MicroPAVER Implementation and
Pavement Condition Index (PCI) Survey Project

State of the Streets Report
including
MicroPAVER Technical Documentation

Prepared for:

City of Bismarck, North Dakota






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EXECUTIVE SUMMARY

The objectives of this project were to: (1) perform a comprehensive upgrade of the City's existing MicroPAVER pavement management system, (2) perform a network-level condition survey of the City's pavements, (3) estimate the future maintenance and rehabilitation (M&R) requirements of the City's pavements, and (4) feed the City's pavement management system data and analysis information into the Bismarck-Mandan Metropolitan Planning Organization's (MPO) Transportation Improvement Program (TIP) and Long Range Transportation Plan (LRTP) processes for effective transportation prioritization and planning.

The scope of the project included the City's approximately 310 miles of paved roadways, which include 43 miles of collector roadways and 80 miles of arterial roadways. The City's approximately 5.6 miles of alley pavements were also included in this project. Based on available historical pavement construction and rehabilitation records, approximately 57% of the City's pavement network has been resurfaced, reconstructed, or newly constructed within the past fifteen years.

The Pavement Condition Index (PCI) method was used in assessing the condition of the City's pavements. The PCI method is a more objective and repeatable method for assessing pavement conditions and is widely used in industry. Pavement conditions were categorized based on PCI values using the criteria shown in Table ES.1.

Table ES.1: City's Pavement Condition Assessment Criteria

Condition Assessment	PCI Value
Adequate	71 – 100
Degraded	56 – 70
Unsatisfactory	0 – 55

At the time of Dynatest's May 2012 inspection, the City's roadway pavements were found to be in overall "Adequate" condition, with an average PCI of 81. The condition distribution of the City's pavements at the time of inspection is shown in Figure ES.1.

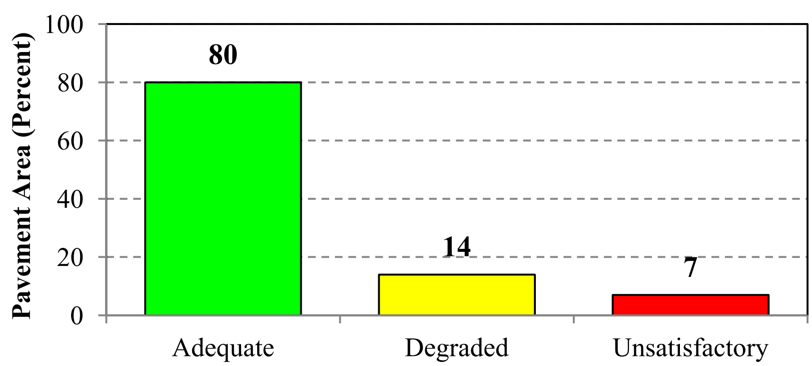


Figure ES.1: Overall Roadway Pavement Condition Distribution

Using the MicroPAVER pavement management system, the following five-year M&R budget analyses were performed on the City's roadway pavements:

- Determine required annual budget to eliminate the City's Major M&R backlog, $11.4M/YR
- Determine required annual budget to maintain a PCI of 80, $10.1M/YR
- Determine effect of City's existing budget, $9.5M/YR (Approx.)
- Determine effect of 75% of the City's existing budget, $7.1M/YR (Approx.)
- Determine effect of 50% of the City's existing budget, $4.8M/YR (Approx.)
- Determine effect of $0.0M/YR

Figure ES.2 depicts the estimated change in the City's backlog of Major M&R, such as resurfacing and reconstruction for the budget analyses considered.

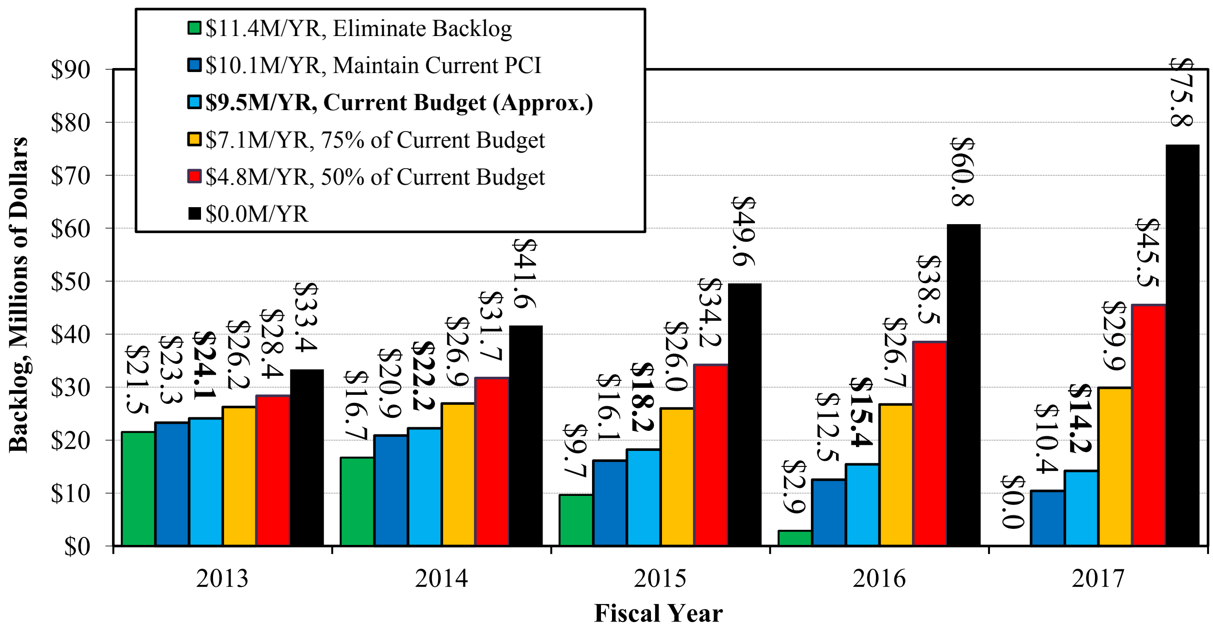


Figure ES.2: Effect of Budget on Roadway Pavement Major M&R Backlog

The economic consequences of annual budgets ranging from $0.0M/YR to $11.4M/YR including their total costs and costs relative to the Major M&R "Eliminate Backlog" budget are shown in Table ES.2. This table shows that if both the annual M&R expenditures as well as the remaining M&R backlog are treated as costs incurred by the City, then the total overall cost to the City is less if the City eliminates its Major M&R backlog over a five year period.

Table ES.2: Estimated Five Year Roadway Pavement Major M&R Budget Costs

Budget Scenario	Total Five Year M&R Costs (2013-2017)	Remaining M&R Backlog[1)] (2017)	Total Five Year Cost[2)]	Cost Differential
Eliminate Backlog $11.4M/YR	$57.0M	$0.0M	$57.0M	*Baseline*
Maintain PCI of 80 $10.1M/YR	$50.5M	$10.4M	$60.9M	$3.9M
Current Budget (Approx.) $9.5M/YR	**$47.5M**	**$14.2M**	**$61.7M**	**$4.7M**
75% of Current Budget (Approx.) $7.1M/YR	$35.5M	$29.9M	$65.4M	$8.4M
50% of Current Budget (Approx.) $4.8M/YR	$24.0M	$45.5M	$69.5M	$12.5M
$0M/YR	$0K	$75.8M	$75.8M	$18.8M

1) "M&R Backlog" equals the lump-sum cost to resurface/reconstruct all pavements at or below the critical PCI value.
2) "Total five year cost" equals the sum of the five year Major M&R expenditures plus the remaining Major M&R backlog at the end of the five year analysis period.

Due, in part, to the rapid expansion of the City's pavement network over the last several years, it is important to understand that the funding levels required over the next five years will likely need to be increased over the next six to ten years and beyond. The City's overall average PCI value is currently relatively high. The large inventory of pavements that are in good condition today will continue to deteriorate and will require more significant rehabilitation, such as resurfacing or reconstruction, a decade or so from now. Consequently, the City should anticipate and plan for an increase of its pavement M&R budgets in the mid- to long-term.

Moving forward, it is recommended that the City evaluate the effectiveness of its extensive, ongoing patching program. The impact that the City's patching program has on reported pavement conditions is unclear; however, it is possible that the patching program may be masking serious underlying deficiencies with many pavements.

As the City continues to grow and add new pavements to its inventory, it is recommended that the City's preventive maintenance program be expanded to include concrete pavements, many of which lack functional joint sealant. The City's alley pavements should also be maintained in a manner similar to the roadway pavements.

In an effort to continue to improve its pavement management decision-making capabilities, it is also recommended that the City perform network-level pavement condition surveys on a three-year cycle. Doing so will enable the City to better model the deterioration of its pavements and continue to assess the effectiveness of its M&R activities.

1 INTRODUCTION

1.1 Background

Founded in 1872, the City of Bismarck (City) has been the capital of North Dakota since it gained statehood in 1889. Home to more than 61,000 residents, the City is the second most populous in North Dakota after Fargo. Fueled in large part by the growing oil industry in the nearby western region of the state, the City's population is growing at a brisk pace. New roadways are being constructed to support new housing development and existing roadways are experiencing increased volumes of traffic.

The City's roadway network is comprised of approximately 310 miles of paved roadways, which include 43 miles of collector roadways and 80 miles of arterial roadways. Asphalt-surfaced roadways account for approximately 86% of the City's pavement inventory, and concrete roadways account for approximately 9%. The City also maintains a small percentage of hard surfaced and gravel roadways. Based on available historical pavement construction and rehabilitation records, approximately 57% of the City's pavement network has been resurfaced, reconstructed, or newly constructed within the past fifteen years.

Over the next five years, the City's total pavement maintenance and rehabilitation (M&R) budget is anticipated to be approximately $9.5M/YR. Approximately $750K/YR is targeted for localized patching of asphalt-surfaced pavements, and approximately $800K/YR is targeted for chip sealing of asphalt-surfaced pavements. The remaining $8M/YR is allocated for pavement resurfacing and reconstruction. As the City's relatively young pavement network simultaneously expands and ages, it will be necessary for the City to gradually increase its pavement M&R funding levels.

In the Spring of 2012, in an effort to improve the City's existing in-house pavement management program and more objectively assess the network-level needs of its roadway pavement inventory, the City – in collaboration with the Bismarck-Mandan Metropolitan Planning Organization (MPO) – retained Dynatest to perform several pavement management-related services.

1.2 Pavement Management Overview

Pavement management is a systematic approach to forecasting pavement M&R requirements and then optimizing and prioritizing available M&R funding. As shown in Figure 1, the primary objective of pavement management is to preserve pavements in good condition rather than wait for them to fail and then reconstruct them.

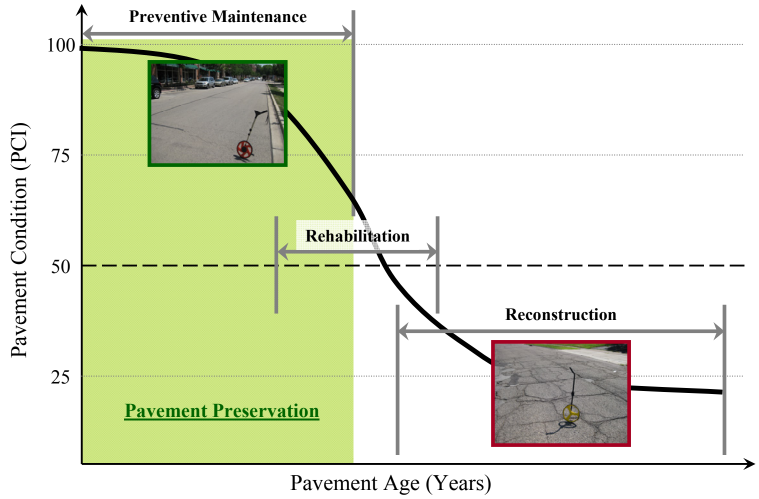


Figure 1: Pavement preservation.

When the appropriate preventive M&R treatments (e.g., crack sealing, seal coats, etc.) are applied at the correct times during a pavement's service life, these relatively inexpensive preventive M&R treatments can cost-effectively extend the service life of the pavement, as shown in Figure 2.

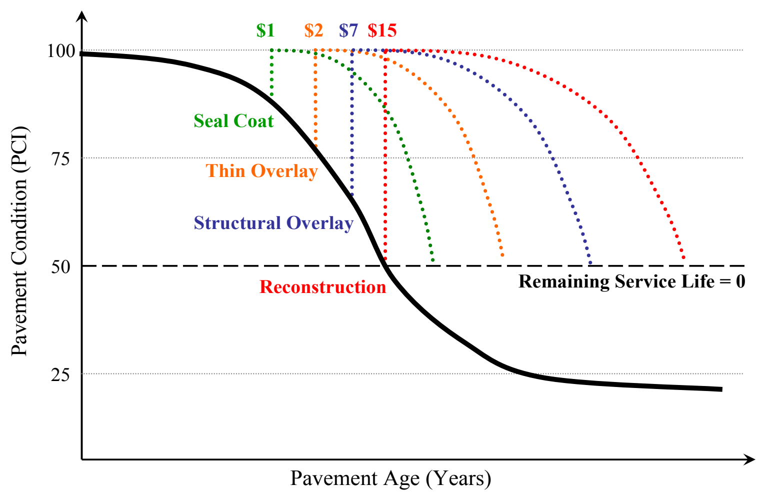


Figure 2: Increasing price and decreasing relative benefit of M&R as a function of pavement condition. ***(Note: Illustrative prices only.)***

As pavement management concepts have gained acceptance, computer-based pavement management systems have been developed to assist agencies in more optimally managing their pavements. Pavement management systems currently rely on a comprehensive pavement inventory, regular pavement condition assessments, pavement performance modeling, and sophisticated analysis tools that forecast future pavement condition and estimate future M&R needs.

1.3 Project Objectives

The primary objectives of this project were to: (1) perform a comprehensive upgrade of the City's existing pavement management system, and (2) perform a network-level pavement condition survey of the City's roadway pavements. Upon successful completion of this project, the City will be able to more objectively assess the relative conditions of its roadway pavements, better optimize and prioritize the expenditure of its existing M&R funding, and more effectively identify and justify future roadway pavement M&R funding needs. In addition, the results of this project will support the Bismarck-Mandan MPO 2010-2035 Long Range Transportation Plan (LRTP). Pavement condition data, which may be displayed within the City's existing GIS, will be used in conjunction with other geocentric data to identify maintenance and operations projects in future updates of the LRTP.

1.4 Project Approach

In order to successfully accomplish the objectives of this project, Dynatest performed the following three major tasks:

1. Pavement management system upgrade – *Assisted City staff in the upgrade of the MicroPAVER pavement management system.*
2. Pavement Condition Index (PCI) inspection – *Performed a network-level PCI inspection of the City's roadway pavements.*
3. Pavement M&R budget analyses – *Performed several five-year, network-level budget analyses to determine the impact of different funding levels on the City's pavement conditions.*

These tasks and their outcomes are described in the following sections.

2 PAVEMENT MANAGEMENT SYSTEM UPGRADE

2.1 Objective

The original objective of this task was to migrate the City's existing implementation of the MicroPAVER pavement management system to the current version of the software. Based on a thorough review of the City's existing implementation, however, it was determined that it would be more cost effective to begin with a new implementation rather than attempt a migration.

There were three primary factors that led to this decision: (1) the City's existing MicroPAVER database was not linked to a Geographical Information System (GIS), (2) data inconsistencies were found within the City's existing MicroPAVER database, and (3) data in the City's existing MicroPAVER database had not been recently updated. Attempting to reconcile these issues would have required a significant level of effort but would not have resulted in significant benefits.

The following section provides a brief description of the major functional capabilities of MicroPAVER. This is followed by a description of the City's new MicroPAVER database.

2.2 MicroPAVER Pavement Management System Overview

The MicroPAVER pavement management system helps agencies determine when, where, and what level of pavement maintenance and rehabilitation (M&R) is required and approximately how much it will cost. The system provides a suite of pavement management software tools that assist agencies in: (1) developing and organizing their pavement inventory; (2) assessing the current condition of their pavements; (3) developing models to predict future pavement conditions; (4) reporting on past and future pavement performance; (5) developing scenarios for M&R based on either budget or condition requirements; and (6) planning M&R projects. The primary MicroPAVER modules include:

- Inventory
- M&R History
- Inspection
- Prediction Modeling
- Condition Analysis
- M&R Planning
- Project Planning
- Reporting

A brief description of these modules is presented in the following sections.

2.2.1 Inventory and M&R History Modules

The MicroPAVER Inventory and Work History modules are based on a hierarchical structure composed of networks, branches, and sections, with the section being the smallest "managed" pavement area (e.g., street block). This structure allows users to easily organize their inventory and historical M&R data while providing numerous fields for storing pavement data.

2.2.2 *Inspection Module*

MicroPAVER uses the Pavement Condition Index (PCI) per ASTM D 6433 as its primary measure of pavement condition. The Inspection module enables agencies to store raw pavement condition survey data and then calculate PCI values.

2.2.3 *Prediction Modeling Module*

The Prediction Modeling module in MicroPAVER helps identify and group pavements of similar construction that are subjected to similar traffic, weather, and any other factors affecting pavement performance. Historical pavement condition data are used to build models that can be used to predict future pavement performance. If historical pavement data are not available, MicroPAVER provides default pavement prediction curves and allows the user to develop custom prediction curves.

2.2.4 *Condition Analysis Module*

The Condition Analysis module allows agencies to view the condition of the entire pavement network or any specified subset of the network over time. The module reports past conditions based on interpolated values between historical condition data, and it reports projected conditions based on prediction models.

2.2.5 *M&R Planning Module*

The MicroPAVER M&R Planning module is a sophisticated, flexible tool for multi-year, network-level and project-level M&R planning, scheduling, and budgeting. The M&R Planning module is able to determine the consequence of a predetermined budget on pavement condition and the resulting backlog of major work and is also able to determine budget requirements to meet specific management objectives. These capabilities enable agencies to: (1) develop optimal M&R programs given available resources, and (2) justify optimal M&R budget needs.

2.2.6 *Reporting Module*

Each module of MicroPAVER is capable of generating reports that assist the user in analyzing and interpreting data. MicroPAVER also comes equipped with several "canned" reports, which include:

- Summary Charts – *Simple graphs and data tables of inventory and inspection data*
- Inspection Reports – *Summary of collected pavement condition data*
- Work History – *Summary of historical maintenance, repair, and rehabilitation data*
- Branch Listing – *Summary of overall pavement inventory data*
- Branch Condition – *Summary of overall pavement condition data*
- Section Condition – *Summary of individual section data*
- GIS reports – *Internal/external reporting of inventory and condition data*

MicroPAVER is capable of generating "user-defined" reports, which can be tailored to meet the agency's specific reporting needs. MicroPAVER user-defined reports enable the user to extract any data stored in the system and export it to either a spreadsheet or a text file.

2.3 Development of City's MicroPAVER Database

As previously discussed, the City's existing MicroPAVER database could not be readily migrated to the latest version of MicroPAVER. As a result, a new MicroPAVER database was created. Fortunately, the City's existing centerline GIS was found to be in excellent condition and the City was able to capitalize on many of the data elements already contained within the GIS.

The first step in the MicroPAVER implementation was to divide the City's roadway pavements into pavement sections. Each pavement section typically represents a single "block" of pavement (i.e., intersection to intersection). Pavement sections may be thought of as "homogenous" areas of pavement to which Major M&R (e.g., resurfacing and reconstruction) would be applied. The City's existing GIS served as the foundation for the MicroPAVER section definitions, and approximately 3,071 pavement sections were defined.

Dynatest then worked with the City to identify data attributes to be included for each pavement section in the MicroPAVER database, such as surface type, address from/to locations, construction dates, etc. Once the required pavement data had been collected, verified and entered into GIS by City staff, the GIS was used to create the MicroPAVER database.

As shown in Figure 3, approximately 86% of the City's pavements are asphalt surfaced. The City's concrete pavements account for less than 10% of the pavement network. In addition to its asphalt-surfaced and concrete roadways, the City has several non-engineered pavements referred to as "hard surfaced." These roadways are scheduled for replacement in the upcoming years. A few gravel roadways are also present in the City's network, but these account for less than 1% of the total roadway area.

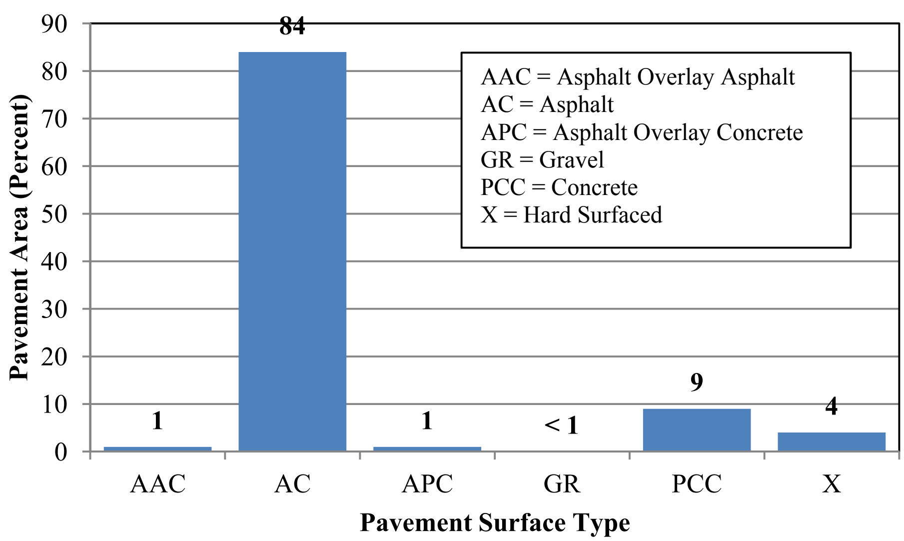


Figure 3: Pavement Area by Surface Type

Dynatest worked with the City to migrate the most recent resurfacing, reconstruction, or original construction record for each pavement section into the new MicroPAVER database. Pavement age is calculated from the date of resurfacing or reconstruction that is stored in the MicroPAVER database. If a pavement has not been resurfaced or reconstructed, its age is calculated from its original construction date. Figure 4 shows the distribution of pavement area by age.

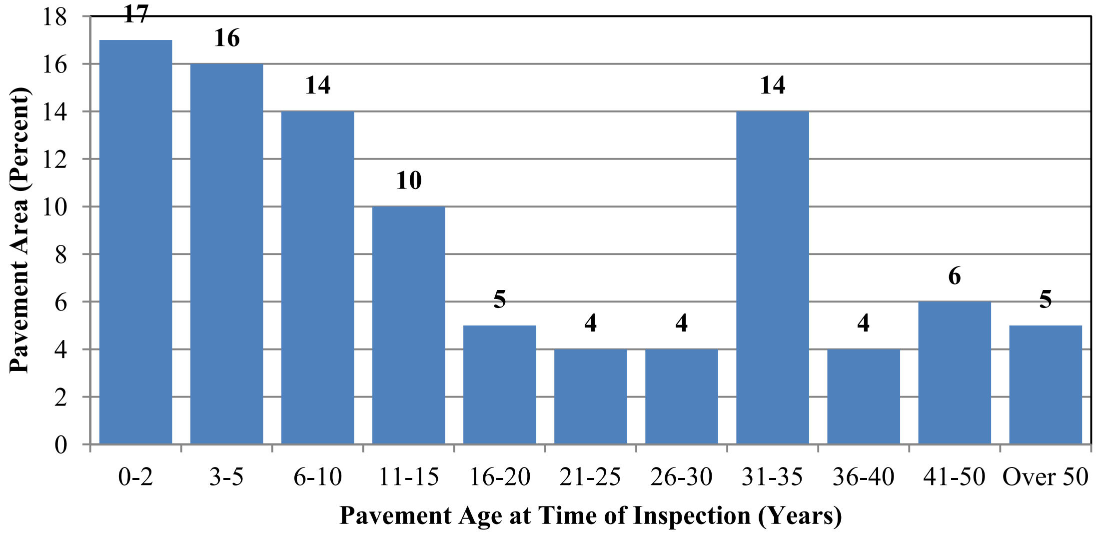


Figure 4: Pavement Area by Age

It is important to note that the ages shown in Figure 4 are based on available historical construction records. Some records are not available or are incomplete. Based on available records, approximately 57% of the City's pavement network has been resurfaced, reconstructed, or newly constructed within the past 15 years.

2.4 Customization of the City's MicroPAVER Database

Following the successful migration of data into the MicroPAVER database, Dynatest worked with the City to establish MicroPAVER's system tables. MicroPAVER's system tables provide the foundation for all of MicroPAVER analyses. The tables include user-defined inventory fields, M&R policies, estimated M&R unit costs by pavement condition, M&R priorities, etc. The system tables were established to reflect the City's M&R practices, priorities, and projected funding levels. Dynatest also established pavement condition prediction models using both the City's historical pavement construction data and the results of the PCI inspection. The customization of the City's database is described in detail in the following sections.

2.4.1 MicroPAVER Inventory Fields

Several pavement inventory fields were identified by the City for inclusion in the MicroPAVER database. These fields are listed in Table 1.

Table 1: MicroPAVER Standard and Customized Inventory Fields

Level	Field Name	Field Values
Network	Network Name	"City of Bismarck"
Network	Network ID	"BISMARCK"
Branch	Branch Name	Street Name (e.g., BISMARCK EXPRESSWAY)
Branch	Branch ID	Ten (10) Character truncation of Branch Name (e.g., BISMA_EX)
Branch	Branch Use	"ROADWAY" or "ALLEY" (Note: May be "DRIVEWAY," "PARKING," etc. for future data additions to MicroPAVER database.)
Section	Section ID	Numeric section number beginning with 5 and increasing in increments of 5 from West to East and South to North (e.g., 5, 10, 15, etc.)
Section	From	Cross street or other identifier at start of section.
Section	To	Cross street or other identifier at end of section.
Section	Surface Type	Pavement section surface type. Values include: AC – Asphalt Concrete – Includes Chip Seal* AAC – Asphalt overlay AC – Includes Chip Seal* APC – Asphalt overlay PCC – Includes Chip Seal* GR – Gravel PCC – Portland Cement Concrete X – Hard surfaced roadways *Note: We have assumed that all AC pavements have been Chip Sealed.
Section	Rank (Classification)	Pavement rank (classification). (Note: Populated from City's existing GIS.) Values include: A – Principal Arterials B – Minor Arterials C – Collectors E – Residential I – Industrial
Section	Last Construction Date	Date of last Major M&R performed on pavement.
Section	Length	Length of pavement section. (Note: Populated from City's existing centerline GIS.)
Section	Width	Width of pavement section.
Section	Slab Length	Length of typical concrete slab.
Section	Slab Width	Width of typical concrete slab.
Section	Lanes/Spaces	Number of lanes.
Section	Shoulder	Type of shoulder along section. Values include: C&S – Curb and Gutter, Standard CGH – Curb and Gutter, Half of roadway MNT – Concrete mountable rolled curb HDC – Header curb – curb that protrudes through the asphalt INT – Integral concrete curb RUR – Rural, open section typically with drainage ditch but no curb
Section	THICKNESS1	Total thickness of surface course and base course, if known.
Section	ORIGSURF	May be deleted. Temporary field used to track hard surfaced sections.
Section	ORIGBRNCHUSE	May be deleted. Temporary field used to track bridge sections.

Due to the fact that several of these inventory attribute fields were populated from the City's existing GIS and that these attributes may change over time, it is strongly recommended that these attributes be verified during the City's routine, tri-annual pavement condition surveys.

2.4.2 MicroPAVER Pavement Prediction Models

Based on the results of the 2012 Pavement Condition Index (PCI) survey and the City's existing historical Major M&R data, pavement prediction models were created and used to forecast future pavement conditions. As shown in Table 2, six prediction models were generated for the City's pavements.

Table 2: MicroPAVER Customized Prediction Models based on 2012 PCI Data Only

Model Number	Model Name	Description	Equation	Critical PCI*
1	BIS_ABCI_AC_0_15	Non-residential asphalt-surfaced pavements less than 15 years old.	100-2.16506X	60
2	BIS_ABCI_AC_15_ALL	Non-residential asphalt-surfaced pavements greater than 15 years old.	100-2.5X	60
3	BIS_ABCI_PCC	Non-residential concrete pavements	100-1.14106X	55
4	BIS_E_AC_0_15	Residential asphalt-surfaced pavements less than 15 years old.	100-2.65134X	60
5	BIS_E_AC_15_ALL	Residential asphalt-surfaced pavements greater than 15 years old.	100-3.0X	60
6	BIS_E_PCC	Residential concrete pavements.	100-0.96221X	55

* The Critical PCI value represents the condition at or below which Major M&R (e.g., resurfacing and reconstruction) is typically recommended.

Preliminary prediction model development efforts resulted in unrealistically slow deterioration rates for pavements 15 years and older. It was observed that many "older" pavements (e.g., 15 years and older) exhibited relatively high PCI values. This phenomenon may be attributed to two causes: (1) pavement ages are not accurate due to incorrect/missing construction records, and (2) the City's patching and chip sealing program results in older pavements having uncharacteristically high PCI values. While incorrect/missing construction records may be fixed on a case by case basis, addressing high PCI values due extensive patching is more challenging. In an effort to address this issue, models 2 and 5 in Table 2 were created based on engineering judgment. These models modestly increase the rate of deterioration for pavements greater than 15 years old.

Due to the diversity in pavement construction types and ages, the pavement prediction models shown above should be updated following each routine, tri-annual PCI inspection. It is also recommended that historical M&R data in the MicroPAVER database be verified, when possible. As resurfacing and reconstruction projects are completed, it is recommended that pavements be reassigned to the appropriate prediction model.

2.4.3 MicroPAVER Pavement M&R Models

Based on input from the City, it was determined that several pavement M&R models should be developed in order to more accurately predict future M&R costs. As shown in Table 3, these models were based on pavement surface type (e.g., AC, AAC, PCC, etc.), and pavement rank (e.g., A, B, C, etc.).

Table 3: MicroPAVER Major M&R Models

Family Name	Description
BIS_AC_A	Asphalt-surfaced Principal Arterials
BIS_AC_B	Asphalt-surfaced Minor Arterials
BIS_AC_C	Asphalt-surfaced Collectors
BIS_AC_E	Asphalt-surfaced Residentials
BIS_AC_I	Asphalt-surfaced Industrials
BIS_PCC_A	Concrete Principal Arterials
BIS_PCC_B	Concrete Minor Arterials
BIS_PCC_C	Concrete Collectors
BIS_PCC_E	Concrete Residentials
BIS_PCC_I	Concrete Industrials

These models were assigned to the appropriate pavement sections and were used to predict future M&R costs. The unit cost data associated with each of these models are detailed in the following section. As resurfacing and reconstruction projects are completed, it is recommended that pavements be reassigned to the appropriate M&R family model.

2.4.4 MicroPAVER M&R Unit Costs

In order to support the M&R models described in the previous sections, several M&R unit cost tables were developed based on pavement surface type (e.g., AC, AAC, PCC, etc.), and pavement rank (e.g., A, B, C, etc.). As shown in the following tables, typical M&R costs for various pavement types were developed as a function of PCI values based on data provided by the City.

Table 4 and Table 5 show the Major M&R unit costs per square foot as a function of PCI for asphalt-surfaced and concrete roadway pavements, respectively. Table 6 shows Global M&R unit costs per square foot as a function of distress types observed during the PCI inspection.

Table 4: Major M&R Unit Costs for Asphalt-Surfaced Roadway Pavements based on PCI values

		Major M&R Unit Cost per Square Foot				
PCI	Typical Major M&R Strategy	Principal Arterials (A)	Minor Arterials (B)	Collectors (C)	Residential (E)	Industrial (I)
100	No Work	$0.00	$0.00	$0.00	$0.00	$0.00
90	Localized Structural Patching	$0.23	$0.23	$0.20	$0.20	$0.23
80		$0.45	$0.45	$0.40	$0.40	$0.45
70	Mill and Overlay with Localized Base Repairs	$3.35	$2.51	$2.09	$2.04	$3.35
60		$4.28	$3.21	$2.57	$2.51	$4.28
50		$6.69	$5.62	$5.01	$4.53	$6.69
40	Mill and Overlay with Extensive Base Repairs or Reconstruction	$15.70	$14.20	$7.45	$6.54	$9.09
30		$15.70	$14.20	$7.45	$6.54	$9.09
20		$15.70	$14.20	$7.45	$6.54	$9.09
10		$15.70	$14.20	$7.45	$6.54	$9.09
0		$15.70	$14.20	$7.45	$6.54	$9.09

Table 5: Major M&R Unit Costs for Concrete Roadway Pavements based on PCI values

		Major M&R Unit Cost per Square Foot				
PCI	Typical Major M&R Strategy	Principal Arterials (A)	Minor Arterials (B)	Collectors (C)	Residential (E)	Industrial (I)
100	No Work	$0.00	$0.00	$0.00	$0.00	$0.00
90	Localized Structural Patching	$2.10	$1.92	$1.92	$1.92	$2.10
80		$2.10	$1.92	$1.92	$1.92	$2.10
70		$2.10	$1.92	$1.92	$1.92	$2.10
60	Slab Replacement, 25%	$4.37	$4.00	$4.00	$4.00	$4.37
50	Slab Replacement, 40%	$7.00	$6.40	$6.40	$6.40	$7.00
40	Slab Replacement, 50%	$8.75	$8.00	$9.25	$8.34	$8.75
30	Reconstruction	$17.50	$16.00	$9.25	$8.34	$17.50
20		$17.50	$16.00	$9.25	$8.34	$17.50
10		$17.50	$16.00	$9.25	$8.34	$17.50
0		$17.50	$16.00	$9.25	$8.34	$17.50

Table 6: Global M&R Unit Costs for Asphalt-Surfaced Roadway Pavements

Type of Distress	Type of Global Treatment	Global M&R Unit Cost per Square Foot
Minimal Distress	Chip Seal	$1.21
Climate Distress	Chip Seal	$1.21
Skid Causing Distress	Chip Seal	$1.21

These unit costs were assigned to the appropriate M&R models and are used to predict future M&R costs. As M&R costs change over time, it is strongly recommended that these unit cost tables be updated accordingly. Furthermore, it should be noted that these unit costs are network-level unit costs to be used for multi-year cost estimating purposes only. MicroPAVER's multi-year M&R analyses are based solely on these unit costs and predicted future PCI values. It is therefore necessary to perform a detailed project-level survey and cost estimate prior to programming a section for M&R.

2.4.5 MicroPAVER M&R Budget Tables

M&R budget tables were created in MicroPAVER to reflect the City's anticipated five-year funding levels, which are shown in Table 7.

Table 7: Anticipated Five-Year Funding Levels

	Year				
MicroPAVER "Level" of M&R	2013	2014	2015	2016	2017
Stop-Gap M&R[1)]	$754,000	$754,000	$754,000	$754,000	$754,000
Localized Preventive M&R[2)]	$155,000	$155,000	$155,000	$155,000	$155,000
Global M&R	$820,000	$860,000	$904,000	$949,000	$997,000
Major M&R	$7,700,000	$8,000,000	$7,800,000	$8,100,000	$7,900,000

1) Stop-Gap M&R includes patching and related chip sealing.
2) Localized Preventive M&R includes crack sealing.

2.5 Summary

The MicroPAVER pavement management system was successfully implemented for the City. A new MicroPAVER database was created that contains relevant data pertaining to the City's roadway pavement network. The MicroPAVER software was customized to reflect the City's existing and planned pavement management policies. The suite of tools provided by MicroPAVER will enable the City to more effectively manage its roadway pavement network.

3 PAVEMENT CONDITION INSPECTION

3.1 Objective

The objective of the pavement condition inspection was to assess the existing condition of the roadway pavements managed by the City. This was accomplished by performing a semi-automated, network-level pavement condition inspection based on the Pavement Condition Index (PCI) method.

Both the pavement condition inspection procedure and general findings of the inspection are discussed in this chapter.

3.2 Pavement Condition Index (PCI) Procedure

The pavement condition survey was performed using the modified ASTM D 6433-based PCI procedure described in the textbook, Pavement Management for Airports, Roads, and Parking Lots, 2nd Ed. by M. Y. Shahin. The PCI procedure is a more objective and repeatable method for determining existing pavement condition. A PCI value provides an indication of the structural integrity and operational condition for a pavement section. The PCI procedure consists of a routine visual inspection, during which pavement distress types, severity levels, and quantities are identified and recorded. These data are then input into the PCI algorithm to calculate a PCI value. PCI values range from 0 to 100, as shown in Figure 5.

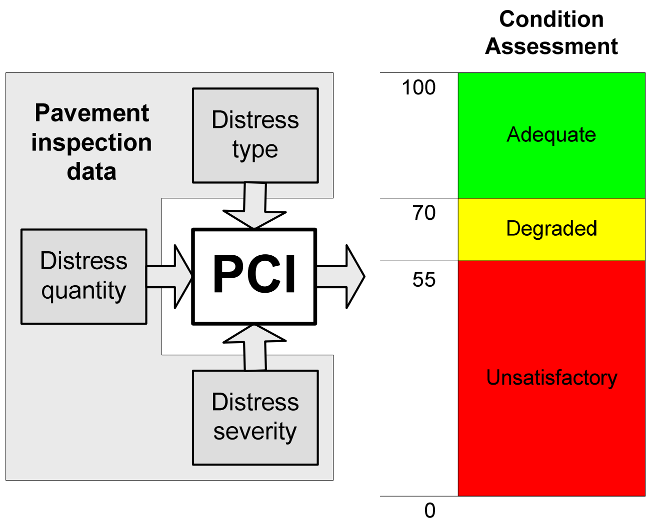


Figure 5: PCI Inputs and the City's Condition Assessment Scale

If properly designed and constructed, a new pavement begins its service life with a PCI of 100. Due to the effects of loading and aging, a pavement deteriorates over time. For each combination of distress type, severity level, and quantity observed, points are deducted from 100, and its PCI decreases. When multiple distresses are present, the deduct values are modified such that the impact of multiple distresses is somewhat lessened. Due to the complexity of the PCI algorithm, PCI values are typically computed using a pavement management software package, such as MicroPAVER.

During a PCI inspection, nineteen (19) distress types are identified and evaluated for asphalt pavements and nineteen (19) distress types for concrete pavements, as shown in Table 8 and Table 9. The City's roadway network consists of asphalt-surfaced and concrete pavements as well as a few gravel roadways.

Table 8: Asphalt Pavement Distress Types

Code	Distress	Cause
01	Alligator Cracking	Load
02	Bleeding	Other
03	Block Cracking	Climate/Durability
04	Bumps and Sags	Other
05	Corrugation	Other
06	Depression	Other
07	Edge Cracking	Load
08	Joint Reflection Cracking	Climate/Durability
09	Lane/Shoulder Drop-Off	Other
10	Longitudinal and Transverse Cracking	Climate/Durability
11	Patching and Utility Cut Patching	Other
13	Pothole	Load
14	Railroad Crossing	Other
15	Rutting	Load
16	Shoving	Other
17	Slippage Cracking	Other
18	Swell	Other
19	Raveling	Other
20	Weathering[1)]	Climate/Durability

1) Extensive Chip Seal deterioration was considered low to medium severity Weathering.

Table 9: Concrete Pavement Distress Types

Code	Distress	Cause
21	Blowup/Buckling	Climate/Durability
22	Corner Break	Load
23	Divided Slab	Load
24	Durability ("D") Cracking	Climate/Durability
25	Faulting	Other
26	Joint Seal Damage	Climate/Durability
27	Lane/Shoulder Drop-Off	Other
28	Linear Cracking	Load
29	Patching, Large and Utility Cuts	Other
30	Patching, Small	Other
31	Polished Aggregate	Other
32	Popouts	Other
33	Pumping	Other
34	Punchout	Load
35	Railroad Crossing	Other
36	Scaling, Map Cracking, and Crazing	Other
37	Shrinkage Cracks	Climate/Durability
38	Spalling, Corner	Climate/Durability
39	Spalling, Joint	Climate/Durability

3.3 Semi-Automated Pavement Condition Index (PCI) Survey Data Acquisition

Dynatest deployed its state-of-the-art Multi Function Vehicle (MFV), shown in Figure 6, to collect high-quality pavement imagery and profile data requisite for the semi-automated PCI survey of the City's pavements. Described in the following paragraphs, the main hardware components of a MFV include:

- Laser Road Imaging System (LRIS) for high-resolution downward pavement imagery
- High-definition digital video right-of-way (ROW) camera for forward facing pavement imagery
- Seven (7) laser Dynatest Road Surface Profiler (RSP-5051) for pavement surface profiling
- Integrated Trimble AgGPS 132 and Applanix POS LV for locating imagery and profile data

The downward imaging LRIS system is composed of two high resolution linescan cameras and lasers that are configured to continuously image 13ft wide lanes (4096 pixels) with 1mm crack width resolution at speeds up to 100 km/h (60 mph). This imaging system was designed to increase the contrast and visibility of both small longitudinal and lateral road cracks.

Downward images were collected in both directions of each of the City’s two-way streets. For City streets with four or more lanes, downward images were collected in just two lanes, one in each direction of travel. A high-definition, forward-facing Panasonic digital video was used to collect ROW images at 20ft intervals along all of the City’s streets.

Figure 6: Dynatest Multi Function Vehicle

The Dynatest Road Surface Profilometer (RSP) mounted on the MFV is designed to provide accurate and repeatable pavement profile data. Using seven (7) lasers and two (2) accelerometers, the RSP is capable of real-time, continuous, highway-speed, dual-wheel-path measurements of longitudinal profile, transverse profile, and rut depth. RSP data were collected for all of the City’s streets and used in establishing PCI values for each pavement section. All imagery and profile measurements collected with the MFV as part of this project are referenced to a linear chainage and coordinates from a Differential Geographical Positioning System (DGPS). The MFV’s integrated Trimble AG-132 receiver and Applanix POS LV systems were used for recording accurate DGPS coordinates.

3.4 Pavement Condition Index (PCI) Survey Data Interpretation

For this project, Dynatest used the ASTM D6433-based modified PCI inspection method developed by the US Army Corps of Engineers (USACOE) for performing image-based PCI inspections. This method incorporates systematic random sampling and requires that distresses be recorded by trained inspectors using software that enables the inspectors to identify and record pavement distress types, severities, and quantities visible on collected downward images.

The image-based pavement condition survey was executed using Dynatest’s Distress Rating Module (DRM) software, which was developed specifically for performing PCI surveys on image data. As shown in Figure 7, DRM provides users with a graphical representation of and the ability to edit all the data sets collected using the MFV. These data sets, which are accessed and organized by DRM, include downward pavement images, right-of-way (ROW) images, profile datasets, DMI, and GPS readings.

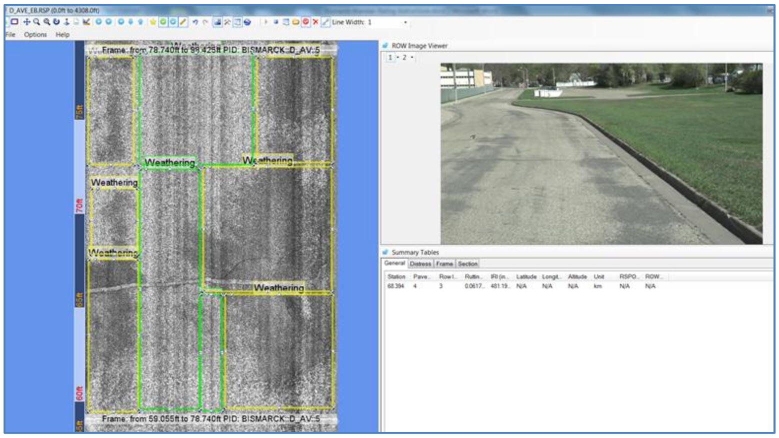


Figure 7: Dynatest's Distress Rating Module (DRM) Software

Dynatest used trained and experienced pavement inspectors under the supervision of Project Engineers for post processing collected pavement image data for the City. Each inspector was equipped with a workstation with two high-resolution LCD monitors that enabled him to identify, classify and report the pavement surface distresses using DRM. Visually recorded distress data were then supplemented in DRM by profile data to include any rutting data that was not visible on the collected images.

As previously mentioned, in an effort to achieve a comprehensive, network-level baseline PCI inspection, the City requested that data be collected in two directions for each roadway. A systematic random sampling procedure was then applied in interpreting the collected data. In keeping with standard network-level PCI inspection practices, a 33% sampling rate was implemented.

The following procedure was followed for inspecting the City's roadway pavments. For each section, the pavement surface is divided into "frames." Each frame is 20FT long by the 12FT wide. Beginning with the first frame, 33% (i.e., 1 out of every 3) of the frames in each pavement section are inspected, as shown in Figure 8. *Note: For concrete pavements, each frame was assumed to encompass an entire concrete slab.*

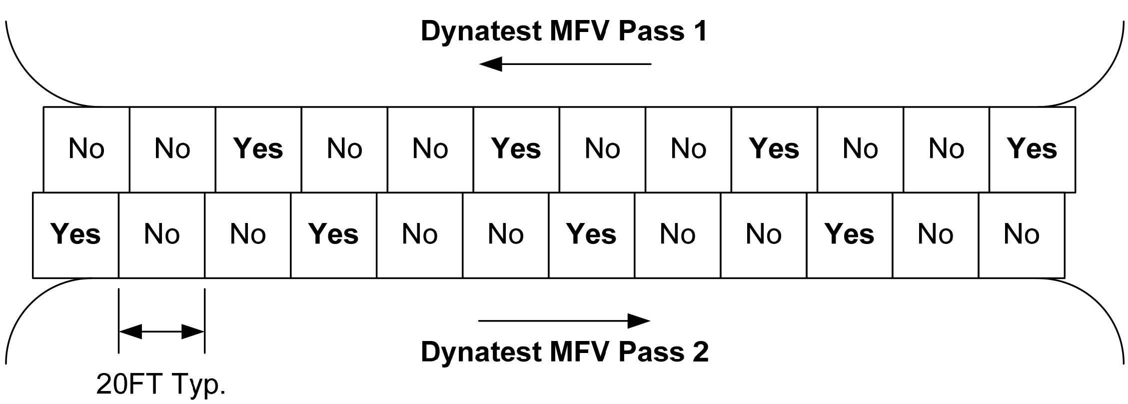


Figure 8: Systematic, Random Sampling PCI Procedure Using 20FT Long "Frames"

During the PCI survey, data are recorded in DRM. Following the completion of the PCI survey, these data are then exported to *.XML files and then imported into MicroPAVER.

3.5 Summary of City's Existing Pavement Conditions

Once the pavement images had been interpreted by Dynatest inspectors, resulting distress data were imported into MicroPAVER and PCI values were calculated for each pavement section. Table 10 shows the PCI condition assessment criteria used to analyze the pavement network.

Table 10: City's Pavement Condition Assessment Criteria

Condition Assessment	PCI Value
Adequate	71 – 100
Degraded	56 – 70
Unsatisfactory	0 – 55

At the time of Dynatest's May 2012 inspection, the City's roadway pavements were found to be in overall "Adequate" condition, with an overall average PCI of 81. The condition distribution of the City's pavements at the time of inspection is shown in Figure 9, and Table 11 illustrates pavement condition by pavement surface type.

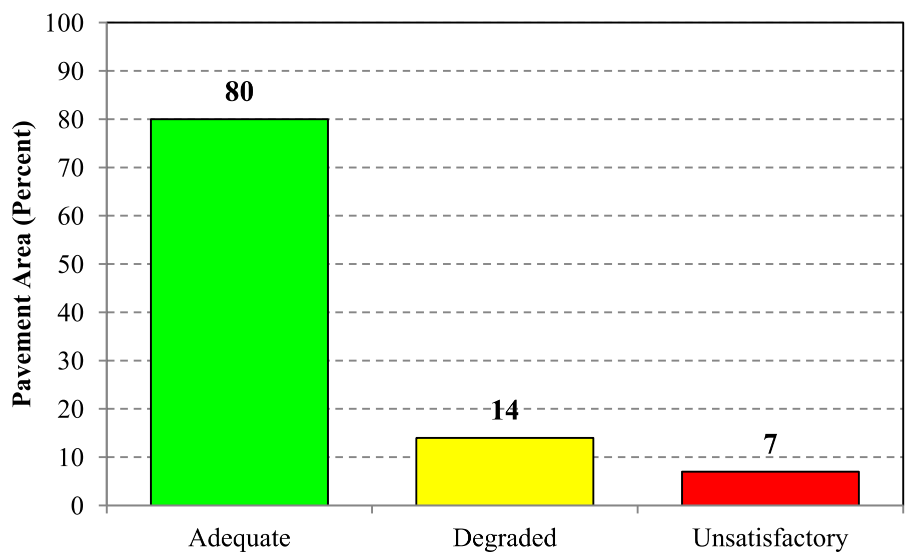


Figure 9: Overall Roadway Pavement Condition Distribution

Table 11: Roadway Pavement Condition Distribution by Surface Type

Pavement Surface Type	Inspected Pavement Area (SF)	Pavement Area (%)	2012 Average PCI
Asphalt overlay over asphalt concrete (AAC)	429,960	1	97
Asphalt concrete (AC)	52,668,900	84	82
Asphalt overlay over Portland cement concrete (APC)	664,532	1	83
Gravel/unpaved (GR)	69,888	< 1	NA
Portland cement concrete (PCC)	5,742,867	9	87
Hard surfaced (X)	2,769,302	4	46
All Combined	62,345,449	100	81

As shown in Figure 10, the overwhelming majority of the City's asphalt-surfaced roadways were observed to be in "Adequate" condition, with an overall average PCI value of 81. The City's hard surfaced pavements were observed to be in "Unsatisfactory" condition, with an overall average PCI value of 46, as shown in Figure 11. As shown in Figure 12, the City's concrete roadway pavements were observed to be in "Adequate" condition, with an overall average PCI of 87.

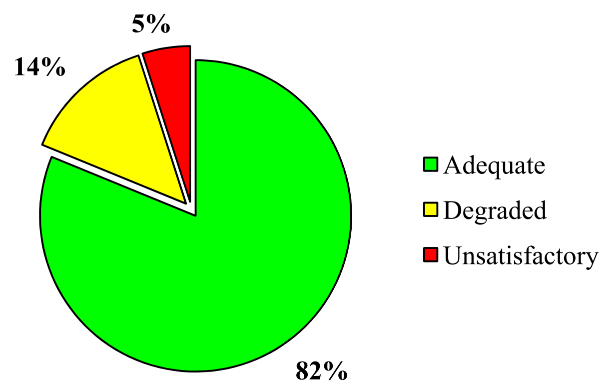


Figure 10: Asphalt-Surfaced Roadway Pavement Condition Distribution at Inspection

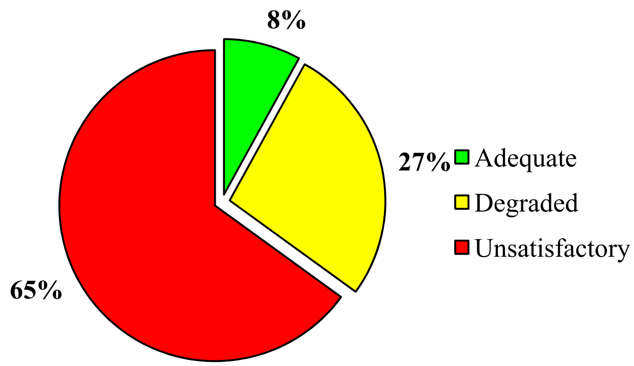


Figure 11: Hard Surfaced Roadway Pavement Condition Distribution at Inspection

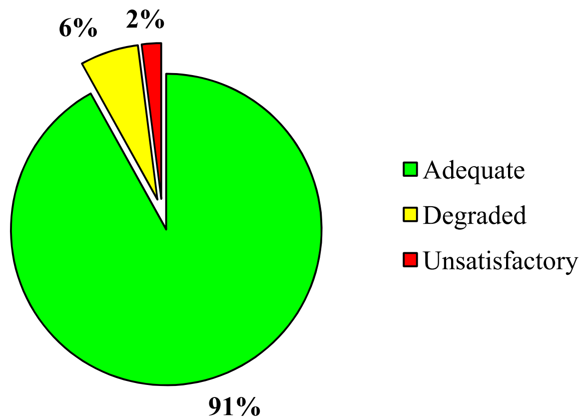


Figure 12: Concrete-Surfaced Roadway Pavement Condition Distribution at Inspection

As shown in Figure 13, the City's alley pavements were found to be in "Unsatisfactory" condition. The City's alleys are comprised of both asphalt-surfaced and concrete pavements. Both types of pavements were observed to be in "Unsatisfactory" condition.

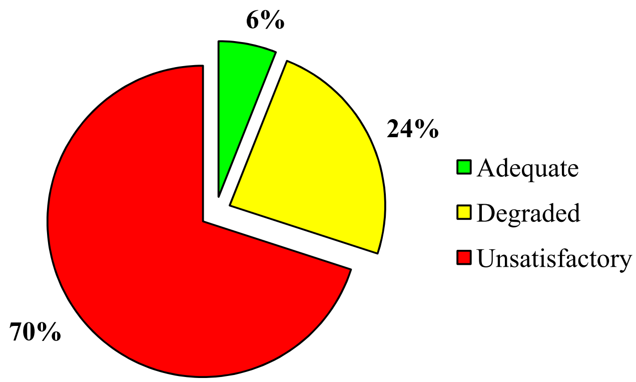


Figure 13: Alley Pavement Condition Distribution at Inspection

The causes of pavement deterioration may be divided into the following three general categories: (1) Load Related, (2) Climate/Durability Related, and (3) Other. Table 12 shows the primary causes of pavement deterioration observed throughout the City's pavement network.

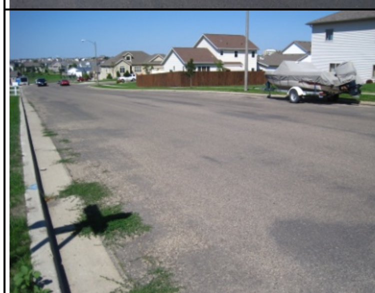
Table 12: Categorization of Observed Roadway Pavement Distresses

Distress Category	Example Distresses	Percentage of Observed Distresses
Load Related	Asphalt pavement distresses such as rutting and alligator cracking. Concrete pavement distresses such as corner breaks and divided slabs.	19%
Climate/ Durability Related	Asphalt pavement distresses such as weathering, longitudinal and transverse cracking, and block cracking. Concrete pavement distresses such as joint and corner spalling and joint seal damage.	76%
Other	Pavement distresses such as bleeding, patching, and slippage cracking for asphalt pavements. Popouts and scaling for concrete pavements.	5%

The deterioration observed on the City's pavements was caused primarily by a mixture of climate- and load-related distresses. Climate-related distresses – in particular, weathering of chip sealed pavements – were found across the City's concrete pavement inventory. Load-related distresses, such as alligator cracking and potholes, were also observed on the City's roadways. However, perhaps due to the City's proactive patching program, these distresses may not appear to be as widespread.

3.6 Field Observations of Typical Pavement Conditions

Figure 14 illustrates a variety of pavement conditions observed throughout the City during the survey.

	Location	PCI	Recommended M&R Activity (Typical)
	Selkirk Rd. *Section 5* *Between Colt Ave. and Huron Dr.*	100	Do Nothing
	Valley Dr. *Section 50* *Between Mustang Dr. and Overland Rd.*	92	Do Nothing or Preventive Maintenance *Surface Treatment*
	Washington St. *Section 325* *Between Juniper Dr. and Aspen Ave.*	86	Preventive Maintenance *Crack Seal, Surface Treatment*
	D Ave. *Section 40* *Between 3rd St. and 4th St.*	83	Preventive Maintenance *Crack Seal, Surface Treatment*
	University Dr. *Section 10* *Between Yegen Rd. and Airport Rd.*	79	Preventive Maintenance *Crack Seal, Localized Patching and Surface Treatment*

	Colt Ave. *Section 10* *Between Selkirk Rd. and Washington St.*	77	Preventive Maintenance *Crack Seal, Localized Patching, Surface Treatment*
	Ash Coulee Dr. *Section 70* *Between Valley Dr. and Mustang Dr.*	59	Major M&R *Localized Structural Patching and Resurfacing*
	Tacoma Ave. *Section 10* *Between San Angelo Dr. and 12th St.*	53	Major M&R *Localized Structural Patching and Resurfacing or Reconstruction*
	Overlook Dr. *Section 50* *Between Brunswick Dr. and Selkirk Rd.*	51	Major M&R *Localized Structural Patching and Resurfacing or Reconstruction*
	Juniper Dr. *Section 20* *Between Cherry Ln. and Washington St.*	45	Major M&R *Localized Structural Patching and Resurfacing or Reconstruction*

Figure 14: Pavement Conditions Observed during PCI Inspection

A distress observed on many of the City's concrete pavements was joint seal damage, as shown in Figure 15. Joint seal damage may be caused by several mechanisms, including: (1) thermal expansion of adjacent slabs during hot temperatures, which may cause the sealant to "pop out" of the joint and be dragged away by traffic; and (2) oxidation of the sealant material, which may cause the sealant become brittle and debond from the joint.

	Recommended M&R Activity (Typical)
	**Localized M&R** *Joint Seal Replacement*

Figure 15: Deteriorated/Missing Joint Sealant between Concrete Slabs

Irrespective of the mechanism causing joint seal damage, the resulting unsealed (or partially sealed) joint may lead to premature deterioration and failure of the concrete pavement. For example, unsealed joints allow water to infiltrate into the underlying pavement structure, and the presence of water may significantly weaken the pavement structure and reduce the service life of the pavement. Furthermore, unsealed joints may become filled with incompressible materials such as loose stones. These incompressible materials may restrict the expansive movement of adjacent slabs and result in high compressive stresses in the concrete slabs. These compressive stresses may lead to spalling of the concrete and, in extreme cases, vaulting of adjacent slabs and slab “blowups.”

4 MAINTENANCE AND REHABILITATION BUDGET ANALYSES

4.1 Objective

The objectives of a pavement M&R budget include maintaining satisfactory overall pavement conditions and reducing the Major M&R backlog over time. Doing so will eventually ensure that all pavements in the City are in good condition and are therefore being managed as cost effectively as possible through preventive maintenance and less costly and less frequent rehabilitation projects. By incorporating recommendations and data obtained from MicroPAVER into its existing decision-making processes, the City should be able to not only better optimize and prioritize the expenditure of its existing M&R funding but also better justify its immediate and future roadway pavement M&R funding needs.

The M&R planning module in MicroPAVER provides *recommendations* for when and where M&R activities are needed and approximately how much they will cost. M&R plans may be developed either by: (1) defining an annual budget, or (2) specifying a desired pavement condition. Based on either an inputted annual budget or a desired condition, MicroPAVER will output an economically viable work plan.

The following five-year M&R budget analyses were performed on the City's roadway pavements:

- Determine required annual budget to eliminate the City's Major M&R backlog, $11.4M/YR
- Determine required annual budget to maintain a PCI of 80, $10.1M/YR
- Determine effect of City's existing budget, $9.5M/YR (Approx.)
- Determine effect of 75% of the City's existing budget, $7.1M/YR (Approx.)
- Determine effect of 50% of the City's existing budget, $4.8M/YR (Approx.)
- Determine effect of $0.0M/YR

These analyses *did not* consider the City's alley or hard surfaced roadway pavements; separate analyses were performed for these two groups of pavements.

The following sections summarize the assumptions underlying the analyses performed and then present the findings of the analyses.

4.2 Assumptions

The M&R budget analyses performed as part of this project were based entirely on the data stored in the City's new MicroPAVER database. The pavement prediction models shown in Table 2 were used in forecasting future pavement conditions, and critical PCI values of 60 and 55 were set for the asphalt-surfaced and concrete roadway pavements, respectively.

The City's existing $9.5M/YR (approx.) budget was determined by summing the "Stop-Gap M&R," "Global M&R" and "Major M&R" budgets shown in Table 7. The M&R unit cost data provided by the City, and shown in Tables 3 though 6, were used directly in MicroPAVER. The City's "Localized Preventive" (e.g., crack sealing) budget of $155K/YR *was not* considered in the analyses due to the fact that MicroPAVER's multi-year work planning capabilities are based only on PCI values only – distresses are not considered directly. Hence, it could not be guaranteed that the $155K/YR budget would be applied to crack sealing. An inflation rate of 3% was used for all analyses.

4.3 Results for the City's Roadway Pavements

The results of the six budget analyses are shown in the following two figures. Figure 16 illustrates the estimated five-year change in pavement condition resulting from the analyzed budget scenarios while Figure 17 depicts the estimated change in the City's Major M&R backlog.

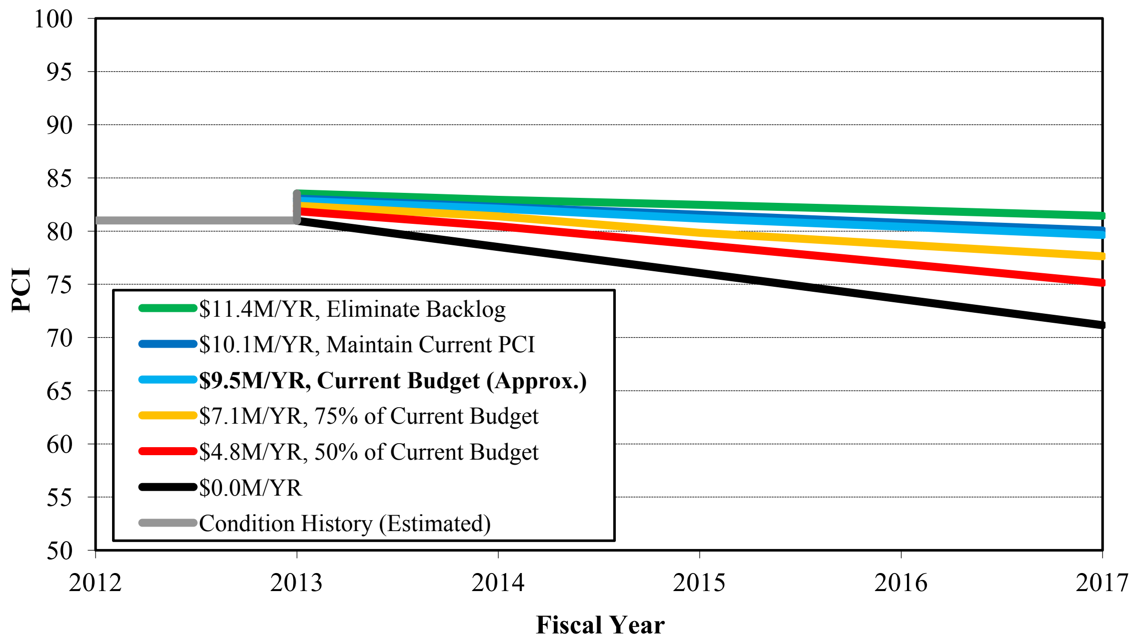


Figure 16: Effect of Budget on Overall Roadway Pavement Conditions

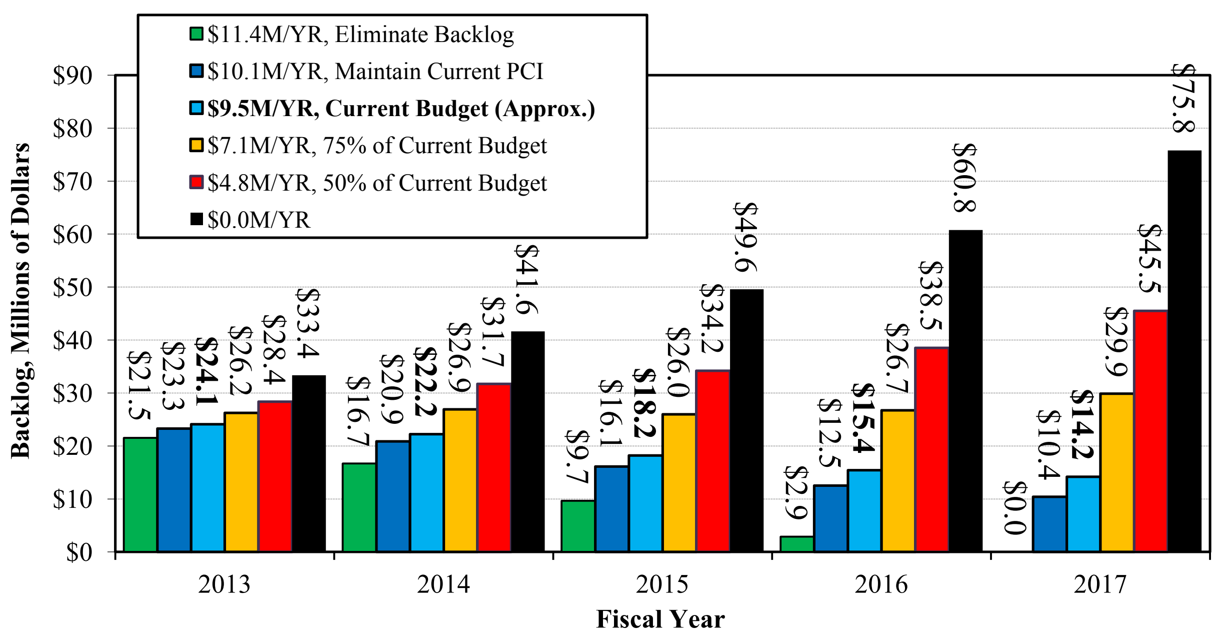


Figure 17: Effect of Budget on Roadway Pavement Major M&R Backlog

The economic consequences of annual budgets ranging from $0.0M/YR to $11.4M/YR including their total costs and costs relative to the Major M&R "Eliminate Backlog" budget are shown in Table 13. This table shows that if both the annual M&R expenditures as well as the remaining M&R backlog are treated as costs incurred by the City, then the total overall cost to the City is less if the City eliminates its Major M&R backlog over a five year period.

Table 13: Estimated Five Year Roadway Pavement Major M&R Budget Costs

Budget Scenario	Total Five Year M&R Costs (2013-2017)	Remaining M&R Backlog[1)] (2017)	Total Five Year Cost[2)]	Cost Differential
Eliminate Backlog $11.4M/YR	$57.0M	$0.0M	$57.0M	*Baseline*
Maintain PCI of 80 $10.1M/YR	$50.5M	$10.4M	$60.9M	$3.9M
Current Budget (Approx.) $9.5M/YR	**$47.5M**	**$14.2M**	**$61.7M**	**$4.7M**
75% of Current Budget (Approx.) $7.1M/YR	$35.5M	$29.9M	$65.4M	$8.4M
50% of Current Budget (Approx.) $4.8M/YR	$24.0M	$45.5M	$69.5M	$12.5M
$0M/YR	$0K	$75.8M	$75.8M	$18.8M

1) "M&R Backlog" equals the lump-sum cost to resurface/reconstruct all pavements at or below the critical PCI value.
2) "Total five year cost" equals the sum of the five year Major M&R expenditures plus the remaining Major M&R backlog at the end of the five year analysis period.

4.3.1 Major M&R Backlog Elimination (Eliminate Backlog)

MicroPAVER was used to estimate the annual funding required to eliminate the City's Major M&R backlog for roadway pavements. This plan identifies which roadway pavements require stop-gap maintenance (e.g., pothole filling) and Major M&R (e.g., resurfacing and reconstruction) during the upcoming five years so that – at the end of the five year period – all City maintained roadway pavements are either at or above their respective critical PCI value.

It was determined that approximately $11.4M/YR are needed to eliminate the City's existing M&R backlog over the next five years. This scenario results in a slight overall PCI decrease from 83 at the beginning of 2013 to 81 at the end of 2017. Typically, this scenario results in a PCI increase over the five year analysis period. However, due to the fact that the City's pavements already have a high overall average PCI, an overall decrease in the network average PCI is observed even as pavements with PCI values below critical are being rehabilitated.

Furthermore, it is worth noting that if the City spends $11.4M/YR over the next five years, the annual funding required to maintain the City's roadway pavements at or above their respective critical PCI values from 2018 to 2022 is estimated by MicroPAVER to be roughly $12.3M/YR. This is due to the fact that many of the City's pavements that are currently in relatively good condition will be in need of Major M&R between the next five to ten years.

4.3.2 Maintain Current Conditions (Maintain PCI of 80)

A similar MicroPAVER analysis was performed to estimate the annual funding required to maintain the current overall average PCI value of the City's roadway pavements for the next five years. However, it was not possible to achieve this goal using MicroPAVER, again due to the fact that the City's pavements currently have a high overall average PCI value.

An alternative analysis was therefore performed to determine the annual funding level required to maintain the City's roadway pavements at or above a PCI value of 80 over the next five years. Typically, an overall average PCI value of 80 is considered a good goal to target, since it indicates that a significant percentage of an agency's pavement M&R budget may be directed toward preventive maintenance activities. It was determined that approximately $10.1M/YR are needed to achieve this goal.

4.3.3 Budget Consequence: Fixed Budget Analyses

Several additional analyses were performed to determine the consequences of the following annual M&R budgets:

- $9.5M/YR, City's current budget (approx.)
- $7.1M/YR, 75% of City's current budget (approx.)
- $4.8M/YR, 50% of City's current budget (approx.)
- $0M/YR

As would be expected, the more money that the City spends on its roadway pavements, the greater the improvement in pavement condition and the greater the reduction in backlog. The City's existing $9.5M/YR budget results in a decreasing backlog as well as a decreasing overall average PCI. Both the $7.1M/YR and $4.8M/YR budgets result in less desirable consequences.

As was previously discussed, many of the City's pavements that are currently in relatively good condition will be in need of Major M&R between the next six to ten years. Therefore, it is important to note that while the City's backlog does appear to decrease over the next five years under current, anticipated funding levels, the backlog will likely grow considerably between 2018 and 2022. This suggests that appropriate increases in pavement funding should be planned for.

4.4 Results for the City's Alley Pavements

The City's alleys account for less than 1% of the City's paved surface area, and they are comprised of both asphalt-surfaced and concrete pavements. The City's alleys are in overall "Unsatisfactory" condition, with an average PCI value of 40. Should the City decide to eliminate the Major M&R backlog for these pavements, an estimated $800K/YR would be required to do so over the next five years.

4.5 Results for the City's Hard Surfaced Pavements

The City's hard surfaced (i.e., non-engineered) pavements account for approximately 4% of the City's paved surface area. These pavements are in overall "Unsatisfactory" condition, with an average PCI value of 46. For the past few years, the City has programmed approximately $3.0M/YR to reconstruct its hard surfaced pavements. It is anticipated that the majority of the City's hard surfaced pavements will be reconstructed over the next five years utilizing this funding. This estimate was substantiated using MicroPAVER, which estimated essentially the same (within $50K annually) funding requirement.

5 MORE EFFECTIVE TRANSPORTATION PLANNING AND PRIORITIZATION

The Bismarck-Mandan MPO will use data and analysis results from the City's pavement management program directly in developing its Transportation Improvement Program (TIP) and Long Range Transportation Plan (LRTP). The pavement management program provides the City and MPO with the following pavement management data and analysis capabilities:

1. Objective, repeatable, distress-based pavement condition values based on industry accepted methods and procedures (i.e., ASTM D6433 and E950)
2. Identification and prioritization of existing and future pavement preventive (e.g., crack sealing) and stop-gap (e.g., pothole filling) maintenance requirements
3. Identification and prioritization of existing and future pavement rehabilitation (e.g., mill and overlay) and reconstruction requirements
4. Multi-year network- and project-level pavement maintenance and rehabilitation project cost estimating
5. "Geocentric" data and analysis reporting, thus facilitating the development and coordination of projects involving pavement and other City assets (e.g., utilities)

The Counties of Burleigh and Morton and the City of Lincoln should be afforded every opportunity by the MPO to participate in the existing pavement management program. Specifically, these agencies will be extended the opportunity to participate in future pavement condition surveys and pavement management training sessions coordinated by the MPO and the Cities of Bismarck and Mandan. Should these agencies opt to participate in these collective pavement management activities, the MPO's system wide transportation planning efforts will be enhanced with a unified, consistent system of surveying, analysis, and prioritization of the roads within the MPO area. Additionally, significant cost savings, data sharing and overall system wide efficiencies will be realized by all the participating jurisdictions partnering with the MPO in this endeavor.

The MPO will also cooperate and integrate its pavement management program to the best of its ability with the NDDOT's pavement management system. These cooperative efforts could yield cost and data efficiencies between the two systems. There should always be some common streets and roads that are surveyed and analyzed by both the MPO's and NDDOT's pavement management systems within the same relative time frame. A meeting of both parties, MPO jurisdictions and NDDOT, for comparison rating results of the same roadways is recommended.

How pavement management program data and capabilities will be used by the Bismarck-Mandan MPO in developing its TIP and LRTP are described in the following sections.

5.1 Transportation Improvement Program (TIP)

The Bismarck-Mandan MPO Policy Board, in 2010, adopted a process for prioritizing and selecting Urban Road Program (URP) projects for the MPO's TIP. Preservation of the existing transportation system's roadway pavement network is one of the criteria associated with the prioritization and selection process. With respect to pavement preservation, the MPO's prioritization and selection process considers the following information – all of which may be obtained from the City's up-to-date pavement management program: (1) relative conditions of candidate roadway pavement sections; and (2) the appropriate timing of project implementation with respect to pavement structural and non-structural integrity issues.

The City's pavement management system contains data necessary for the MPO's prioritization and selection process. Specifically, Pavement Condition Index (PCI) and International Roughness Index (IRI) values determined for each of the City's roadway pavement sections as part of this project are readily available in the City's pavement management system. Prior to selecting any roadway pavement for inclusion in the MPO's TIP, the MPO will request detailed pavement condition data (i.e., PCI and IRI values) from the City – in the form of either a report, spreadsheet, or GIS map generated from the pavement management program – to assess whether the pavement meets the MPO's criteria for inclusion in the TIP. Reported pavement condition data will assist the MPO in ensuring that its TIP program includes pavements that best meet the MPO's goals and objectives for the program.

Equally as important, the PCI and IRI data in the pavement management program will greatly assist the City in more optimally developing its own TIP requests, within the context of the City's own pavement management plan. By using the pavement management program's analysis and reporting tools, which are described in detail within this report, the City will be able to determine when and where pavement maintenance and rehabilitation activities are most needed, and approximately how much these activities will cost. Detailed pavement condition data stored in the pavement management program – down to the type and extent of various pavement distress types – will enable the City and MPO to truly determine the most optimal maintenance and rehabilitation activity for each roadway pavement. Consequently, the TIP requests generated by the City will better meet not only the goals and objectives of MPO's TIP, but also the pavement management goals of the City.

5.2 Long Range Transportation Plan (LRTP)

While the pavement inventory and condition data stored in the City's pavement management program improves the short-term time frame project selection for the MPO's TIP, longer term project selection involving the MPO's LRTP is also directly and positively impacted by the data generated from the City's pavement management program. Goal 4 of Bismarck-Mandan 2010-2035 LRTP specifically states: "Preserve the existing and planned system." Similar to the TIP prioritization and selection process, the MPO will request detailed, forecasted pavement condition data from the City prior to selection of roadway pavements in the LRTP. The requested data will be provided by the City directly from the City's pavement management program, in the form of a report, spreadsheet, or GIS map. A major benefit of the City's pavement management program in this process is that the program is capable of forecasting and prioritizing future pavement maintenance and rehabilitation activities, hence, improving the overall multi-year optimization and prioritization of both agencies' available pavement maintenance and rehabilitation-related funding. In general, information obtained from the pavement management program will significantly enhance the MPO's ability to identify significant "maintenance/operations" projects in updates of the LRTP.

Furthermore, the pavement management project captured visual images of roadways in the participating MPO jurisdictions. These images will be uploaded to the City's intranet and made available to the MPO for use in visualization techniques for future MPO planning related efforts – both TIP and LRTP planning related activities. Lastly, the data collected and reported from the pavement management program will be linked to the City's GIS and be made available to the MPO. This will enable the City and the MPO to visually represent pavement conditions in a geographically referenced format. This allows for roadway conditions to be analyzed in a more quantifiable and objective context with a variety of GIS information which may assist in identifying contributing factors to pavement deterioration. As previously mentioned, GIS-based visualization of the City's pavement data will enable the MPO to better coordinate multi-disciplinary projects for the member agencies.

6 SUMMARY AND RECOMMENDATIONS

6.1 Summary

The primary objectives of this project were to: (1) perform a comprehensive upgrade of the City's existing pavement management system, and (2) perform a network-level pavement condition survey of the City's roadway pavements. Both objectives were successfully completed, and the City has in place an up-to-date implementation of the MicroPAVER pavement management system populated with recent pavement condition data.

The City's roadway pavements were found to be in "Adequate" condition, with an average PCI value of 83. The asphalt-surfaced pavements, which account for slightly more than 85% of the pavement inventory, had an average PCI value of 81. The concrete pavements, which account for 9% of the pavement inventory, had a somewhat higher average PCI value of 87. Both the City's alley and hard surfaced pavements were found to be in "Unsatisfactory" condition, with average PCI values of 40 and 46, respectively.

MicroPAVER was used to analyze the impact of different five-year funding scenarios on the condition of the City's roadway pavement network. It was determined that the City's currently anticipated $9.5M/YR (approx.) funding level would likely result in a three point decrease in the overall PCI but still result in a gradual reduction of the existing M&R backlog. While the $11.4M/YR "Eliminate Backlog" funding level was determined to result in the lowest "total cost" to the City over the five-year analysis period, this funding level may still result in a one point decrease in the overall average PCI value.

Due, in part, to the rapid expansion of the City's pavement network over the last several years, it is important to understand that the funding levels required over the next five years will likely need to be increased over the next six to ten years and beyond. The City's overall average PCI value is currently relatively high. The large inventory of pavements that are in good condition today will continue to deteriorate and will require more significant rehabilitation, such as resurfacing or reconstruction, a decade or so from now. Consequently, the City should anticipate and plan for an increase of its pavement M&R budgets in the mid- to long-term.

6.2 Recommendations

6.2.1 Evaluate Effectiveness of City's Existing Patching Program

The City currently has an extensive pavement patching program in place. Localized patches are applied to temporarily correct severe pavement distresses. These patches are often large and attempt to remedy significant, advanced-stage structural distresses. This type of widespread patching results in higher PCI values than would otherwise be observed. It is difficult to quantify the impact that this patching program has had on overall pavement conditions; however, it is likely that the City's relatively high overall average PCI value is due, in part, to the patching program. While pavement patching is a necessary stop-gap maintenance activity, the economic benefit of patching diminishes when it is performed repeatedly to the same pavements.

It is recommended that the City evaluate the long-term effectiveness of its existing patching program. Using MicroPAVER, it is recommended that the City track which pavements are being patched, how frequently they are being patched, and approximately how much the patching actually costs. A life-cycle cost analysis should then be performed to assess the economic impact of the City's existing patching program.

6.2.2 Perform Regular Pavement Condition Inspections

In an effort to capitalize on this PCI inspection effort and better track the condition of its pavements, it is strongly recommended that the City continue to perform PCI surveys on a three year cycle. Doing so will enable the City to:

1. Better track the deterioration of its pavements,
2. Develop pavement deterioration trends to better predict future pavement conditions, and
3. Assess the effectiveness of its pavement maintenance, preservation, and Major M&R activities.

While the City's pavements are currently in "Adequate" condition, the majority of the pavements were rehabilitated or constructed within the past fifteen years and are relatively young. This suggests that future M&R needs will increase as the City's pavements deteriorate over time. It is necessary that this deterioration be proactively and systematically monitored to more accurately predict future pavement M&R funding needs.

6.2.3 Migrate Historical Work Data to MicroPAVER

It is recommended that the City import all work history records from its old MicroPAVER database into the new database created as part of this project. Due to data integrity issues with the City's old MicroPAVER database, it was only possible to migrate the most recent historical Major M&R records into the new MicroPAVER database. Since the creation the new MicroPAVER database, some progress has been made in "cleaning" the records stored in the earlier MicroPAVER database. Once these records have been verified, they should be imported into MicroPAVER. This effort will likely require outside programming support.

6.2.4 Expand Existing Preventive Maintenance Program

Currently, the City allocates approximately $155K/YR toward crack sealing of asphalt pavements, which is a proven method for extending the life of asphalt pavements. In addition, the City's existing practice of chip sealing newly-constructed pavements not only improves the pavements friction characteristics but also serves as a preventive maintenance activity by sealing the pavement and providing a wearing surface. It is recommended that the City investigate whether microsurfacing, which has been shown to be more durable than chip seals in some applications, may be a more effective preventive maintenance treatment for more heavily trafficked asphalt pavements.

It is also recommended that the City adopt preventive maintenance activities for its concrete pavements, such as joint seal replacement and crack sealing. The replacement of failed or missing joint sealant helps keep incompressible debris such as stones, out of the joints. The accumulation of debris in concrete pavement joints may lead to premature pavement deterioration. Similar to crack sealing asphalt pavements, crack sealing concrete pavements helps slow pavement deterioration by preventing moisture and debris from entering the pavement structure.

6.2.5 Develop a Maintenance and Rehabilitation Program for Alley Pavements

The City's alley pavements are in overall "unsatisfactory" condition. Many of the City's alleys exhibit severe structural distresses, including potholes, which can make driving on them challenging. In an effort to provide navigable routes for the City's garbage trucks and residents, it is recommended that the City develop a maintenance and rehabilitation program for its alley pavements. It is recommended that the City's alleys should be maintained in a similar way as the City's other pavements.

APPENDIX A PAVEMENT MANAGEMENT MAPS

1. Pavement Ranks (Classifications)
2. Pavement Surface Types
3. Pavement Condition Index (PCI) Values

CITY OF BISMARCK, ND
Bismarck-Mandan
Metropolitan Planning Organization
N
0
0.5
1
2
Miles
2012 Pavement Condition Index (PCI)
Adequate (PCI > 70)
Degraded (55 < PCI < 70)
Unsatisfactory (PCI < 55)
Not Inspected
Map displays the Pavement Condition Index (PCI) for each pavement section.
Coordinate System: GCS North American 1983
PCI Data Collected: 04/14/2012 to 05/10/2012
Map Date: 10/01/2012
Dynatest®
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012

CITY OF BISMARCK, ND
Bismarck-Mandan
Metropolitan Planning Organization
N
0
0.5
1
2
Miles
2012 Pavement Ranks
Principal Arterial (A)
Minor Arterial (B)
Collector (C)
Residential (E)
Industrial (I)
Map displays the pavement rank for each pavement section.
Coordinate System: GCS North American 1983
PCI Data Collected: 04/14/2012 to 05/10/2012
Map Date: 10/01/2012
Dynatest®
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012


CITY OF BISMARCK, ND
Bismarck-Mandan
Metropolitan Planning Organization
N
0
0.5
1
2
Miles
2012 Pavement Surface Types
Asphalt over AC (AAC)
Asphalt Concrete (AC)
Asphalt over PCC (APC)
Gravel (GR)
Portland Cement Concrete (PCC)
Built-Up (X)
Map displays the pavement surface type for each pavement section.
Coordinate System: GCS North American 1983
PCI Data Collected: 04/14/2012 to 05/10/2012
Map Date: 10/01/2012
Dynatest®
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012