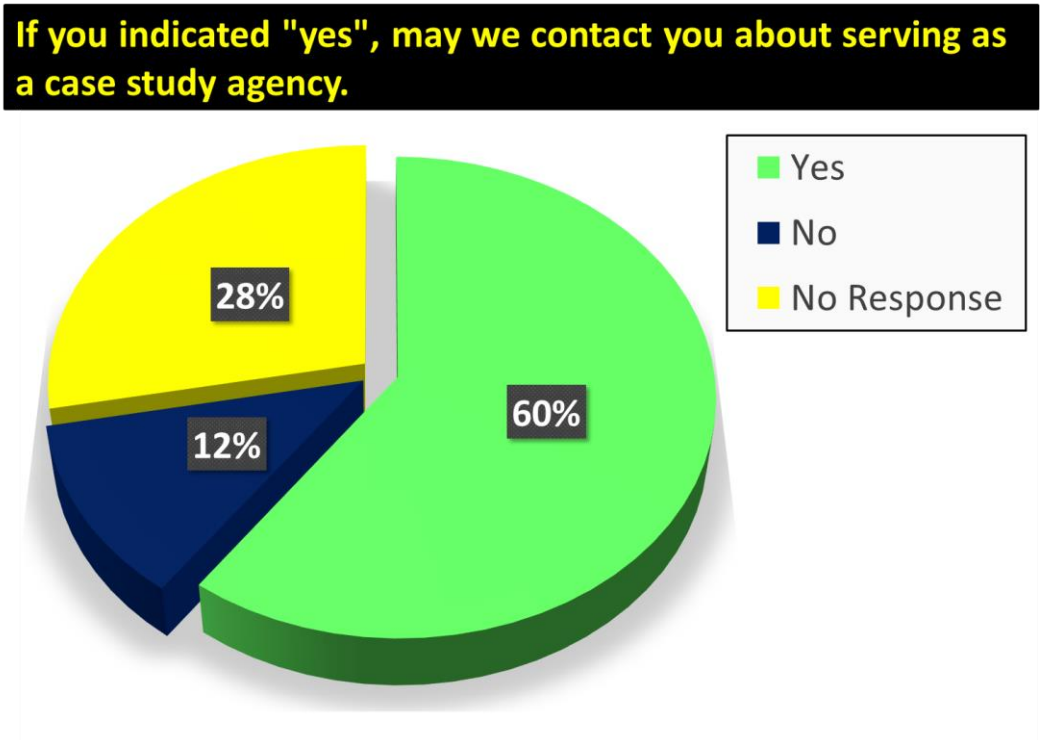


Figure 3.34: Survey result—contact permission

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4.0 On-Site Interviews

4.1 Purpose

The research team conducted interviews of selected online survey participants. The purpose of the interviews was to obtain greater depth and insights into the agency's PMS and how their PMS impacts their investment decisions. The interview questions focused on data management, data reporting, deterioration prediction, whether their PMS incorporates treatment selection rules and unit cost information, selection of investment decisions, and the impact of implementing a PMS on maintenance and rehabilitation plans.

4.2 On-Site Interview Questions

The objective of these interviews was to obtain greater depth and insights into each agency's pavement management system practices. The first step in achieving this objective was to develop a standardized set of questions that would be asked to each interview participant.

The list of questions was developed by the research team and approved by the MassDOT Project Champions prior to conducting any interviews. The final approved list of questions is shown in Table 4.1. The questions addressed a wide variety of topics including: PMS selection, condition surveys and indices, deterioration prediction, treatment selection, investment decisions, data reporting, and data management.

Based on the approved questions, a standardized interview form was developed as shown in Appendix B. This form was completed for each interview.

Table 4.1: Approved interview questions

No.	Question
1	What criteria(s) did you use to select your current PMS?
2	How do you use the output of your PMS to make investment decision?
3	Does your PMS incorporate treatment selection decision trees/matrices and unit cost information?
4	What rehabilitation alternatives do you consider, are they triggered by age or condition, and how are costs calculated?
5	Do you collect structural condition data for your roads?
6	Which pavement distress identification manual does your agency use?
7	What is the impact of implementing a PMS on your agency plans for maintenance and rehabilitation?
8	What service or guidance, if any, do you receive from your MPO as related to pavement asset management?
9	How often do you report your condition data and to whom? How is your data reported?
10	What method(s), if any, do you use to predict deterioration?
11	How is your PMS data managed and by whom?
12	How are your condition indices calculated? If used, how is cost versus benefit calculated?
13	Who should we contact to obtain representative data to be used for potentially correlating different PMS outputs?
14	If MassDOT were to pay for a unified PMS software to be used by agencies within the state, would your MPO/agency be willing to switch software?

4.3 Interview Participant Selection Process

Based on the results of the online survey described in Section 3.0, several participants needed to be selected for the on-site interviews. This section outlines the selection process.

It was proposed that the following factors be addressed (in hierarchal order) when selecting a potential interview participant:

1. Type of pavement management software utilized
2. MPO affiliation
3. Geographical location within the state
4. Willingness to participate further in this research project

The first selection consideration was the type of PMS software utilized. Figure 4.1 shows the corresponding online survey responses. The first group of participants were selected in an attempt to interview at least one agency using each software type, including “Other.”

This initial group of participants was reviewed and their MPO affiliations documented. More participants, with different MPO organization affiliations, were added to the group in an

attempt to interview participants from each MPO organization noted in the online survey as shown in Figure 4.2.

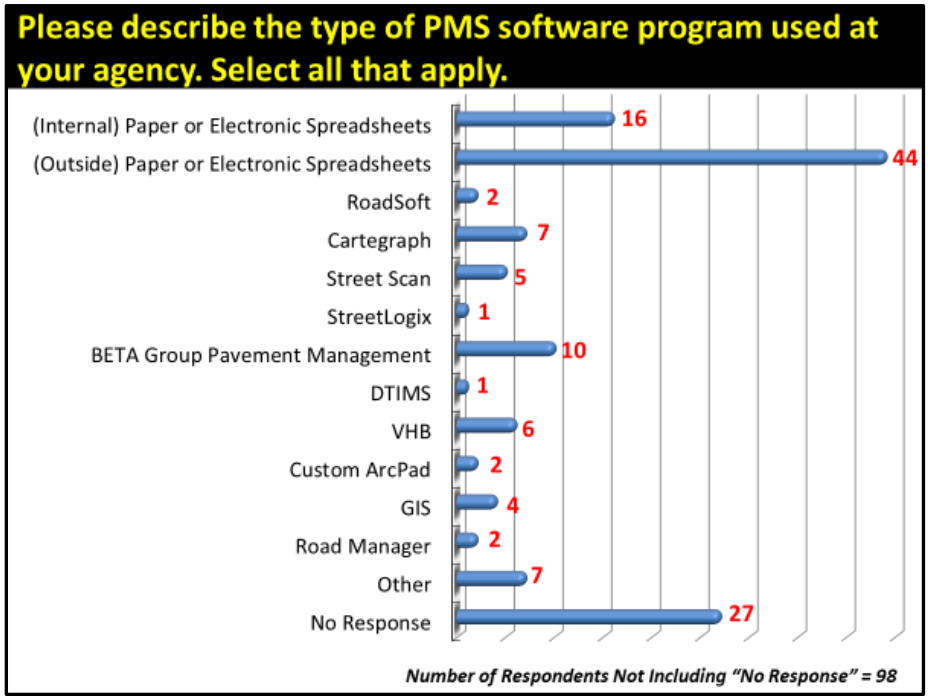

Figure 4.1: Internet survey results—PMS software

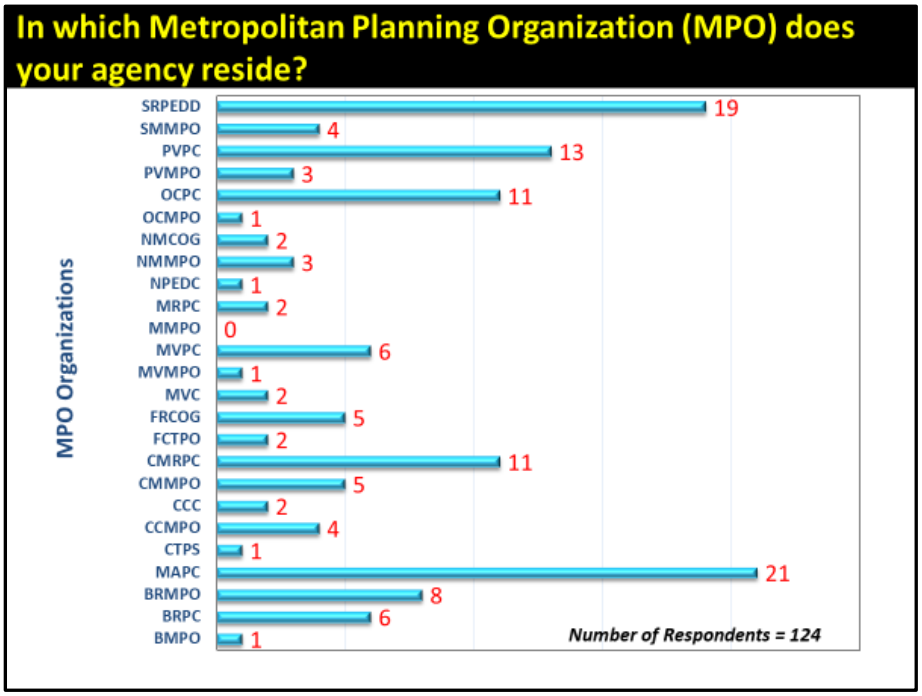

Figure 4.2: Internet survey results—MPO Affiliation

Next this expanded list was plotted on a map to ensure that the different geographic regions (north, south, east, west, central, and Cape Cod/islands) of the state were represented. Figure 4.3 shows the geographic location of the selected municipalities, whereas the selected MPO organizations are shown in Figure 4.4.

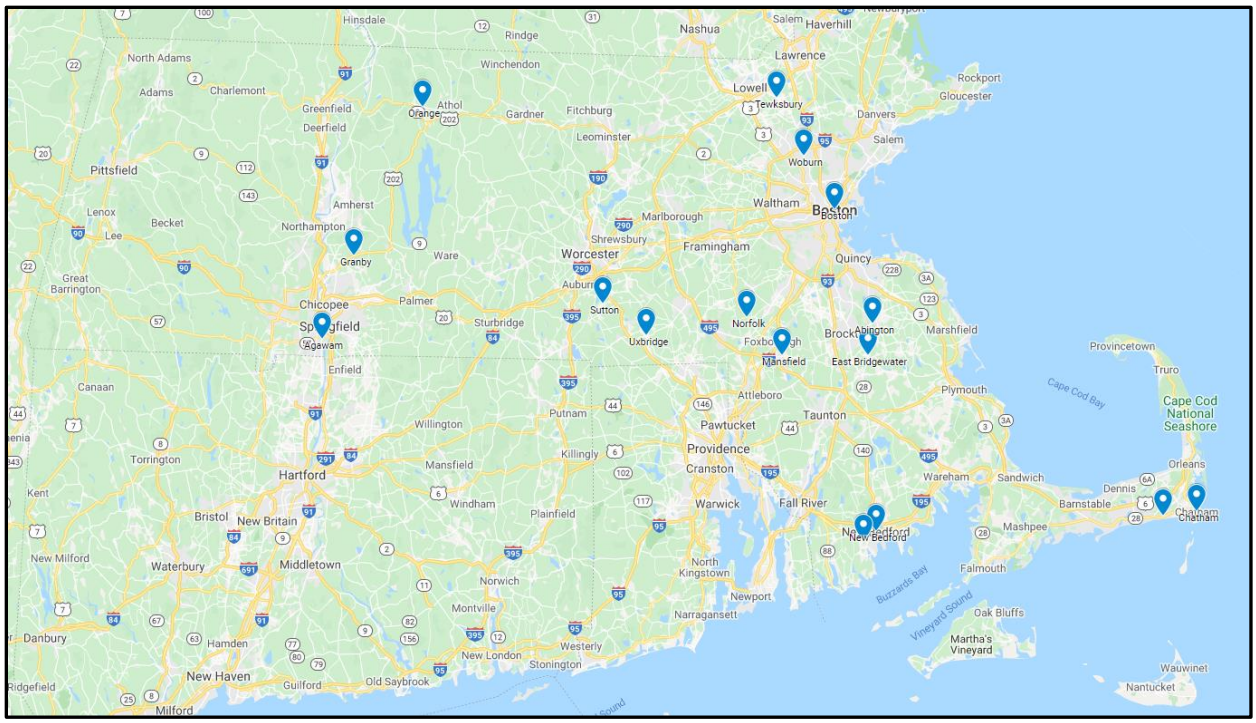

Figure 4.3: Geographic location of selected municipalities

Finally, the expanded list was checked against the online survey question response about the respondent's willingness to participate further in this research. When possible, those respondents indicating they did not wish to participate were removed from the list. There were cases where this could not be accommodated as the respondent interview was needed based on their PMS software type or their MPO organization affiliation.

From all these selection factors, a proposed list of interview participants was assembled as shown in Tables 4.2 and 4.3 for municipalities and MPOs respectively. These tables show the agency, selection criteria evaluated, and justification for selection. A total of sixteen municipalities and eight MPOs were selected to be interviewed.

Finally, it should also be noted that after a few initial interviews were conducted, the MassDOT Project Champions requested that an attempt be made to interview all 14 MPOs in the state as opposed to just the initial eight that were selected. This is reflected in the interview list shown in Table 4.3 which indicates 14 MPOs to be interviewed.

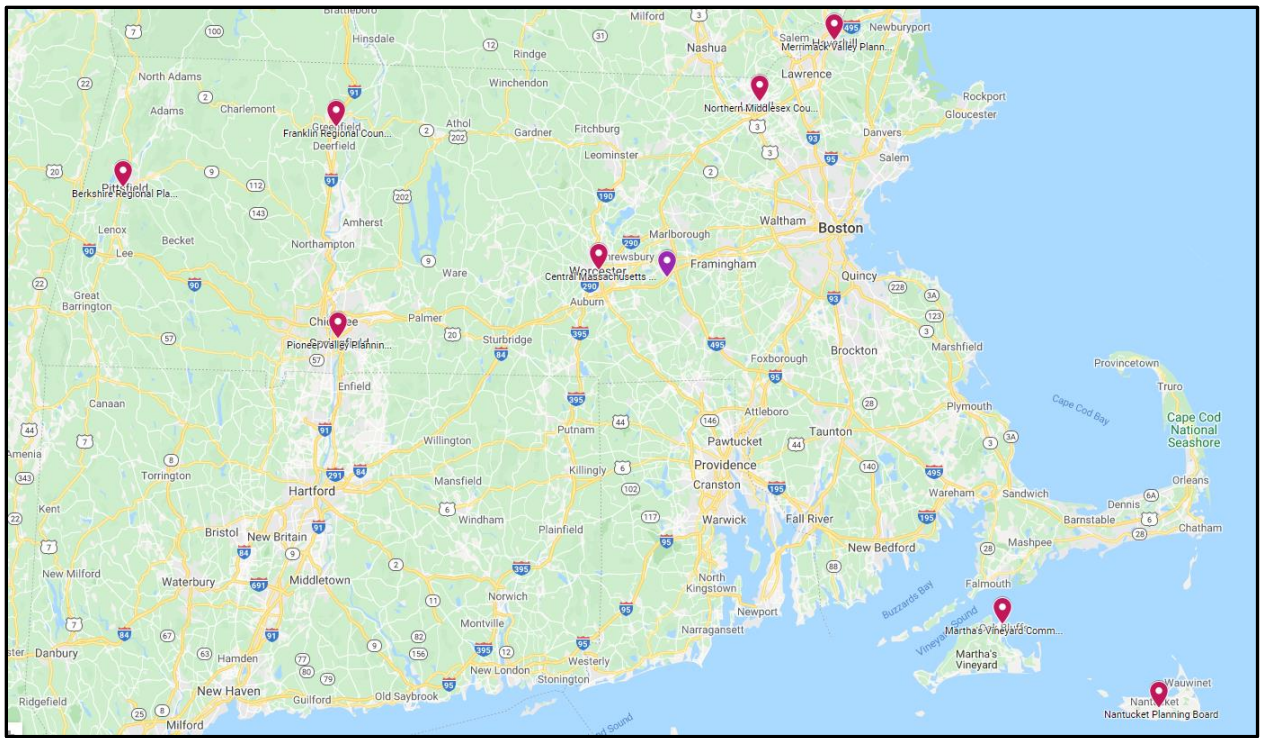

Figure 4.4: Geographic location of initial selected MPOs

Table 4.2: Selected interview participants—municipalities

Municipality	PMS Software	Affiliation	Region	Willingness to Participate	Justification for Selection
Town of Norfolk DPW	Access Database	MAPC	Central	Yes	Respondent MPO/RPA is MAPC and only one to use Microsoft Access Database for PMS software.
City of New Bedford DPI*	StreetLogix	SRPEDD	South	Yes	Only respondent that uses StreetLogix for a PMS software. MPO/RPA is SRPEDD.
Town of Abington	PASER	NCMPO	East	Yes	Only respondent that uses PASER for a PMS software.
Town of Mansfield	Roadsoft	SRPEDD	East	No	One of two respondents that uses Roadsoft for a PMS software. Would not be interested in participating as a case study.
Dartmouth DPW Engineering*	SimpliCITY/ PeoplesGIS	SMMPO & SRPEDD	South	Yes	Respondent MPO/RPA is SMMPO and uses SimpliCITY/ PeoplesGIS as a PMS software.
Town of Chatham	SimpliCITY/ PeoplesGIS	CCMPO	Cape & Islands	Yes	Respondent MPO/RPA is CCMPO and uses SimpliCITY/ PeoplesGIS as a PMS software.
Boston Public Works Department	Cartegraph	BRMPO	East	Yes	Respondent MPO/RPA is BRMPO and uses Cartegraph as a PMS software.
Uxbridge DPW*	ArcGIS/ GIS	CMMPO & CMRPC	Central	Yes	Respondent MPO/RPA is CMMPO and uses ArcGIS/GIS based PMS software.
Town of Harwich DPW	Streetscan & Internal Paper/ Sheets	CCMPO & CCC	Cape & Islands	Yes	Respondent MPO/RPA is CCC and is the only one of five that use Streetscan as a PMS software.
Sutton*	External Sheets	CMMPO	Central	Yes	Respondent use external sheets as a PMS software.
Town of Orange	External Sheets	FRCOG	West	Yes	Respondent use external sheets as a PMS software.
Town of Tewksbury*	Internal Sheets	NMMPO & NMCOG	North	Yes	Respondent MPO/RPA is NMMPO and uses internal sheets as a PMS software.
Agawam DPW	Internal Sheets	PVPC & PVMPO	West	Yes	Respondent MPO/RPA is PVMPO and uses internal sheets as a PMS software.
East Bridgewater DPW	BETA/ Manage My Roads	OCPC	East	Yes	Respondent MPO/RPA is OCPC and uses BETA/ManageMyRoads as a PMS software.
City of Woburn	BETA/ Manage My Roads	MAPC	East	Yes	Respondent uses BETA/ManageMyRoads as a PMS software.
Granby Highway Department*	Road Manager/ VHB	PVMPO	West	Yes	Respondent uses Road Manager/VHB as a PMS software.

** Successfully Interviewed*

Table 4.3: Selected interview participants—MPOs

MPO/RPA	PMS Software	Affiliation	Region	Willingness to Participate	Justification for Selection
Northern Middlesex Council of Governments (NMCOG)*	IWorQ	NMCOG	North	No	Only respondent that uses IWorQ for a PMS software. Would not be interested in participating as a case study.
Berkshire Regional Planning Commission (BRPC)*	Roadsoft	BMPO	West	No	One of two respondents that uses Roadsoft for a PMS software. Would not be interested in participating as a case study.
Central Massachusetts Regional Planning Commission (CMRPC)*	Cartegraph	CMMPO	Central	Yes	Respondent MPO/RPA is CMMPO and uses Cartegraph as a PMS software.
Pioneer Valley Planning Commission (PVPC)*	Cartegraph	PVPC	West	Yes	Respondent MPO/RPA is PVPC and uses Cartegraph as a PMS software.
Merrimack Valley Planning Commission (MVPC)	Cartegraph	MVMPO & MVPC	North	Yes	Respondent MPO/RPA is MVMPO and uses Cartegraph as a PMS software.
Franklin Regional Council of Governments (FRCOG)*	Road Manager/ VHB	FCTPO	West	Yes	Respondent MPO/RPA is FCTPO and uses Road Manager/ as a PMS software.
Martha's Vineyard Commission (MVC)	n/a	MVC	Cape & Islands	Yes	Respondent MPO/RPA is MVC and does not currently use a PMS software.
Nantucket Planning & Economic Development Commission (NPEDC)	n/a	NEPDC	Cape & Islands	Yes	Respondent MPO/RPA is NEPDC and does not use a PMS software.
Metropolitan Area Planning Council (MAPC)	n/a	BRMPO	East	No	Respondent is an MPO/RPA. Would not be interested in participating as a case study.
Central Transportation Planning Staff (CTPS)	n/a	BRMPO	East	Yes	Respondent is an MPO/RPA.
Montachusett Regional Planning Commission (MRPC)*	Road Manager/ VHB	MRPC	Central	No	Respondent is an MPO/RPA. Would not be interested in participating as a case study.
Southeastern Regional Planning and Economic Development District (SRPEDD)*	Road Manager/ VHB	SMMPO/ SRPEDD	South	Yes	Respondent is an MPO/RPA.
Cape Cod Commission (CCC)*	Internal Spreadsheets	CCMPO	Cape & Islands	Yes	Respondent is an MPO/RPA.
Old Colony Planning Council (OCPC)*	VHB GPMS	OCPC	East	Yes	Respondent is an MPO/RPA.

** Successfully Interviewed*

4.4 Interview Results Summary

Interviews were conducted both in-person (on-site) and virtually beginning in September 2021 through the end of February 2022.

The research team was successful in conducting interviews with six of sixteen municipalities for a success rate of 37 percent. The successfully completed municipality interviews are noted with an asterisk in Table 4.2. For MPOs, the research team was successful in conducting interviews with nine of fourteen for a success rate of 64 percent. Similarly, the successfully completed MPO interviews are noted with an asterisk in Table 4.3. Numerous attempts were made to interview the remaining municipalities and MPOs on the approved list, but those efforts were unsuccessful.

4.4.1 Findings from Municipality Interviews

The major findings from the municipality interviews were as follows:

- Municipality PMS software selection was based on user friendliness, being open-source software (i.e. reduced cost), compatibility with existing condition survey practices, capability to include other municipal asset work (utilities), and recommendations from other municipal users.

- Municipal investment decisions made with PMS data included recommending repair methods, cost-benefit analyses, planning decisions, and development of capital plans.

- Treatment selection and unit costs were typically handled within the utilized PMS software. Some municipalities used this information combined with field observations to make treatment selections. The PMS software usually indicated a generic category of service (reconstruction, rehabilitation, preventive maintenance, etc.), each with different treatment options.

- Triggers for treatment included condition index, age, user complaints, budget analysis, experience, and engineering judgement. Costs were based on proposed work estimates and MassDOT weighted bid averages.

- No municipalities collected any structural condition data. Some collected field cores to determine pavement layer thicknesses.

- Municipalities used the following distress identification manuals: none (no manual), BETA manual, US Army Corp of Engineers manual, RSMS manual, and older MassDOT distress manuals.

- Municipalities use their PMS for general guidance, prioritization, to assist in the development of a capital plans, to educate public on what they are doing, and to prioritize and fix roads using a nonarbitrary method.

- One municipality interviewed indicated they receive traffic data and vehicle counts from their MPO. Otherwise, MPO assistance was characterized as limited or minimal.

- Condition data was collected at varying intervals from annually to every five years. Data collection was completed both in-house and by consultants. Some municipalities reported data in capital plans while others did not report it at all.

- Deterioration prediction was typically completed by the PMS software utilized.

- Data was managed both in-house and by outside consultants.

- Little information was available/known on exactly how condition indices were calculated. These calculations were generally made by the PMS software.

4.4.2 Findings from MPO Interviews

The major findings from the MPO interviews were as follows:

- All MPOs interviewed indicated that they would be willing to consider switching to a unified PMS software if MassDOT would be willing to pay for and support it. Many MPOs are currently looking at upgrading/changing their PMS software.

- MPOs are primarily concerned with the condition of the federal aid eligible roads under their jurisdiction.

- PMS software selection was based on legacy (already in-use at agency), part of a group-based purchase for multiple MPOs at the same time, initial setup and annual maintenance costs, and compatibility with existing GIS systems.

- MPOs generally did not make investment decisions with their PMS data. Data was generally used to make prioritization lists/recommendations to municipalities or to simply report conditions.

- Treatment selection and unit costs were typically handled within the utilized PMS software. Most agencies could specify the available treatment options during the initial software setup. Unit costs could be default or input/updated by a specific agency.

- Triggers for treatment included condition index, road classification, maintenance/repair cost, or a combination of these factors.

- No MPOs collected any structural condition data.

- MPOs used the following distress identification manuals: in-house manuals, VHB Road Manager manual, FHWA distress identification manual, and older MassDOT distress manuals.

- MPOs primarily used their PMS to prioritize funding for Transportation Improvement Projects (TIPs) or to assist in the development of a regional transportation plan.

- Generally, MPOs are developing a regional transportation plan every four years. Condition data is typically collected/reported on a three-year cycle. This timing does not apply to all MPOs. Data is often reported on a website or in a published report. To whom the data is reported varied.

- Methods used to predict deterioration were typically deterioration curves generated by the PMS software utilized.

- Data was primarily managed internally by each individual MPO.

- Little information was available/known on exactly how condition indices were calculated. These calculations were generally made by the PMS software. No information was available on how distresses were weighted in a combined index like PCI or OCI. It appears these calculations were left to the discretion of the PMS software supplier during initial setup.

5.0 Exploring the Potential of a Unified PMS Software to be used by MPOs and/or RPAs in Massachusetts

5.1 Purpose

The research team assisted MassDOT in exploring the idea of a unified PMS software to be used by the MPOs and/or RPAs in Massachusetts.

5.2 Methodology

The first step in exploring the idea of a unified PMS software was to add a question to the on-site interviews of the MPOs and RPAs. As shown in Section 4.2, Question #14 was added to these on-site interviews. The specific question was:

> *"If MassDOT were to pay for a unified PMS software to be used by agencies within the state, would your MPO/agency be willing to switch software?"*

The responses received from the MPOs to the added question was positive. Furthermore, all the MPOs interviewed on-site indicated that they would be willing to consider switching to a unified PMS software if MassDOT would be willing to pay for and support it because many are currently looking at upgrading/changing their PMS software.

Based on the interview responses, the second step in exploring the idea of a unified PMS software was to have each vendor demonstrate their PMS software for the MPOs and RPAs. Thus, the MassDOT project champions asked the research team to arrange and coordinate a virtual demonstration day of selected PMS software vendors. This was held on May 26, 2022. During this day, PMS software vendors (BETA, VHB, Cartegraph) showcased their software to the Massachusetts MPOs and answered related questions. A one-hour discussion session with MassDOT, the research team from UMass Dartmouth, and the MPOs was conducted after the demonstrations.

At the request of the MassDOT PCs, the research team created a follow-up online survey to determine feedback from the MPOs and RPAs regarding the PMS software demonstration day. Specifically, the following questions were asked:

- *Please indicate which PMS software that your MPO/RPA would prefer to use if the state were to select one unified PMS software for all MPOs/RPAs to utilize. (Please select only ONE choice). [Choices: Cartegraph, BETA, VHB SAM IS]*

- *Please provide any comments or feedback on why you selected that particular software.*

- *Please provide any insights on why you DID NOT select the other two software programs.*

5.3 Findings

The following findings were determined based on the interviews of MPOs/RPAs, demonstrations of PMS software and follow-up online survey:

- The MPOs interviewed on-site indicated that they would be willing to consider switching to a unified PMS software if MassDOT would be willing to pay for and support it.

- Eleven responses were received for the demonstration follow-up survey. The preferred PMS software vote was nearly identical with two PMS software packages receiving four votes each and one receiving three votes. Thus, there was no consensus among MPOs and RPAs as to which software was preferred.

- Feedback on why a certain software was selected included existing familiarity with a particular software, user friendliness, trust in the software vendor and vendor support, flexibility for end users to perform their own pavement evaluations without a third-party consultant, and currently using a particular software.

- Feedback on why a certain software was not selected included that a particular software seemed like products in development, the vendors appeared to be focused on the data collection contract rather than the software itself, the software did not seem very accessible in terms of support or customization, they felt unfamiliar with software, they felt the software was geared toward municipal use, there would be a loss of existing data and inventories conducted over the past years, the software was more of an operations management program with lots of extras that can get in the way of its use, the software seemed outdated and more complicated to use, the vendor did not seem open to the MPOs/RPAs doing data collection, they were concerned about the extra work that would be required to export existing data from the proprietary software used and import it into whichever software was selected, the cost of the software far exceeded needs, the software had too much information that would not be used, data collection will still not be suitable for a windshield survey and thus it will not provide accurate results, and they had a prior poor experience with vendor technical support.

5.4 Future Steps

Based on the follow-up online survey to the demonstrations of PMS software, there was no consensus among MPOs and RPAs as to which of the three presented software programs was preferred. Specifying one unified PMS system without a consensus agreement as to which one to use presents some major challenges. The selected system would be new to some MPOs and RPAs, thus requiring a learning curve and adjustment period for implementation and use. Moreover, there is a high probability that some MPOs and RPAs would revert back to their former PMS system that they were familiar with if the unified PMS system selected became too cumbersome to implement or use. These factors prompted much discussion and deliberation among the research team and MassDOT to determine a simpler and easier solution. Ultimately it was decided that it would be easier to use a standardized index to categorize the functional characteristics of roads evaluated by each MPO and RPA. Thus, the following proposed framework was developed:

1. MPOs and RPAs will continue to use their current PMS software or any software provider they want. MassDOT would like all pavement data to be shared with geoDOT so that it can be incorporated into a dashboard.

2. MPOs and RPAs would annually provide MassDOT with an Overall Condition Index (OCI). A generic dashboard on geoDOT will be created for all municipalities (towns & cities).

The OCI will be loosely based on a similar combined FHWA metrics approach where specific distresses are given ratings from 1 to 4. It is proposed to use only the following four distresses to determine OCI:

- Cracking
- Rutting
- Ride Quality
- Utility Patching

For each distress the following condition ratings should be used:

Condition	**Rating**
Good	4
Poor	2-3
Fair	1

Specific guidance will be developed and provided as to what is considered Good, Poor, and Fair for each distress.

A standardized formula for the OCI based on these four distresses will be developed by MassDOT and provided to the MPOs and RPAs to report the OCI on an annual basis.

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6.0 Summary & Discussion

This study was conducted as an initial step toward MassDOT's goal to have an overall idea of the pavement condition in Massachusetts for both state and local roads, with corresponding backup data and a means to report such data. In this study, the different pavement asset management systems being used in Massachusetts by local/regional agencies such as cities, towns (municipalities), MPOs, and RPAs were researched and cataloged. A comprehensive literature review was performed. An internet-based survey was developed and administered to these Massachusetts local/regional agencies. Interviews with members of the agencies were also conducted. Finally, the potential for using a unified PMS software for MPOs and RPAs within the state was explored.

From the literature review, it was evident that there were some research studies conducted regarding local agency PMS practices and data in the 1980s and 1990s. The focus of the majority of these studies was the development and establishment of PMS systems, condition surveys, calculation of indices, prioritization, etc. None of the studies were directly related to cataloging the PMS systems being used within a state, how the data was reported, or how the data was included in the overall pavement condition reporting for the state. There was also no information on how local agency data was used in overall decision-making beyond local prioritization of priorities. Thus, the literature review indicated that the objectives of this study were unique and have not been attempted before.

The internet survey was responded to by 109 municipalities (towns and cities) and 15 MPO/RPA agency representatives. Of the respondents, 81 percent indicated they use a PMS. The results further indicated that there are currently 13 different PMS software programs being used in Massachusetts. They are listed as follows:

1. Paper or Electronic Spreadsheets (Internal)
2. Paper or Electronic Spreadsheets (Outside)
3. RoadSoft
4. Cartegraph
5. StreetScan
6. StreetLogix
7. BETA Group Pavement Management
8. DTIMS (MassDOT Only)
9. VHB
10. Custom ArcPad
11. GIS
12. VHB Road Manager
13. Other

The survey results also indicated that varied approaches are taken for condition data collection at the local/regional level. Windshield surveys, detailed walking surveys, a combination of approaches, and automated vans are all being utilized. Additionally, this data

is being collected by both in-house staff and/or outside consultants. The frequency of data collection varied widely, but annually and every three years were most noted. Actual indices determined from the data that are being used include the Pavement Condition Index (PCI), Present Serviceability Index (PSI), Remaining Service Life (RSL), overall pavement index, PASER rating (1 to 10), general ratings (good, fair, poor), and Roadway Surface Rating (RSR). Thus, the survey indicated that there is significant variation in condition data collection and subsequent development of indices throughout the state. These indices are what are primarily being used by local/regional agencies to make investment decisions. Interviews of local/regional agencies indicated that these investment decisions include the recommendation of repair methods, cost-benefit analyses, planning decisions, and development of capital plans.

The different PMS programs being used in the state were researched and compared. It was noted that each is uniquely different. These differences include how condition data should be collected, how condition data is inputted, how indices are calculated from the input condition data, how data is managed, how roads are prioritized, and what treatment options are suggested. It was noted that the calculation of distress indices was specific or proprietary to each software, meaning that the true mathematical formula for each one was not available. This was confirmed in the interviews of local/regional agencies. This leads to the conclusion that distress indices for the same condition data calculated using different software programs might be different. Thus, a distress index value calculated from one software might not have the same physical meaning as one calculated using a different software. In terms of reporting, this means that the values for pavement or distress conditions are not standard across the state in terms of what the values physically mean in terms of condition; rather they are all independent of each other and only applicable to similar indices calculated using the same program. This presents a major challenge for MassDOT's goal of reporting statewide condition for both state and local roads, as most local/regional agencies use different PMS software programs.

Attempting to correlate the outputs from each of the thirteen different PMS software programs to each other would be a significant and complex research undertaking. A more simplified approach was explored in this study to help meet MassDOT's goal of statewide condition reporting for both state and local roads by investigating the potential of using a unified PMS software for MPOs and RPAs in Massachusetts. Interviews conducted with MPOs and RPAs indicated that they would be willing to consider switching to a unified PMS software if MassDOT would be willing to pay for and support it. Based on this positive response, a virtual demonstration day of selected PMS software vendors was held. Based on the internet survey and interviews, the top three noted commercially available PMS software vendors were invited. During this day, these PMS software vendors showcased their software and answered related questions. Then a follow-up online survey was developed to determine feedback regarding the demonstration day. The survey indicated that there was no consensus among MPOs and RPAs as to which software was preferred. Various reasons were supplied by the MPOs and RPAs as to why each software was either selected or not selected. This suggests that implementing a unified PMS software for the MPOs/RPAs may be challenging.

Overall, this study helps outline the existing PMS state of practice at the local and regional level in Massachusetts. It also helps identifies obstacles that lay ahead in achieving MassDOT's goal to have an overall idea of the pavement condition in Massachusetts, for both state and local roads.

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8.0 Appendices

Appendix A: Survey Questions

Understanding Asset Management Systems Utilized by Municipalities in Massachusetts

The University of Massachusetts Dartmouth is conducting a research project for the MassDOT with the aim to catalog the different asset management systems, specifically pavement management systems being used by cities, towns, and Regional Planning Agencies (RPAs) throughout Massachusetts. Also, for municipalities that do not utilize a pavement management system, the study aims to understand their methods for assessing road conditions and keeping an inventory of their road conditions.

* Required

1. Email *

Demographic Information

2. Name

3. Title

4. Agency

5. Address

6. Telephone

7. Email

_____

8. Can we contact you by phone?

Mark only one oval.

- ◯ Yes
- ◯ No

Agency Information

9. Please indicate your agency type.

Mark only one oval.

- ◯ Town
- ◯ City
- ◯ RPA
- ◯ Other: _____

10. What is the approximate population of your jurisdiction?

_____

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

_____

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

Mark only one oval.

- ◯ Rural
- ◯ Suburban
- ◯ Urban

13. Do you have road inventory for the roads your city/town owns?

Mark only one oval.

- Yes
- No

14. If you selected No, please describe what are the obstacles to obtaining/conducting a road inventory.

15. In which Metropolitan Planning Organization (MPO) does your agency reside?

Check all that apply.

- [ ] Berkshire Region Metropolitan Planning Organization (BMPO)
- [ ] Berkshire Regional Planning Commission (BRPC)
- [ ] Boston Region Metropolitan Planning Organization (BRMPO)
- [ ] Metropolitan Area Planning Council (MAPC)
- [ ] Central Transportation Planning Staff (CTPS)
- [ ] Cape Cod Metropolitan Planning Organization (CCMPO)
- [ ] Cape Cod Commission (CCC)
- [ ] Central Massachusetts Metropolitan Planning Organization (CMMPO)
- [ ] Central Massachusetts Regional Planning Commission (CMRPC)
- [ ] Franklin County Transportation Planning Organization (FCTPO)
- [ ] Franklin Regional Council of Governments (FRCOG)
- [ ] Martha's Vineyard Commission (MVC)
- [ ] Merrimack Valley Metropolitan Planning Organization (MVMPO)
- [ ] Merrimack Valley Planning Commission (MVPC)
- [ ] Montachusett Metropolitan Planning Organization (MMPO)
- [ ] Montachusett Regional Planning Commission (MRPC)
- [ ] Nantucket Planning and Economic Development Commission (NPEDC)
- [ ] Northern Middlesex Metropolitan Planning Organization (NMMPO)
- [ ] Northern Middlesex Council of Governments (NMCOG)
- [ ] Old Colony Metropolitan Planning Organization (OCMPO)
- [ ] Old Colony Planning Council (OCPC)
- [ ] Pioneer Valley Metropolitan Planning Organization (PVMPO)
- [ ] Pioneer Valley Planning Commission (PVPC)
- [ ] Southeastern Massachusetts Metropolitan Planning Organization (SMMPO)
- [ ] Southeastern Regional Planning and Economic Development District (SRPEDD)

Other: [ ] _____

Pavement Management System

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.

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

Mark only one oval.

- ◯ Yes
- ◯ No - But I am interested in knowing more about pavement management — *Skip to question 34*
- ◯ No – I am not interested in knowing more about pavement management — *Skip to question 34*

17. If you selected No PMS, please describe how you make investment decisions for your road network.

_____

_____

_____

_____

_____

Details of PMS

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

Mark only one oval.

- ◯ < 2 Years
- ◯ 2 to 5 Years
- ◯ 5 to 10 years
- ◯ >10 Years

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

- [ ] Windshield Survey
- [ ] Detailed Walking Survey
- [ ] Automated Vans
- [ ] Combination

Other: [ ] _____

20. If your agency collects condition data using windshield survey and/or detailed walking survey, which of the following tools do you use to conduct the survey.

Check all that apply.

- [ ] Pen & paper
- [ ] Tablets
- [ ] Portable pc's
- [ ] Smartphones
- [ ] Combinations of the above

Other: [ ] _____

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

Check 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)
- [ ] Road Care

Other: [ ] _____

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

Mark only one oval.

- ◯ 0 to 25%
- ◯ 26 to 50%
- ◯ 51 to 75%
- ◯ 76 to 100%

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

Check all that apply.

- [ ] In-house staff
- [ ] Consultants/vendors
- [ ] Combination
- [ ] Other: _____

24. If you selected combinations or other, please list the tools.

_____

_____

_____

_____

_____

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

Mark only one oval.

- ◯ Every year
- ◯ Once every two years
- ◯ Once every three years
- ◯ Other: _____

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

Mark only one oval.

- ◯ 0 to 25%
- ◯ 26 to 50%
- ◯ 51 to 75%
- ◯ 75 to 99%
- ◯ 100%

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

Check 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

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

Check all that apply.

- [ ] Pavement Condition index (PCI)
- [ ] Present Serviceability Index (PSI)
- [ ] Remaining Service Life (RSL)
- [ ] Overall Pavement Index
- [ ] PASER Rating (1 to 10)
- [ ] General ratings of good, fair, poor

Other: [ ] _____

Investment Decisions

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

Mark only one oval.

- ◯ More than once a year
- ◯ Annually
- ◯ Every 2 to 3 years
- ◯ More than 3 years
- ◯ Other: _____

30. Please provide an estimated total budget for pavements.

_____

31. Is your pavement budget based on an annual budget or lump sum for a period of time?

32. Please specify your agency's total annual pavement management budget (e.g., cost of software, condition data collection, etc.) in $/year?

33. Please describe how you make investment decisions. How does the PMS assist in your decision making?

Thank You & Interest Questions

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

Mark only one oval.

- Yes
- No

35. If you indicated "yes", we may contact you about serving as a case study agency.

Mark only one oval.

- Yes
- No

Appendix B: On-Site Interview Form

On-Site Interview Form

Name of Person Interviewed: _____
Agency: _____
Date: _____

Question 1: What criteria(s) did you use to select your current PMS?

Answer from Related Online Survey Question: "Please describe the type of PMS software program used at your agency."

Question Response:

Question 2: How do you use the output of your PMS to make investment decision?

Answer from Related Online Survey Question: "Please describe how you make investment decisions. How does the PMS assist in your decision making?"

Question Response:

Question 3:Does your PMS incorporate treatment selection decision trees/matrices and unit cost information?

Question Response:

Question 4: ***What rehabilitation alternatives do you consider, are they triggered by age or condition, and how are costs calculated?***

Question Response:

Question 5: Do you collect structural condition data for your roads?

Answer from Related Online Survey Question: "Please indicate what type(s) of pavement condition data are incorporated into your agency's PMS."

Question Response:

Question 6: Which pavement distress identification manual does your agency use?

Question Response:

Question 7: What is the impact of implementing a PMS on your agency plans for maintenance and rehabilitation?

Question Response:

Question 8: What service or guidance, if any, do you receive from your MPO as related to pavement asset management?

Question Response:

Question 9: How often do you report your condition data and to whom? How is your data reported?

Question Response:

Question 10: What method(s), if any, do you use to predict deterioration?

Question Response:

Question 11: How is your PMS data managed and by whom?

Question Response:

Question 12: How are your condition indices calculated? If used, how is cost versus benefit calculated?

Question Response:

Question 13: Who should we contact to obtain representative data to be used for potentially correlating different PMS outputs?

Question Response:

Question 14: If MassDOT were to pay for a unified PMS software to be used by agencies within the state, would your MPO/agency be willing to switch software?

Question Response: