



CAPE COD  
COMMISSION

2023 REGIONAL TRANSPORTATION PLAN  
Technical Appendix J:  
Pavement Management

**FINAL JULY  
2023**



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# Introduction

As an essential task required by the Cape Cod Metropolitan Planning Organization (MPO) through its Unified Planning Work Program, this report provides the status of pavement condition assessment activities on Cape Cod. The objectives of this effort are to collect data and implement a regional pavement management system for Cape Cod to provide an objective rating of pavement conditions and needs. These efforts assist the local municipalities in their decision making as well as with the MassDOT Municipal Pavement Program. The MassDOT Municipal Pavement Program, created in 2021 as a part of the Transportation Bond Bill, seeks to improve the condition of municipally owned state numbered routes to support the long-term condition of the state network, contribute to National Highway System (NHS) pavement performance, and assist municipalities in the management of local infrastructure. The Municipal Pavement Program has been authorized by legislation for \$140M in future years and is funded in the FY23-27 Capital Investment Plan (CIP) for \$25M a year.

The pavement management process is conducted with the intent to keep the roadway system in the best possible condition with the most efficient use of available funds. There are distinct advantages to managing pavement condition and significant cost savings that can take place with preventative or rehabilitation measures rather than waiting until a road needs reconstruction. As stated in the MPO-approved Cape Cod Regional Transportation Plan, the goal of the pavement management process is for all federal aid-eligible roads to be maintained in “excellent” condition. Of course, due to the reality of limited financial resources, it is necessary to prioritize pavement repair based on affordability. Deciding which roads to improve and by what technique in a fiscally responsible manner is the essence of Pavement Management.

## **PAVEMENT MANAGEMENT SYSTEMS - BACKGROUND**

Pavement Management is the practice of planning for pavement repairs and maintenance with the goal of maximizing the value and life of a pavement network.

To accomplish this, a community needs to have several repair techniques in its arsenal and the knowledge of when to apply them. This is where pavement management comes into play. With a comprehensive database of road conditions, the pavement management software can model when to perform which repairs on a road network. Of course, engineering judgment is required to finalize any list of street repairs, as no computer model can take every variable analyzed in making a repair decision into account. The computer system is a great springboard to help a community start its repair program for each year and is an excellent method of storing the repair data.

Below is a model of how a street’s pavement deteriorates over time. Interpreting the curve, a street starts out in excellent condition when it is newly constructed. Midway through life, low-cost repairs

such as crack seal and full depth patch can extend the quality of the road. It takes only a few years for the window of opportunity to perform this low-cost maintenance to pass after which the road would need a more costly repair such as a mill and overlay or full-depth reclamation. By performing timely maintenance using low-cost methods, road conditions can be improved thereby extending the life of the road and save municipalities from spending more in the future.

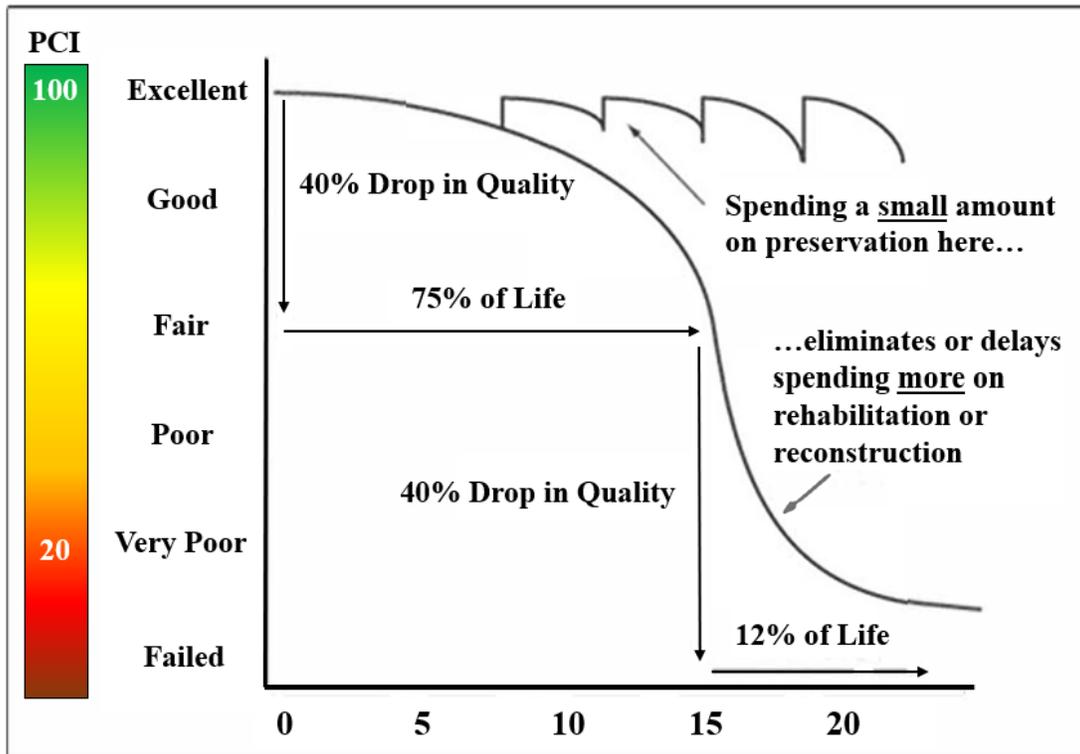


FIGURE 1. Pavement Deterioration Curve  
 Source: Federal Highway Administration

## EVALUATION CRITERIA FOR CCC DATA COLLECTION

The Cape Cod Commission has continued to collect pavement condition data since 2011 through a series of “Windshield Surveys”. These “Windshield Surveys” involve driving the roadways in need of collection and filling out a brief survey with observations. Observers were given photographs and descriptions of example pavement distresses. Observers used a 1 – 5 rating system and made notations of distresses. Copies of the observations are provided in the appendix of this report. The following table is a summary of the guidance given to observers:

TABLE 1. CCC Evaluation Criteria

CONDITION	DESCRIPTION	CRITERIA
1	Very Good to Excellent	New pavement with no cracking, rutting, raveling/ signs of wear
2	Good to Very Good	No cracking, rutting, showing a little wear
3	Fair to Good	Showing evidence or more wear and possibly repairs that are in good condition
4	Poor to Fair	Evidence of cracking, rutting, serious wear
5	Poor	Severe cracking, rutting, potholes

## SURVEY OF CAPE COD COMMUNITIES' PAVEMENT MANAGEMENT ACTIVITIES

In the Fall of 2021, an email survey was sent to each of the 15 towns' Department of Public Works directors. Follow-up inquiries were made in following years. The survey included the following questions:

1. Do you maintain records of pavement quality on your community's roadways?
2. Can you send [electronically preferred] summaries of pavement quality assessments?
3. What system/method do you use to assess pavement quality?
4. Can you send us a report/documentation of methods used?
5. What method do you use to determine repair strategies?
6. Do you have estimated costs for implementing various repair strategies?
7. Can you forward us cost estimates sheets?
8. Do you have a capital plan for pavement improvement?
9. Can you forward us a copy of the capital plan?

Several communities have responded and the sections following are a summarization of those responses and the up-to-date pavement management efforts underway in each municipality.

### Barnstable Pavement Management Activities

The Town of Barnstable utilizes detailed survey and analysis performed by VHB as a Consultant. Their work is entered onto Barnstable's database and periodic reports are provided and discussed. The DPW participates in the data analysis, particularly in the cost analysis. DPW reviews project

bids received by the Town and establishes base line costs for each pavement treatment band, these costs are discussed with the town's consultant - then utilized in the pavement conditions report. In addition to the VHB work, the DPW maintains a record of roadway repairs and relies upon experienced field personnel to assist in planning for individual maintenance tasks such as crack & chip seal. DPW also informally monitors the performance of all treatments. Key to the pavement management program is coordination with other utilities and proposed roadway rehabilitation information is passed to utility companies. A moratorium is in place for 5 years after application of a new surface. The Town of Barnstable does not maintain a public "5-year plan" - because of political considerations.

Submitted materials include:

- VHB-prepared "2010 Pavement Management Report." See section 1.4.1 for discussion of VHB Pavement Management Systems.
- Excel workbook containing typical costs for various items involved in pavement repair and related road work.

## **Bourne Pavement Management Activities**

The Town has retained the services of Environmental Partners, Inc. (EP) to continue the Town's Pavement Management Program (PMP) efforts to adapt to the Town's Capital Improvement Plan (CIP) to accommodate recent changes in staff, environment, and society. The PMP incorporates an extensive database of roadway surface conditions to produce a prioritized list of improvements. The PMP is a planning tool intended to provide the foundation to manage the town's roadway resources by combining professional engineering metrics with local institutional knowledge. EP and Town Staff will work together to identify goals regarding roadway network condition.

The roadway survey in Bourne, consisting of paved, town-accepted roadways, was most recently completed in the Fall of 2017. A total of 97.85 miles of roadway were inspected. The collection effort focused on the primary categories of roadway data including roadway length, width, segment start/end points, surface type, and pavement condition. Additional roadway elements including curbing, sidewalks, striping, roadway width, and pavement material were also assessed as part of this inspection process and recorded in the database.

Upon completion of the survey, the overall Road Surface Rating (RSR) value for Bourne's public roadway network was 75.97. The overall RSR represents a benchmark for performance measuring of the Town's pavement management program moving forward. If the overall RSR were to drop in the years to come, this would be a sign that the program needs to be adjusted or funding for the program may need to be increased. Repair strategies and associated unit costs were defined to develop the Backlog Summary. The current backlog summary for the Town's roadway network is approximately \$10.8 Million. This budgetary dollar figure represents the funding necessary if the Town were to perform all required maintenance for the Town's roadway network within the next year.

The Town will continue to monitor its progress and roadway rating by performing periodic network inspections and is committed in maintaining and improving its roadway network.

## **Brewster Pavement Management Activities**

In 2015, the Town of Brewster published its “Pavement Management Plan.” Prepared by the consultant CDM Smith, the plan included the following findings:

- The Town’s overall Pavement Condition Index (PCI) was a 73.
- If no further money were spent on roadways for 10 years, that PCI would decline to 63.
- Performing all the work necessary on the roads as of the inventory date would cost in the order of magnitude of \$12 Million.
- Maintaining the existing PCI of 73 would cost approximately \$1.1 Million per year over the next 5 years.
- Continuing to spend at present levels (\$470K, if all went to roadway work) will result in a decline over the next 5 years to a PCI of 71. As it nears the critical PCI of 55, the overall condition will decline more rapidly.
- To reach a target PCI of 80 in 5 years, the Town would need to spend approximately \$2.3 Million per year.

Within the past few years, Brewster has retained BETA Group, Inc. (BETA) to provide a Pavement Management Program (PMP) to better maintain the Town’s roadway network. BETA’s pavement services include performing a detailed visual inspection, calculation of a Roadway Surface Rating (RSR), and recommendation of required maintenance for each roadway segment. BETA compiles the pavement data into a web-based application to allow the town to actively manage their priorities.

A total of 48.3 centerline miles were inspected during the summer of 2020. The required field inspections were preformed autonomously using a smartphone application utilizing machine-learning technology. Based on the inventory in 2020, the overall Road Surface Rating (RSR) for Brewster’s Town roadway network was 78.64. The PMP allows for the Town to develop a Capital Improvement Plan (CIP) for the existing roadway network. The Town has shown a commitment to maintaining the PMP and improving its roadway network.

## **Chatham Pavement Management Activities**

The Town of Chatham has retained the firm of BETA Group, Inc. (BETA) to develop a Pavement Management Program (PMP). BETA’s pavement services include performing a detailed visual inspection, calculation of a Roadway Surface Rating (RSR), and recommendation of required maintenance for each roadway segment. BETA compiles the pavement data into a web-based application to allow the town to actively manage their priorities.

## **Dennis Pavement Management Activities**

The Town of Dennis contracted StreetLogix to provide their Pavement Management System. In 2021, the Town hired StreetLogix to perform an inventory of their roadways (approximately 142 miles) and sidewalks (approximately 29 miles). The results of the inventory completed by StreetLogix is in an interactive, web-based system, which the Town will use as a guide to determine which roads to work on and to project future budgets. The Town will use the system as a guide as yearly construction needs to consider other factors that the pavement management system cannot factor into the calculations such as funding, fairly spreading the improvements through the 5 villages in Dennis and maximizing the bids received by contractors.

Based on the inventory conducted in 2021, the Town's overall PCI rating is 80 (Good condition). The town's road budget for pavement improvement has been consistently funded between \$400,000 to \$600,000 per year through Capital Requests for "secondary roads" but can vary depending on other capital requests. Chapter 90 funds are also used to maintain the Town's roads and are usually spent on larger resurfacing projects or on arterial and collector roads

## **Eastham Pavement Management Activities**

The Town of Eastham is developing a pavement management system. Current efforts include detailed spreadsheets identifying treatment strategies.

Submitted materials include:

- Spreadsheet listing of town roads with summary of face type
- Spreadsheet listing of Town & Private Roads in Town of Eastham with summary of surface type
- Spreadsheet listing of town roads with itemized surface type

These assessment surveys of all the Town's private ways and town-maintained public roads, prompted mainly by the on-going construction of its town-wide water distribution network, are to assist in the preparation of a Capital Improvements Plan (CIP). The Town of Eastham is also a Massachusetts Complete Streets Tier 3 community, and as such will be looking to include multimodal access options in all repairs related to its Roadway Capital Improvements Plan.

## **Falmouth Pavement Management Activities**

Falmouth uses VUEWorks Asset Management Software to track their Public Works Assets. Falmouth has just begun to use the Pavement Condition rating system that is a module of the system. It is based on the ASTM rating system. Falmouth has provided a copy of their Pavement Manual, a report of the roads they have rated so far, and a sample report of one of the roads. Falmouth uses a couple of strategies to determine their repair schedule. The town has a 10-year roadway plan for major repairs. This is funded by the town operating budget and a Capital Plan. Falmouth has provided both documents. The town also has a service call/ work order system to take requests from the public for signs, potholes, sweeping and grading, etc.

Falmouth does not have cost estimate sheets. The town does some work in-house and contracts its crack sealing and large repairs out. These are covered by the town operating budget and Capital Plan.

Submitted materials include:

- Sample Pavement Condition Form
- VUEWorks Pavement Management System Training Guide
- FY 2013-2022 Capital Improvement Program summary form
- Public Works Department Roadway Maintenance Program FY 2012-2023

## **Harwich Pavement Management Activities**

The Town of Harwich DPW previously utilized an online database that was developed with Bonsai Logic (a small local software developer) to maintain a road inventory, to develop cost estimates, to reconcile DPW estimates against actual expenses and to maintain a roadwork history. As of 2018, the Town has contracted StreetLogix to provide their Pavement Management System. The DPW does not utilize the database to develop a PCI (Pavement Condition Index). The town rates roads in 1 of 4 structural conditions: good, fair, deficient, intolerable

The DPW does have a 5-year road maintenance plan that is updated every few years and is available on the Harwich website. The Town uses Chris Nickerson, Highway Road Manager who is a certified pavement inspector, to develop a plan based on his experience, training, and knowledge of Harwich's 481 public roads (142 miles). The Town attempts to balance maintenance with repair to avoid costly reconstruction utilizing many different processes and procedures. For costs, the town utilizes county bid pricing (p. 2 of the town's Five-Year Maintenance Plan).

The Town of Harwich typically spends \$1.4 million on their annual road maintenance program, which is comprised from approximately \$700,000 in Chapter 90 funds and \$700,000 in a local article. The current plan focus is on installing new drainage systems ahead of the sewer project to avoid paving over old infrastructure.

## **Mashpee Pavement Management Activities**

The Town of Mashpee hired now Stantec in 2020 to complete a town-wide pavement assessment and included the Town's major collector roads. The Town had Stantec do an update in 2020 that also included major collector road. The report was issued in May 2020 and is being used to help prioritize projects and determine required funding levels.

The report evaluated roads in two categories - local/neighborhood and collector. Historically, Chapter 90 funds have been used for all projects on collector roads, excluding routine maintenance such as drainage installation, crack sealing, and similar treatments. This funding is no

longer enough to fund "Complete Street" type projects and resurfacing. The Town must compile several years of Chapter 90 apportionments for the larger projects so the latter will now require another funding source to maintain an acceptable PCI on the collector roads.

## **Orleans Pavement Management Activities**

In Spring 2019, the Town of Orleans retained the firm of Vanasse Hangen Brustlin (VHB) to update the Town's pavement management system by performing pavement condition evaluations on all Town-maintained roadways and parking lots with the goal of prioritizing pavement maintenance and rehabilitation projects and analyzing budgetary needs. With this year's efforts, VHB conducted a street survey and compiled a report update. The Town generally performs a pavement management study update every five (5) years.

The current network PCI rating is 83, which is up from 79 in 2013. The Town appropriates about \$384,000 (increases by inflation each year) per year for pavement management above and beyond Chapter 90 funds. VHB estimates that a current budget of approximately \$660,000 per year is anticipated to maintain the average PCI over the five-year study period but will allow the backlog of work to increase due in part to inflation.

## **Provincetown Pavement Management Activities**

Environmental Partners Group (EPG) was hired in 2016 to update the Town's pavement management program that has been used to assess existing roadway pavement conditions and establish a Capital Improvement Plan (CIP) for improvements. The planning tool continues to be utilized to establish an order-of-magnitude budget for roadway maintenance and reconstruction.

Recent roadway improvement activities include:

- Redeveloped 920 linear feet of Conwell Street between Route 6 and Cemetery Road to include dedicated bike lanes, pedestrian sidewalks, stormwater drainage improvements.
- Will perform road surface and storm drain repairs on Route 6 in October 2021.
- Currently planning stormwater improvements to West Vine Street. Work to be performed in Fall 2021.
- Currently planning road resurfacing and stormwater improvements to portions of Standish Street, Alden Street, Montello Street and Conant Street. Work to be started in Spring 2022.
- Currently designing stormwater improvements to Howland Street.

## **Sandwich Pavement Management Activities**

The Town of Sandwich retained the firm of Vanasse Hangen Brustlin (VHB) to perform pavement management services. A comprehensive study was undertaken to re-evaluate pavement conditions in Sandwich and to allow for the analysis of various funding scenarios. VHB performed a detailed inspection of the condition of the pavement on all town-maintained roads and updated a database of this information using VHB's "Road Manager" software.

To determine road repair strategies, the town mainly uses PCI (Pavement Condition Index) and Benefit. For estimated costs for implementing various repair strategies, the town uses the County's bid process and incorporates these into their own spreadsheets. The town's 5-Year plan changes dramatically year-to-year but provides a guide to follow as funds become available.

Submitted materials included the following:

- VHB Presentation on Sandwich Pavement Management
- Road Program Map – color coded map of town roads assigned to years (2006 – 2010)
- Excel workbook listing town roads with PCI, Benefit, and Repair Alternative information
- Excel workbook itemizing bid costs for various repairs by various vendors
- Excel workbook itemized by road; listing planned paving projects
- Excel workbook itemizing repair type, treatment, and comments for town roads, separately for each year 2007-2011
- Pavement Management Update Study – VHB-prepared 2006 report. See section 1.4.1 for discussion of VHB Pavement Management Systems.

### **Truro Pavement Management Activities**

Truro uses local knowledge to determine pavement repair priorities.

### **Yarmouth Pavement Management Activities**

The Town of Yarmouth retained the firm of Vanasse Hangen Brustlin (VHB) to perform pavement management services. VHB services consist of performing a comprehensive study to evaluate pavement conditions in Yarmouth and to allow for the analysis of various funding scenarios; perform a detailed inspection of the condition of the pavement on all town-maintained roads and update a database of this information using VHB's "Road Manager" software.

To determine repair strategies, the town reviews an initial list generated by the software and then decides whether to apply chip seal, double chip seal, or overlay. Main roads are treated with rubber chip seal or overlay. In the town's capital plan, annual spending ranges from \$1.3 million to \$1.5 million for roadway maintenance. As of May 2021, the Town's PCI rating was 80.7.

### **Wellfleet Pavement Management Activities**

The Town of Wellfleet retained the firm of BETA Group, Inc. (BETA) to develop a Pavement Management Program (PMP) in 2015. The Town is currently looking at updating the PMP as of Spring 2022.

In addition, the Town DPW actively keeps their own list and performs inspections on a regular basis. In Fall 2019, the following roads were planned to be resurfaced: sections of Long Pond Road, sections of Gull Pond Rd, Schoolhouse Hill Rd, Coles Neck Road, and sections of Brown's Neck Road. The town also performed crack sealing during the Autumn of 2020 on various roads

including: Chequessett Neck Road, Long Pond Road, Lecount Hollow Road, Nauset Road, Lawrence Road, Cottontail Road, Spring Valley Road, Paine Hollow Road, and Old Wharf Road.

## SUMMARY OF TOWN PAVEMENT MANAGEMENT EFFORTS

Based on responses from the email survey and subsequent follow-up, the following table summarizes the techniques that responding towns use for pavement management.

TABLE 2. Summary of Responding Towns' Pavement Management Techniques

TOWN	PAVEMENT MANAGEMENT TECHNIQUE
Barnstable	BETA – Microsoft Access
Bourne	BETA – Microsoft Access
Brewster	BETA – Microsoft Access
Chatham	BETA – Microsoft Access
Dennis	StreetLogix
Eastham	Locally developed spreadsheets
Falmouth	VUEWorks Asset Management Software
Harwich	StreetLogix
Mashpee	Cartegraph Systems
Orleans	VHB Pavement Management System
Provincetown	MicroPaver system
Sandwich	VHB Pavement Management System
Truro	Local knowledge
Yarmouth	VHB Pavement Management System
Wellfleet	BETA – Microsoft Access

## PAVEMENT MANAGEMENT SYSTEMS

Despite most towns using different management systems, the prevalent techniques (as identified by many of the towns responding to the email survey) are the same. The following sections contain excerpts describing the techniques involved in pavement management systems.

## **METHODOLOGY**

To start assessing the condition of a town's pavement, a detailed condition evaluation of each town's public roadways to build the pavement management system is a typical starting point. The first step is to identify the roadway network. The second step is to further break each street in the roadway network into pavement management sections. The third step is to carefully categorize, measure, and record the individual pavement distresses within each pavement management section and perform the inventory of sidewalks, curbs, and ramps. Finally, the fourth step is to customize the road repair treatment selection and unit costs within the pavement management software through discussions with Town officials. All these steps are typically performed prior to the study of future funding scenarios.

### Network Identification

Network Identification builds an inventory of streets that describe the municipality's complete roadway network. The direction of travel, street length, width, ownership, classification, zone, and pavement type are among the items identified at this initial phase in the pavement management process. This integral step ensures the streets surveyed are the definitive set to be analyzed.

### Pavement Management Section Identification

Once the Network Identification is complete, the field work begins. Each street contains one or more pavement management sections. A pavement management section defines the limits of previous construction or maintenance activities within each street. Sections are defined by having the same width, typical distresses, functional class, etc. The goal is to set up homogenous areas of pavement to aid in assigning the appropriate repair. A "street" may be one section, or it may be comprised of several pavement management sections, depending on its construction history.

### Surface Distress Assessment

For each pavement management section, the severity and extent of nine major pavement distresses are recorded, and then entered into a weighted formula to arrive at a Pavement Condition Index (PCI). The distresses are categorized as base related or surface related distresses. Base related distresses indicate that the pavement structure is inadequate for the existing traffic load and soil conditions. Streets that show significant base related distresses may need to have the pavement structure strengthened with either thicker or stronger base or pavement materials. Surface related distresses are caused by age and weathering of the pavement. Streets that have predominantly surface related distresses are excellent candidates for maintenance sealing to inhibit further pavement oxidization (the main effect of aging). Streets with more of the base related distresses will most likely need some full depth patching, structural overlays, or reclamation/reconstruction.

The four base related distresses are:

- Potholing or non-utility patching
- Alligator cracking
- Distortion
- Rutting

The five surface related distresses are:

- Block cracking
- Transverse or longitudinal cracking
- Bleeding or polished aggregate
- Surface wear or raveling
- Shoving, slippage, or corrugation

### PCI Defined

A PCI is generated for each inventoried pavement management section in a town using the surface distress data collected. PCI is measured on a scale of zero to one hundred, with one hundred representing a pavement in perfect condition and zero describing a road in impassable condition. Each type of observed pavement distress is assigned a deduct value based on the type, severity, and extent of the distress. A weighted sum of the deduct points is subtracted from the perfect “one hundred” road to generate a PCI for each pavement management section. In general, base related (pavement foundation) distresses are weighted more heavily than surface related distresses. For example, if 15% of a road section had medium severity “Alligator Cracking” it would receive a deduction of 40 points. Whereas the same area of “Block Cracking” would only receive a deduction of 15 points. The actual PCI calculation follows:

PCI = 100 – (Highest Deduct Value) – (25% of remaining base related deduct values) – (10% of remaining surface related deduct values)

### The Five Treatment Bands

The pavement management system uses broad ranges to group the individual repair types into five major treatment bands. Treatment bands are a useful tool to summarize data on a Town-wide basis. An individual road segment will fall into a category based on the strategy table’s output of repair types and will vary due to functional classification. The goal is to gain a broad understanding of the existing conditions in simple yet meaningful terms.

TABLE 3. Treatment Band Descriptions

TREATMENT BAND	PCI*	DESCRIPTION
DO NOTHING	93-100	Excellent condition - in need of no maintenance.
ROUTINE MAINTENANCE	86-92	Good condition – may need crack sealing or minor localized repair.
PREVENTIVE MAINTENANCE	76-85	Fair condition – pavement surface may need surface sealing, full depth patch and/or crack sealing.
STRUCTURAL IMPROVEMENT	56-75	Deficient condition – pavement surface structure in need of added strength for existing traffic. Typical repairs are overlay with or without milling.
BASE REHABILITATION	0-55	Poor condition – in need of base improvement. Typical repairs are reclamation or full depth reconstruction.

*\*Note: Treatment bands are defined below. These are only general PCI ranges for reference purposes and represent only one pavement type. There are several fields considered by the strategy table when assigning repair types to each individual street. Source: VHB*

#### Do-Nothing

The Do-Nothing category exhibits roads which need no maintenance. These roads are in excellent condition and existing distresses generally do not need to be addressed.

#### Routine Maintenance

Routine maintenance activities are those which are taken to correct a specific pavement distress. Routine maintenance usually addresses localized pavement defects and includes activities such as:

- Full depth patching
- Skin patching
- Crack sealing

#### Preventive Maintenance

Preventive maintenance activities are those which are performed at planned intervals to protect and seal the pavement. Seals are designed to provide one or more of the following benefits:

- Prevent the intrusion of air and moisture
- Fill small cracks and voids
- Rejuvenate an oxidized binder
- Provide a new wearing surface

### Structural Improvement

Structural improvement includes the work necessary to restore the pavement to a condition that will allow it to perform satisfactorily for several years. Generally, a structural improvement will consist of a milling the existing pavement down and applying a new Hot Mix Asphalt Overlay allowing existing grades to be maintained. When the existing grade can be increased a new Hot Mix Asphalt course can simply be placed upon the existing surface. Structural improvements also include the work necessary to prepare the pavement for an overlay, either with or without milling. The major activities involved in the rehabilitation process are:

- Partial depth patching
- Full depth patching
- Joint and crack sealing
- Grinding and milling
- Hot Mix Asphalt Leveling Courses

### Base Rehabilitation

Base rehabilitation utilizes one of two methods:

- Reclamation
- Reconstruction

Reclamation is the process of rehabilitating existing deteriorated pavements. The existing layers of the roadway are pulverized and then blended to create a homogenous pavement base. This reclaimed pavement base is then paved with a new Hot Mix Asphalt surface. Reconstruction is the complete removal and replacement of a failed pavement, and might also involve widening, realignment, traffic control devices, safety hardware, and major base and drainage work.

### Customizing Repair Strategies

Repairs strategies can also be made specific to fit the specific needs of the town. The overarching goal is to understand a town's decision-making process and simulate that process in the budget analysis software based on the pavement condition and other criteria of each pavement section. This allows for the section of which repair methods are the best to use and when.

### Preparing Budget Scenarios

Once the roadway conditions are inventoried and analyzed, and the repair strategies are defined, the impact of various spending programs on the roadway network is assessed. These studies can range from 1 to 20 years; typically, 5-year studies are used. The purpose of the budget planning process is to determine the impact of various spending levels to find a funding level that will best meet the town's needs. Budget analysis software uses pavement deterioration curves, unit costs,

and strategy tables developed in the repair strategy definition phase to assign each street a repair type and associated cost for each year of the study. Budget analysis software can also assign each street a benefit value that is used to prioritize which streets the software will select for repair each year. It is important to understand that a pavement management system is a network-wide planning tool and is not intended to give definitive street-by-street repair data. Field verification and testing are recommended to confirm any street repair list generated.

### Deterioration Curves

To properly plan for future repairs, pavement management system uses deterioration curves. The deterioration curves estimate the rate at which the pavement condition decreases over time. These pavement deterioration curves depict two major categories of functional classification - arterials and collectors in one curve and local roads in the other. An example deterioration curve is presented in the following figure:

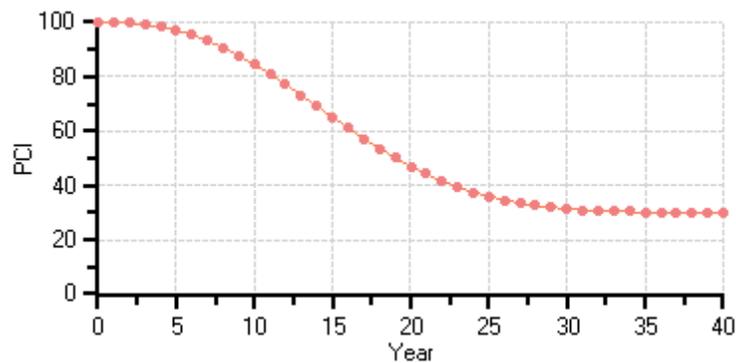


FIGURE 2. Sample Deterioration Curve  
Source: VHB

### Strategy Table

With data collected and processed, a pavement management system would then use a table of repair strategies to assign specific road repair types to individual roadway segments. The repair strategy table incorporates PCI ranges as well as functional class and pavement type to simulate decisions consistent with Barnstable’s repair practices and procedures.

### Project Prioritization

Budget analysis software prioritizes needed system repairs based on the estimated “Benefit Value”. The Benefit Value formula is calculated using variables representing traffic volume, repair service life, PCI, and unit repair costs for each pavement management section. For each plan year, software can prepare a future roadway condition projection, exhausts the assigned budget, and then produces an annual list of roads included in the repair program. The system also allows the user to enter an inflation rate to account for estimated increases in future year construction costs. A 4% inflation rate is typically used.

The Benefit Value prioritization process generally favors cost effective maintenance alternatives. Repair actions are typically delayed on those sections that require reconstruction or major rehabilitation because the benefits for dollars spent are generally lower than maintenance candidates. After the relatively good roads are "saved," improvements are directed towards the poorer arterial and collector roads, and then to the local roads in need of major rehabilitation.

## PAVEMENT MANAGEMENT ANALYSES

The data collected in the monitoring process will be continually analyzed to identify overall pavement conditions in the different Cape Cod towns to assist in programming maintenance and reconstruction activities.

According to information prepared for the Cape Cod Regional Transportation Plan, the Cape Cod Region possesses 739 miles of roadway eligible for federal funding. Of those miles, 565 are under the jurisdiction of the Cape’s local communities.

MassDOT evaluates roads under their own jurisdiction and a selection of municipally owned roadways. The following table lists the corresponding rating from Excellent to Poor, based on a “PSI” (Pavement Serviceability Index) rating – roughly analogous to the “Pavement Condition Index” (PCI) commonly used.

Pavement Condition	Excellent	Good	Fair	Poor
“PSI” Range	PSI >=3.5	PSI 2.8-3.5	PSI 2.3-2.8	PSI < 2.3

### CCC Evaluations of Pavement Conditions – “Windshield” Surveys

Beginning in 2011, Cape Cod Commission staff undertook a series of “windshield” surveys throughout Barnstable County. Starting in 2014, a new data collection strategy was deployed, based on Geographic Information Systems’ needs and strengths. Data-collection regions of each town were identified which contained roughly one-third of the mileage of federal-aid eligible municipal roadways. The quality and accuracy of the data collection was greatly improved using GPS-capable tablet computers. The following figure shows the roadways that the CCC staff collected data on in 2022.



FIGURE 3. Municipal Roads Surveyed in 2022

The following table provides a summary by town of the Cape Cod Commission’s windshield survey data.

TABLE 4. Surveys of Pavement Condition - miles

TOWN	VERY GOOD TO EXCELLENT	GOOD TO VERY GOOD	FAIR TO GOOD	POOR TO FAIR	POOR	TOTALS
Barnstable	3.1	12.2	87.7	7.9	0.3	111.2
Bourne	1.3	2.7	29	8.7	0.2	41.9
Brewster	2.6	10.1	9.8	2.7	1.4	26.6
Chatham	0.0	0.4	11.5	0.9	0.0	12.8
Dennis	0.4	10.6	33.9	0.5	0.0	45.4
Eastham	0.5	2.3	12.4	1.7	0.0	16.9
Falmouth	2.4	11.3	60.7	10.7	0.3	85.4
Harwich	0.3	9.2	30.4	3.2	0.0	43.1
Mashpee	0.0	1.4	23.2	5.0	0.0	29.6
Orleans	0.6	3.6	12.1	0.6	0.0	16.9
Provincetown	0.0	1.4	11.4	0.6	0.0	13.4
Sandwich	0.7	7.5	24.0	5.1	0.7	38.0
Truro	0.0	2.5	6.4	3.5	0.0	12.4
Wellfleet	0.7	2.9	15.5	0.6	0.0	19.7
Yarmouth	1.6	12.6	37.2	0.7	0.0	52.1
Total:	14.2	90.7	405.2	52.4	2.9	565.4

*Source: latest data available from 2020-2022 collected by Cape Cod Commission*

As shown in the table above, approximately 560 miles of roadway have been surveyed at least once as recently as 2022. The most common rating “Fair to Good” yielded over 400 miles and resulted in a higher result in comparison to the 2020 and 2021 observations. This is followed by 90 miles of “Good to Very Good”, 52 miles of “Poor to Fair,” approximately 14 miles for “Very Good to Excellent” and approximately 3 miles of “Poor.” The following figures provide a graphic of the CCC survey data in a series of four maps (Upper Cape, Mid-Cape, Lower Cape, and Outer Cape). The CCC evaluations are shown as colored parallel lines ranging from Blue (Very Good to Excellent) to Red (Poor).

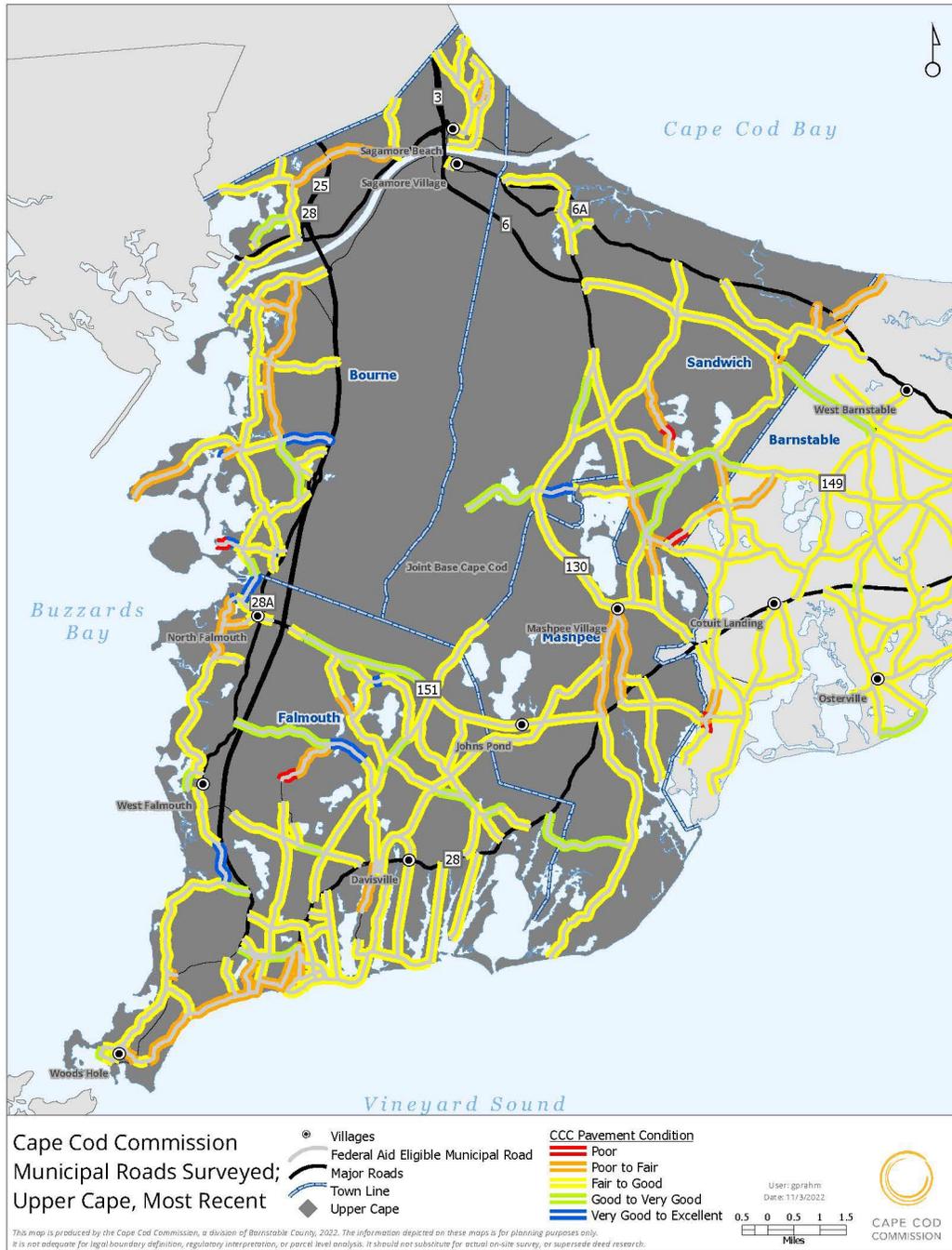


FIGURE 4. Pavement Condition Surveys: Upper Cape  
 Source: latest data available from 2020-2022 collected by Cape Cod Commission

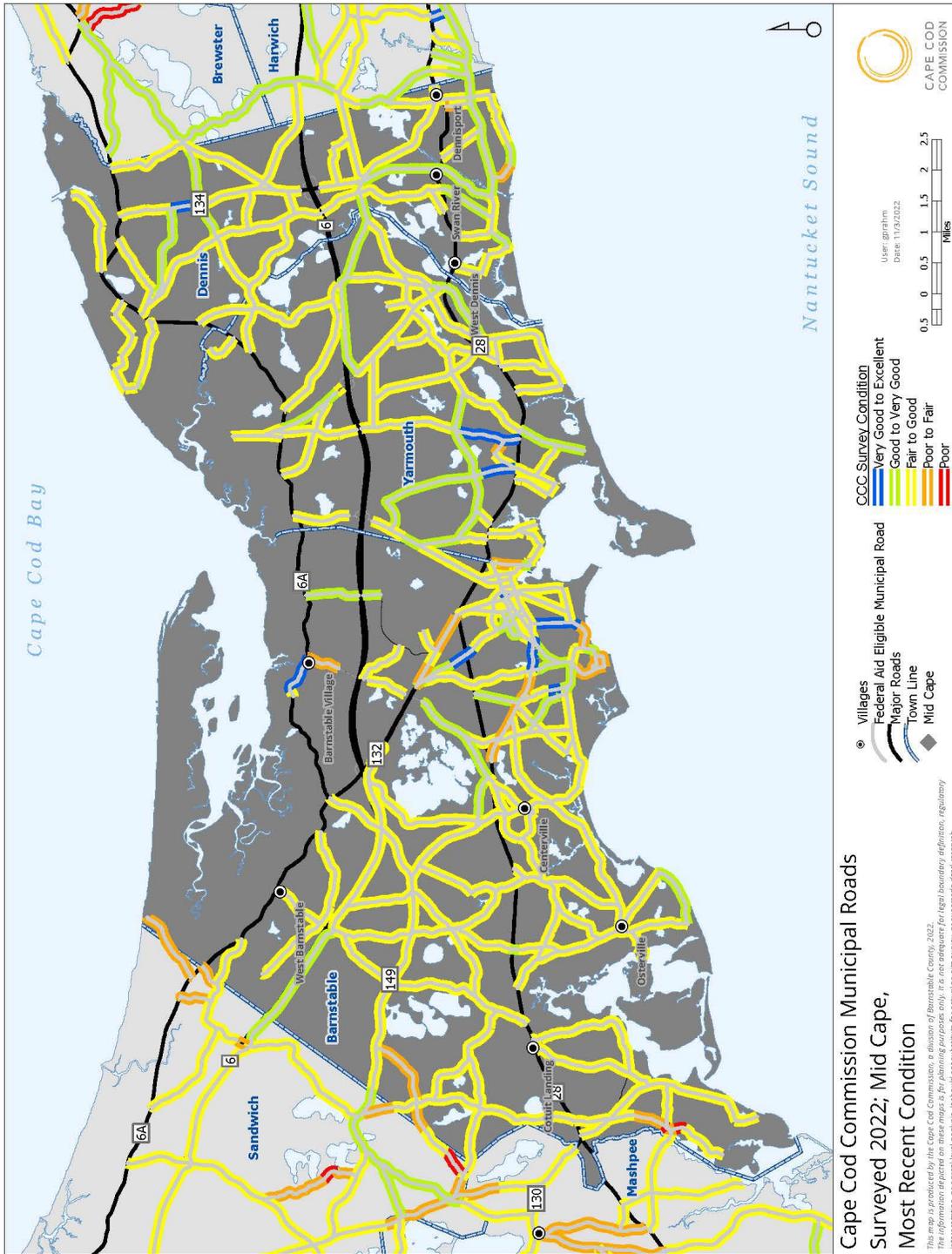


FIGURE 5. Pavement Condition Surveys: Mid-Cape  
 Source: latest data available from 2020-2022 collected by Cape Cod Commission

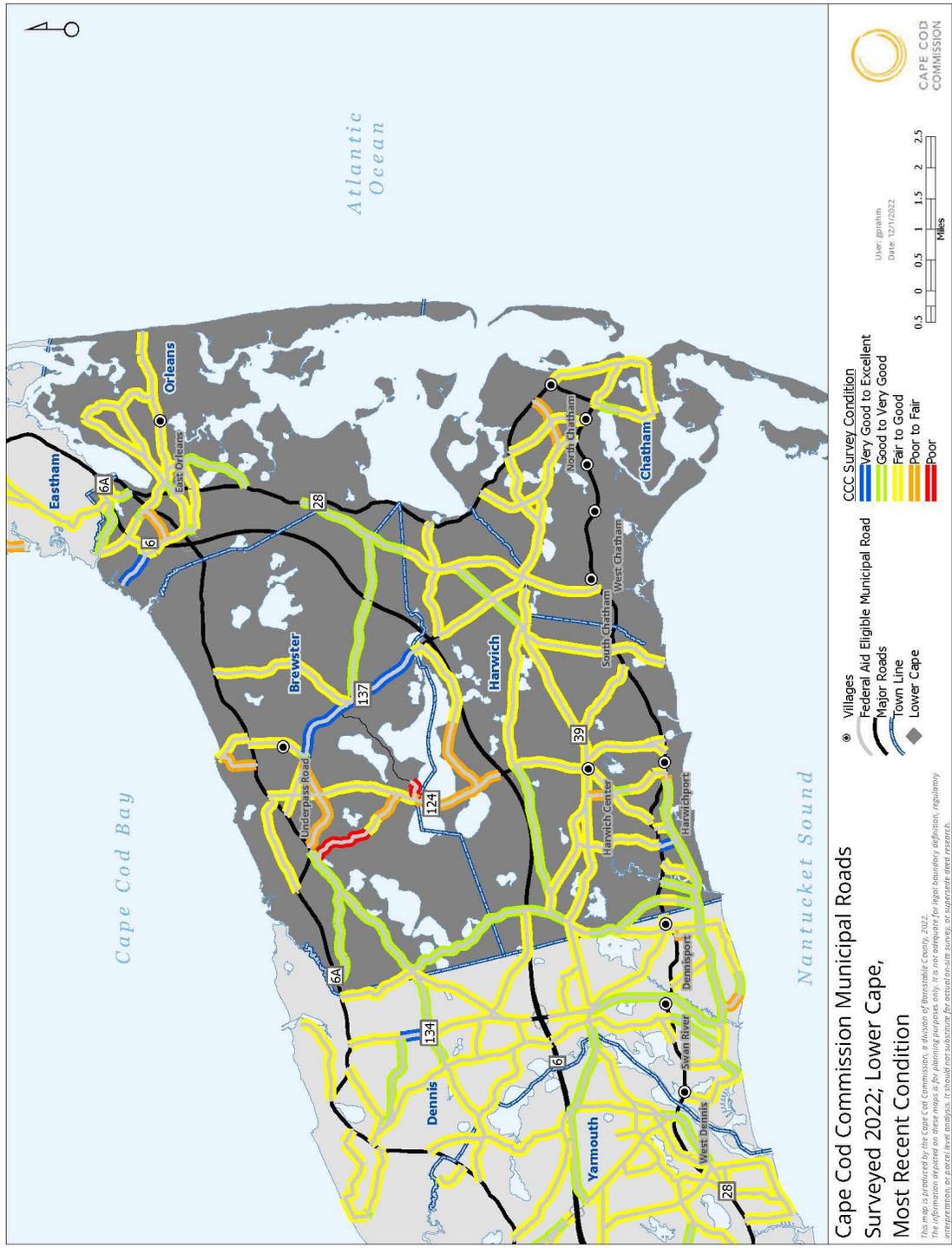


FIGURE 6. Pavement Condition Surveys: Lower Cape  
 Source: latest data available from 2020-2022 collected by Cape Cod Commission



FIGURE 7. Pavement Condition Surveys: Outer Cape  
Source: latest data available from 2020-2022 collected by Cape Cod Commission

## RECOMMENDATIONS FOR ACHIEVING IMPROVED PAVEMENT CONDITION

The pavement deterioration curve shown in Figure 1 demonstrates the advantages of maintaining good roads to avoid expensive rehabilitation and reconstruction. For each level of Pavement Condition there is a corresponding Pavement Condition Index (PCI) – indicated by the column “PCI Start” in the table below.

By plotting the PCI for each condition level on the deterioration curve we can estimate the PCI after 5 years (this number corresponds to the 5-year “time bands” used in the Regional Transportation Plan for programming transportation projects). This is indicated by the column “5 Year – PCI No Repair” in the table below.

Repair strategies for each pavement “Starting Condition” vary according to starting PCI. For example, pavement currently categorized as “Good” or better (PCI greater than 89.0) may undergo “Maintenance” (e.g., crack-sealing, cleaning catch basins, etc.) with an associated modest cost per mile. Pavement currently categorized from Fair to Good (PCI of 80.5) would undergo “Rehabilitation” and with a higher cost. Pavement below Fair condition (PCI below 65.5) would require the most expensive repair of “Reconstruction.” The estimated costs per mile for each repair strategy were originally estimated by the Old Colony Planning Council.

On average, pavement categorized as Good or above that is maintained would retain the same PCI. Pavement that is rehabilitated or reconstructed would on average achieve a PCI equal to “Very Good – Excellent” (PCI 96.5).

Therefore, it is possible to calculate a “Benefit” (i.e., the difference in the PCI between performing a repair and doing nothing). For example, if a segment of road is currently assessed to be at a PCI of 80.5 (Fair to Good) there are two possibilities: (1) rehabilitate the pavement resulting in an average PCI of 96.5 or (2) allow the pavement to deteriorate over the five-year time span down to a PCI of 29.7. In this case, the benefit of performing the repair (i.e., rehabilitation) is calculated to be the difference from 96.5 minus 29.7, or 66.8.

By relating the PCI Benefit of performing roadway repairs to the repair cost per mile, it is possible to calculate a Benefit/Cost ratio. These ratios are shown in the right-most column of the table below. To make the comparisons easier to review, the Benefit/Cost ratio of all the pavement conditions have been factored by 10,000.

TABLE 5. Change in Pavement Condition – Improvement Strategy

STARTING CONDITION	PCI START	5 YEAR - PCI NO REPAIR	REPAIR STRATEGY	REPAIR COST PER MILE	5 YEAR PCI REPAIR	PCI BENEFIT	BENEFIT / COST (SCALED BY 10,000)
Very Good to Excellent	96.5	83.6	Maintain-ance	\$35,000	96.5	12.9	3.69
Good to Very Good	89.0	54.6	Maintain-ance	\$45,000	89	34.4	7.64
Fair to Good	80.5	29.7	Rehabilit-ation	\$100,000	96.5	66.8	6.68
Poor to Fair	65.5	22.2	Recon-struction	\$550,000	96.5	74.3	1.35
Poor	27.5	16.6	Recon-struction	\$554,000	96.5	79.9	1.44

The table above indicates that the most cost-effect repair strategy would be focused on performing maintenance on “Good to Very Good” roads with an estimated Benefit/Cost of 7.64, closely followed by performing rehabilitation on “Fair to Good” roads with an estimated Benefit/Cost of 6.68.

As a matter of policy, it is also recommended that funds be reserved to reconstruct a subset of “Poor to Fair” and “Poor” Roads.

The Cape Cod MPO is committed to exploring improved pavement management strategies and techniques to help optimize investment and achieve maximum improvement in overall PCIs.

## CONCLUSION/RECOMMENDATIONS FOR PMS ENHANCEMENT

Cape Cod Commission staff will continue advance PMS activities throughout the fifteen towns of Barnstable County. Commission staff issue a status report on the pavement condition on Cape Cod each year. The pavement condition data collected during the Commission's summer data collection is modeled and analyzed to provide an objective rating of pavement conditions and needs. The annual assessments contribute to the implementation of a regional pavement management system for Cape Cod that keeps the roadway system in the best possible condition with the most efficient use of available funds. The latest PMS Reports and ones from previous years can be viewed [here](#).

The Cape Cod Commission also has a Pavement Condition Viewer. The viewer displays the annual pavement survey results in a GIS web-based application to assist towns in their pavement management efforts. The GIS web application is available for public viewing on the Cape Cod Commission website on the same page as PMS Reports. The data collected by the Commission, in the monitoring process, will be continually analyzed to identify overall pavement conditions in the different Cape Cod towns to assist in programming maintenance and reconstruction activities. Efforts will continue such as:

- Identify individual towns' methods for pavement condition evaluation and programming for improvements
- Identify "gaps" in pavement condition information on Municipally-owned Federal Aid eligible roadways – and – prioritize and implement CCC data collection activities on these roadways
- Improve CCC skills in performing pavement evaluations
- Analyze local communities' bid prices to develop Cape-specific improvement costs of various pavement conditions
- Generate listings of roadways with poor pavement conditions
- Continue to provide yearly PMS Reports
- Provide a web-viewer to display the most recent pavement condition data collected



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