Commerce City, CO
Pavement Management Report

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1.0 Project Introduction

The nation's highways represent an investment of billions of dollars by local, state and federal governments. For Commerce City, who maintains 260.89 miles of paved roadways, this investment translates into roughly $407M when factoring in a replacement (reconstruction) cost of approximately $1.56 million per mile. The $1.56 million per mile is a national estimate obtained from the American Public Works Association (APWA). This report will only address the needs for the asphalt roads.

Total Pavement Network Value ($)	**$407.0 Million**
Total Distress Value/" Fix" Everything ($) **All Asphalt Roads** **Total**	 $18.2M **$18.2M**

To protect this investment, Commerce City staff hired Transmap Corporation to assist in the development of a Network Pavement Management System. This program is designed to preserve and extend the useful life of paved surfaces throughout the City and optimize the available funds to meet the network condition needs. With careful planning and diligent effort, highest performance standards could be maintained while reducing the overall long-term costs of managing the network pavement system.

1.1 Principles of Pavement Management

Given the persistent shortage of funds for maintaining these street systems, the preservation and stewardship of existing roads have become major activities for all levels of government. An excellent way of maximizing the return on investment for the money that exists for road maintenance is to implement a Pavement Management System.

Pavement management is a systematic approach to extending the life of a pavement network. More specifically, it is the process of planning, budgeting, funding, designing, constructing, monitoring, evaluating, maintaining, and rehabilitating the pavement network to provide maximum benefits with available funds.

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

This process is illustrated in **Figure 1-1**. It details how timely intervention can delay the inevitable total reconstruction for as long as practical. If repairs are delayed until a road is rated in "Fair" condition or worse, the cost of rehabilitation becomes 4 to 5 times more expensive than for those roads in "Good" condition. This means without preventive maintenance; the cost of rehabilitation will be prohibitively expensive.

A Pavement Management System provides a way to store an accurate inventory of all roadways, enriched with links to easements, as-built records, and historical documentation.

The breadth and depth of information they hold, including digital images of roadways, baseline pavement condition data, and reviews of deterioration over time, are invaluable resources for measuring and tracking the effectiveness of Maintenance and Rehabilitation strategies.

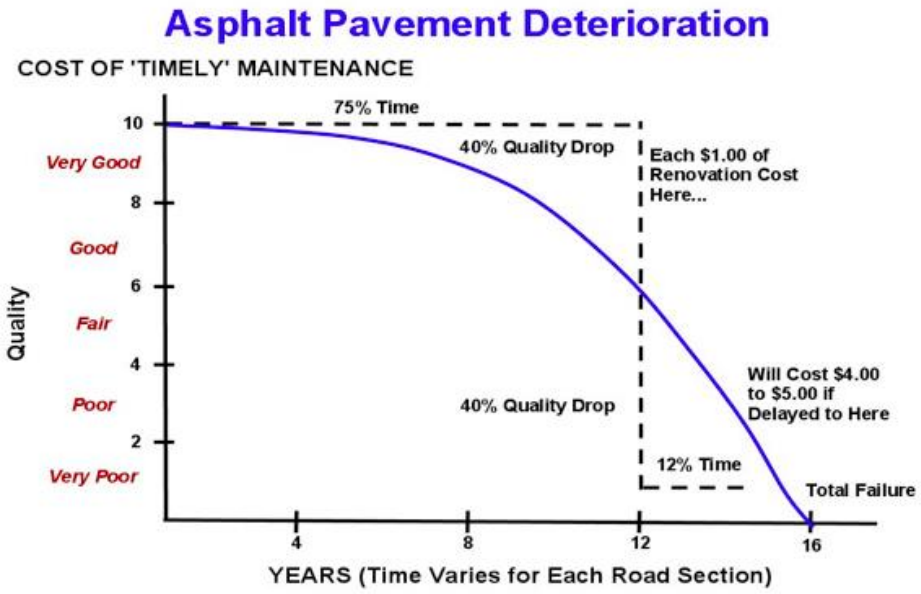


Figure 1-1 - Pavement Life Cycle Curve

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

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

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

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

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

1.2 The Pavement Management Process

Figure 1-2 depicts the three unique, but equally important, steps that comprise the Pavement Management Process.

Figure 1-2 - The Pavement Management Process

1. System Configuration

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

2. Field Data Collection or Field Surveys

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

Surface Distress

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

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

Table 1.1 - Description of Surface Distresses Recorded by Transmap

Pavement Distress for Asphalt Pavement

Alligator Cracking	**Patching and Utility Cut Patching**
Block Cracking	**Potholes**
Bleeding	**Rutting**
Edge Cracking	**Weathering**
Transverse and Longitudinal Cracking	**Raveling**
	Bumps and sags, corrugations and depressions

Pavement Distress for Concrete Pavement

Divided Slabs	**Pop Outs**
Linear Cracking	**Pumping**
Corner Breaks	**Scaling or Map Cracking**
Durability ("D") Cracking	**Shrinkage Cracking**
Faulting	**Corner or Joint Spalling**
Joint Seal Damage	**Small or large patching**

Detailed descriptions of pavement distress and severity can be found in ASTM D6433-11.

Severity

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

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

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

Transmap collected Commerce City's data using GPS and high definition digital images for each road section.

3. Analysis and Reporting

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

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

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

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

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

1.3 Understanding the Pavement Condition Index

The following illustration (**Figure 1-3**) shows how the Pavement Condition Index (PCI) deteriorates over time for 3 different types of roadways. It also compares the PCIs to commonly used descriptive terms (Good, Satisfactory, Fair, Poor, Very Poor, Serious, Failed). The divisions between the descriptive terms are not fixed but are meant to indicate common perceptions of roadway condition.

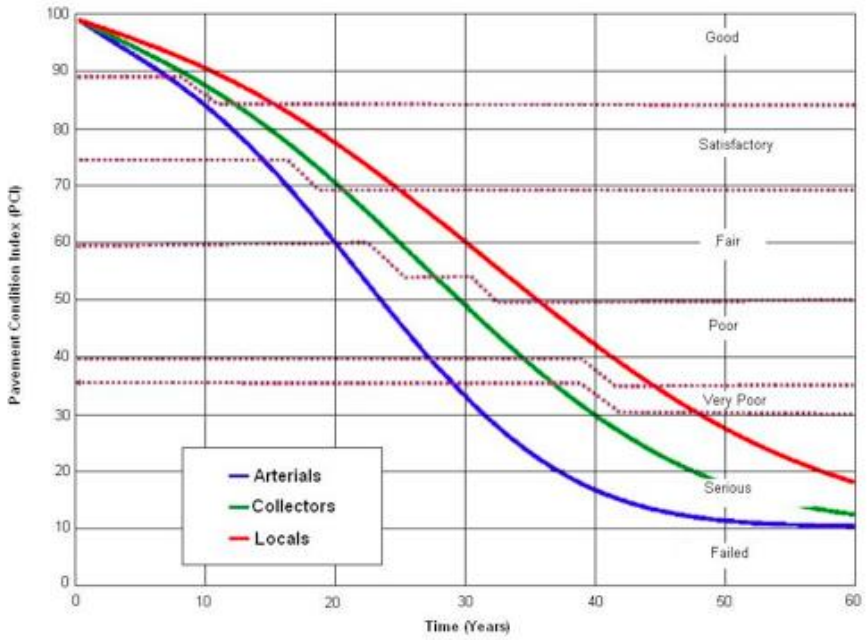


Figure 1-3 - Understanding the Pavement Condition Index Score

Table 1.2 shows a typical PCI condition ranges, the work type, and possible rehabilitation options.

Table 1.2 - Typical PCI Condition Ranges

PCI Range	Work Type	Rehabilitation Options
86-100 Good	**Rejuvenation**	**Little or no maintenance E.g. Crack Seal, Reclimite, fog seal**
71-85 Satisfactory	**Global**	**Routine Maintenance E.g. Seals such as slurry seal**
56-70 Fair	**Critical**	**Non-structural overlay, cape seal**
41-55 Poor	**Conventional**	**Structural overlay Overlay, Mill and overlay**
26-40 Very Poor	**Conventional**	**Structural Overlay Overlay, Mill and overlay**
11-25 Serious	**Reconstruction**	**Reconstruction, rebuild, full depth reclamation**
0-10 Failed	**Reconstruction**	**Reconstruction, rebuild, full depth reclamation**

2.0 Maintenance and Rehabilitation Planning

2.1 Key Analysis Inputs

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

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

2.2 Pavement Preservation

Figure 2-1 represents the American Public Works Association (APWA) industry standard pavement preservation curve.

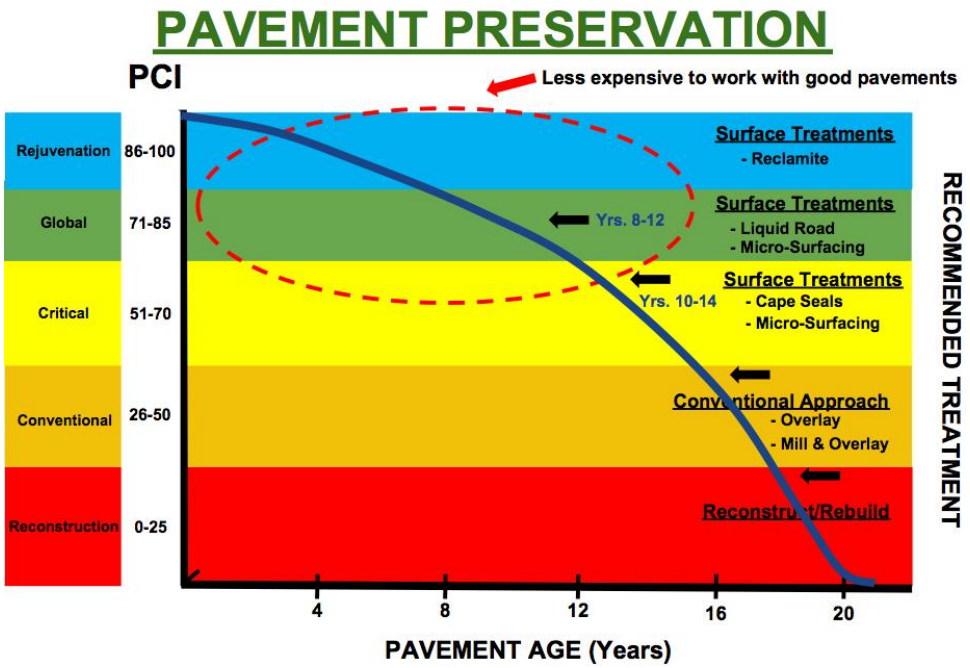


Figure 2-1 Pavement Preservation

Figure 2-2 represents APWA's Pavement Toolbox. This toolbox looks at possible preservation treatments and how they are cost effective to use, as opposed to spending all funding on worst-first maintenance (rehabilitation/reconstruction).

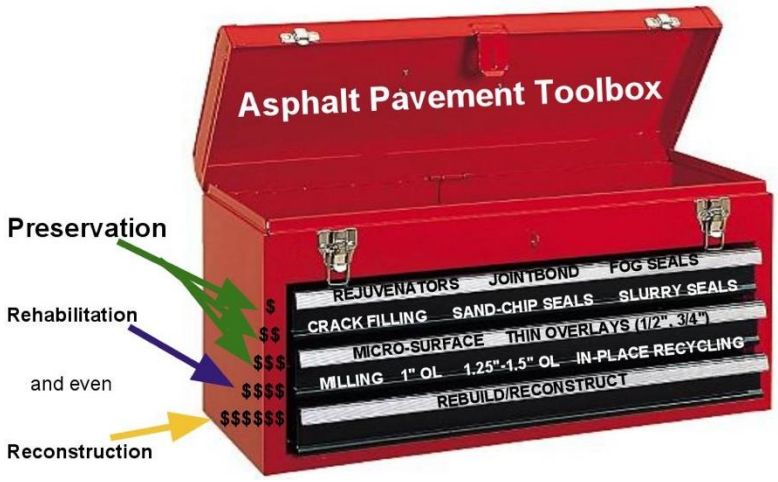


Figure 2-2 Preservation Treatments

This hierarchical strategy ensures that roadways slated for reconstruction remain in the reconstruction pipeline, even if there's a funding shortfall. Available funds are used to

preserve those streets that can be treated with surface treatments and overlays. No real equity is lost when those roads become unacceptable for use, since they were already scheduled for reconstruction.

2.3 Paved Network Present Conditions & Findings

Pavement Sections Investigated for Commerce City

Commerce City has approximately 260.89 miles of pavement. The table below shows the distribution by pavement type for the number of miles, the number of square yards and the weighted average Pavement Condition Index (PCI).

Table 2.1 - Distribution of Roads by Pavement Type

Pavement Type	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
Asphalt	2,861	250.73	4,818,180	93%	79
Concrete	54	10.16	381,047	7%	95
Total	2,915	260.89	5,199,228	100%	80

Since there are 54 sections of roadways designated as concrete with an average network PCI of 95, the remainder of the report will focus on asphalt roadways.

Pavement Sections Investigated for Commerce City

Commerce City has approximately 250.73 miles of asphalt pavement. The table below shows the mileage distribution of asphalt pavement by functional class for the number of miles, the number of square yards, and the weighted average Pavement Condition Index (PCI).

Table 2.2 - Distribution of Asphalt Roads by Functional Class

Functional Class/ Paver Designation	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
Arterial & Collector/ B & C	759	94.17	2,121,064	44%	78
Local/ E	2,102	156.57	2,697,116	56%	79
Total	**2861**	**250.74**	**4,818,180**	**100%**	**79**

3.0 Asphalt (AC) Roads

Pavements are grouped into "families" for further analysis using the MicroPAVER software. Pavements are grouped together for different reasons such as similar construction, similar traffic loads or similar funding categories. The asphalt (AC) pavement network for Commerce City will be evaluated as one network.

Using data from other communities, Transmap developed one pavement performance curve for all asphalt pavements as shown in Appendix A.

3.1 Estimated Costs for Maintenance and Repair (M&R) Categories for Asphalt roads

Asphalt M&R Category Matrix

The unit prices for Maintenance and Repair (M&R) treatments were obtained from the boot camp. Transmap translated the information and placed it into the M&R Category ranges and unit prices shown in **Tables 3.1 and 3.2**. The column titled "Expected Result" reflects the extended life of the pavement as experienced by the Commerce City staff.

Table 3.1 - All Asphalt Roads
Recommended Asphalt M&R Category Ranges, Unit Prices and Treatments

M&R Category	M&R Treatment	Price per Square Yard	Expected Result
Preventative (PCI 86-100)	Do Nothing	N/A	N/A
Global (PCI 56-85)	Slurry Seal	$1.89	3- years
Conventional (PCI 0-55)	2-inch Mill & Overlay	$27.00*	25- years (Reset PCI=100)

*Based on $52.00 per ton for AC and $2.33 per SY for milling

Table 3.2 - 2019 Cost for Repair by M&R Category for All Asphalt Roads

PCI Range	# of Sections	# of Miles	# of SY	Unit Cost per SY	Total Cost
Preventative 86-100 Do Nothing	1,283	105.14	2,072,556	N/A	N/A
Global 56-85 Slurry Seal	1,378	116.96	2,226,115	$1.89	$4,207,357
Mill & OL 0-55 2 - inch	200	28.63	519,509	$27.00*	$14,026,743
Total	**2,861**	**250.73**	**4,818,180**		**$18,234,100**

*Based on $52.00 per ton for AC and $2.33 per SY for milling

4.0 Asphalt Network Budget Scenarios

The budget scenarios were completed using MicroPAVER software, version 7.0.6. The Commerce City's pavement performance model was developed by Transmap using historical data and trends. The performance model is shown in Appendix A.

The Boot Camp Meeting Notes taken on January 10, 2019 follow:

- Transmap began the meeting reviewing the deliverables posted on the project page at tmap.pro/commercecity
- Transmap is currently using the functional class that was provided in the original GIS layer at the beginning of the project.
- Transmap is using the COMPKEY from the same GIS layer as the MicroPAVER Section ID
- Transmap will enter available work history into the MicroPAVER database.
- The City staff provided Chris with bid tabs of recent construction projects so that Transmap can estimate the unit cost per square yard for M&R Treatments. The Transmap staff will attempt to convert the information extracted from the bid tabs into the unit costs. They will provide the units costs to the City staff for their approval. It was discussed during the meeting that this is a very important input parameter to the MicroPAVER software. The unit costs for the M&R Treatments are the primary factor in determining the final budget scenarios for the required work plans.
- The two (2) "families" that will be used in the analysis are: Arterial/Collector Roads and Local Rods.
- The total annual budget to be used is $2.6M.
    - 1/3 of the budget or $0.83M is allocated to the arterial and collector roads.
    - 2/3 of the budget or $1.67M is allocated to the local roads.
        - $380K is allocated to global treatments on the local roads.
- Based on a January 23, 2019 phone conversation it was decided that the $2.5M budget would be split as follows:
    - 46% of the budget allocated to arterial and collector roads
    - 54% of the budget allocated to local roads
        - $380K of the local budget allocated to global M&R Treatments
- The per square yard unit costs are shown in Table 3.1 above
- The start date for the budget scenarios is June 1st for a five (5) year planning horizon. The following budget scenarios will be run using MicroPAVER version 7.0.6:
    - Do Nothing
    - The recommended budget to maintain the average network PCI of 79
    - Given a $2.6M total annual budget and the recommended budget allocated as shown above, provide the resultant PCI and the Deferred Maintenance by year.
- Define Critical Pavement Condition Index (PCI), normally a value between 55 and 70. The Critical PCI is the PCI after which the pavement begins to rapidly deteriorate. It was agreed to use a critical PCI=60.
- The inflation rate is a user-defined input that is used as part of the deferred maintenance calculations. Transmap recommends using 3.0%.
- Budget Scenarios will be completed for Asphalt Pavements only.

4.1 All Asphalt Roads

Table 4.1 - Do Nothing Budget
All Asphalt Roads
Showing the Resultant PCI and Deferred Maintenance

Year Beginning June 1st	Annual Budget	PCI at Year End	Deferred Maint.
2019	$0.00	75	$9.5M
2020	$0.00	71	$12.1M
2021	$0.00	67	$15.4M
2022	$0.00	62	$19.9M
2023	$0.00	58	$25.2M

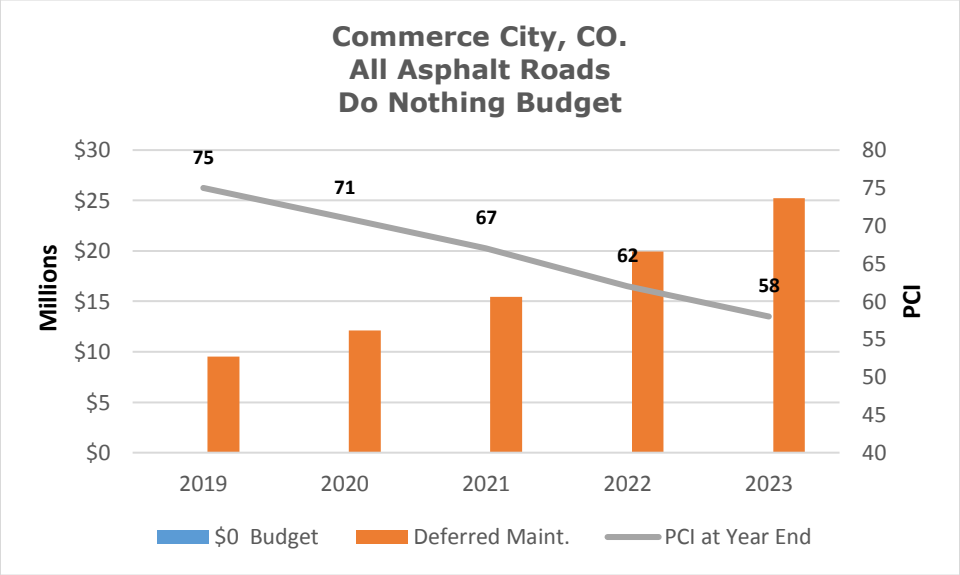


Figure 4.1 - All Asphalt Roads
Do Nothing Budget

Table 4.2 – Determine the Recommended Annual Budget to Maintain the Average Network PCI=79
All Asphalt Roads - Major M&R Treatments Only
Showing the Resultant PCI and Deferred Maintenance

Year Beginning June 1st	Annual Budget	PCI at Year End	Deferred Maint.
2019	$2.6M	79	$6.9M
2020	$2.6M	79	$6.4M
2021	$2.6M	79	$6.0M
2022	$2.6M	79	$6.0M
2023	$2.6M	79	$6.2M

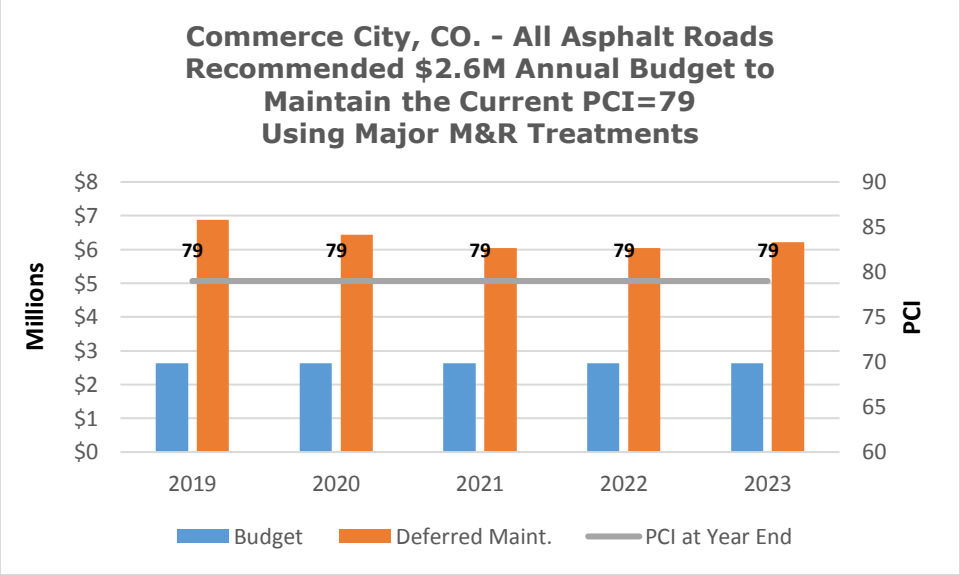


Figure 4.2 - Recommended $2.6M Annual Budget to Maintain the Average Network PCI=79 - All Asphalt Roads Using Major M&R Treatments

Table 4.3 – Determine the Recommended Annual Budget to Maintain the Average Network PCI for the Arterial & Collector Roads
Using Major M&R Treatments Only
Showing the Resultant PCI and Deferred Maintenance

Year Beginning June 1st	Annual Budget	PCI at Year End	Deferred Maint.
2019	$1.16M	78	$3.8M
2020	$1.16M	78	$3.6M
2021	$1.16M	78	$3.4M
2022	$1.16M	78	$3.5M
2023	$1.16M	78	$3.4M

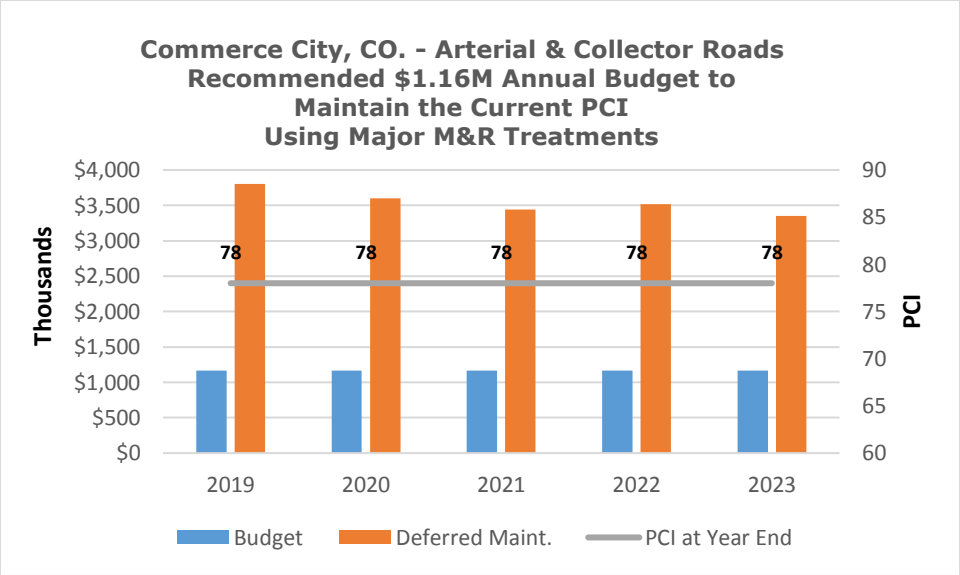


Figure 4.3 - Recommended $1.16M Annual Budget to Maintain the Average Network PCI – Arterial & Collector Roads Using Major M&R Treatments

Table 4.4 – Given $1.38M Annual Budget to Maintain the Average Network PCI for the Local Roads
Using Major and Global ($380K) M&R Treatments Only
Showing the Resultant PCI and Deferred Maintenance

Year Beginning June 1st	Annual Budget (Global=$380K)	PCI at Year End	Deferred Maint.
2019	$1.38M	79	$4.6M
2020	$1.38M	79	$4.4M
2021	$1.38M	79	$4.7M
2022	$1.38M	79	$4.1M
2023	$1.38M	79	$3.8M

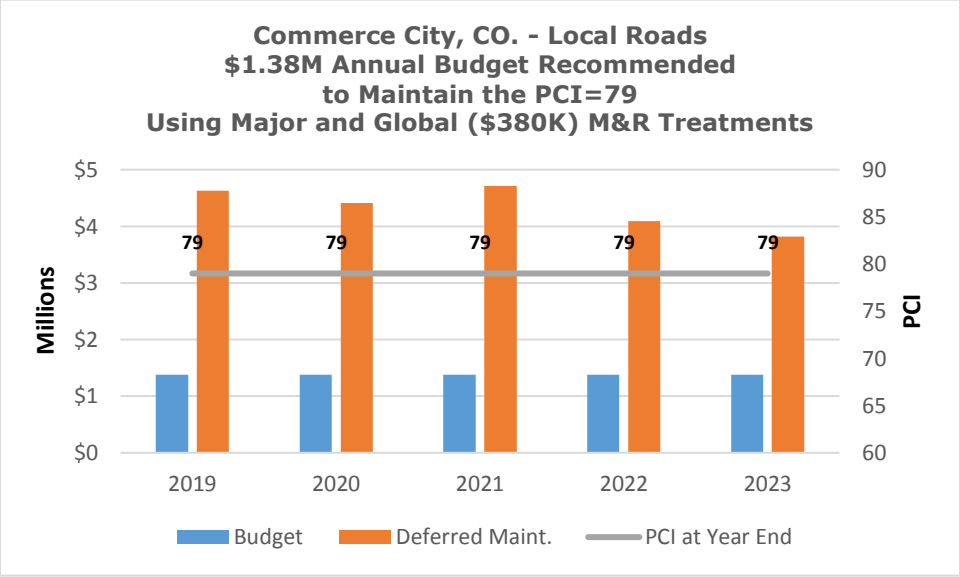


Figure 4.4 - $1.38M Annual Budget Recommended to Maintain the Average Network PCI – Local Roads Using Major and Global ($380K) M&R Treatments

5.0 Summary

All Asphalt Road Network

Transmap staff made MicroPAVER budget scenario runs using the 1/3 of the $2.5M annual budget allocated to Arterial & Collector Roads, and 2/3 of the budget allocated to Local Roads. On January 16, 2019, the following results were sent to Commerce City staff for their review and comment.

The first MicroPAVER run was made for all asphalt pavements as one group. The result was a $2.5M annual budget was required to maintain the current PCI of 79. The next runs were made by the functional classes. The results showed that given a $2.54M annual budget, the following allocation is recommended:

- Arterial & Collector roads be allocated a budget of $1.16M or 46%
- Local roads be allocated a budget of $1.38M or 54%

Below are the results of the MicroPAVER runs using the 1/3 of the budget allocated to Arterial & Collector Roads and 2/3 of the budget allocated to Local Roads:

- The budget allocation for Arterial & Collector roads of $0.832M allows the PCI to drop to a 72 at the end of the planning horizon.
- The budget allocation for the Local Roads of $1.675M allows the PCI to increase to an 81 at the end of the planning horizon.

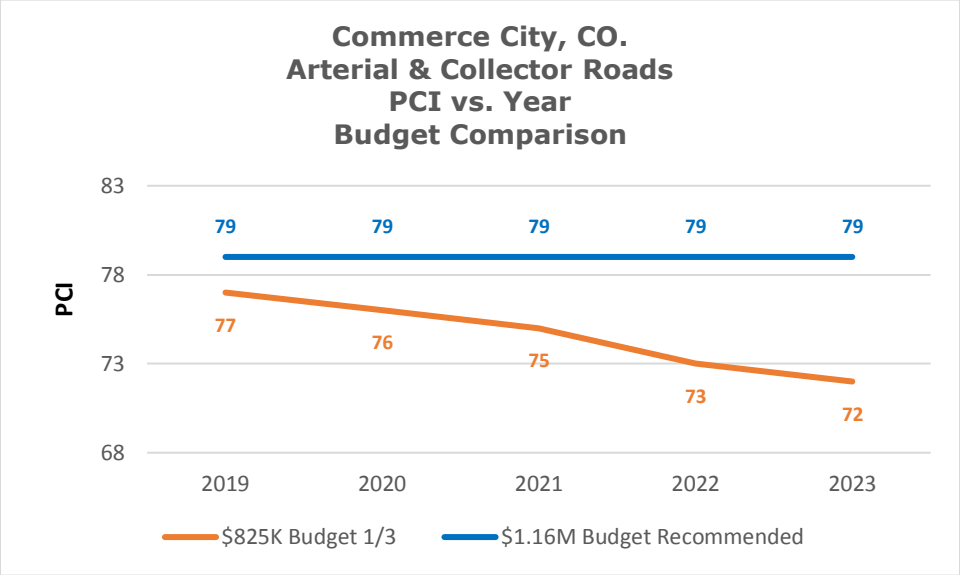
The current budget of $2.5M is adequate to maintain the road networks at the current PCI of 79. This budget approaches system stabilization with a constant network PCI and a reduction in the deferred maintenance or backlog. The deferred maintenance is defined as the estimated cost to repair roads with a PCI less than 55. It represents the work that is needed but not funded.

All these factors are an indication of network stabilization. The following is the recommended budget allocation:

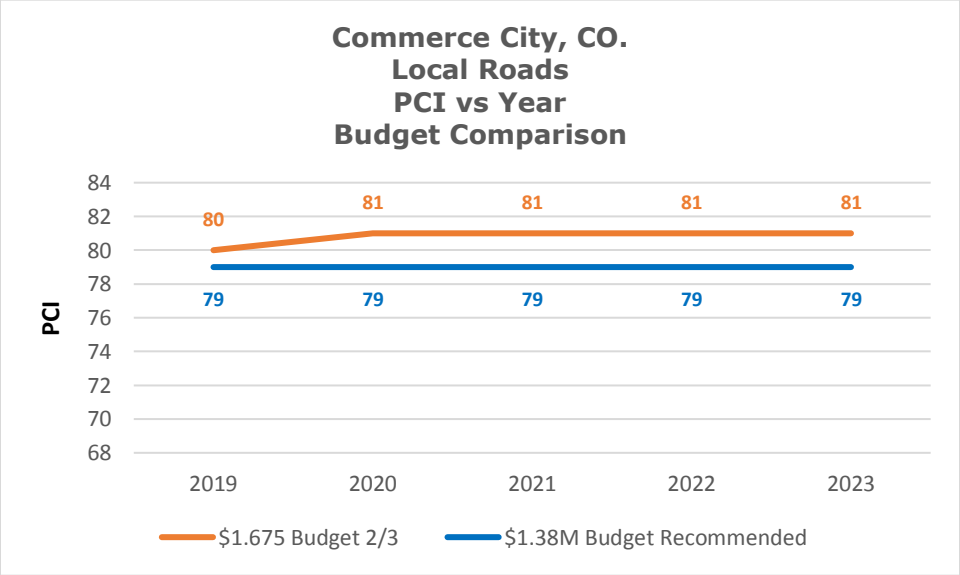
- Recommended budget allocation for arterial and collector roads is $1.16M.
- Recommend budget allocation for the local roads is $1.38M with $380K of that used for global M&R Treatment such as slurry seal.

Below are two graphs that show the comparisons of the budget allocations.

Arterial & Collector Roads



Local Roads



Appendix A

Commerce City, CO

Asphalt Pavement Performance Curve

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

The performance curve plays an important role in the development of network level budget analysis. If the deterioration rate of the curve is too steep, the required budget to repair these pavements will increase. If the deterioration rate of the curve is too flat, the required budget to repair these pavements will be too small. Both situations are erroneous.

The model shown below was developed using general shape of a curve for asphalt pavement performance. As additional field data is added from future surveys the model will be updated which will increase its accuracy.

Figure A-1 shows the results for the asphalt performance model.

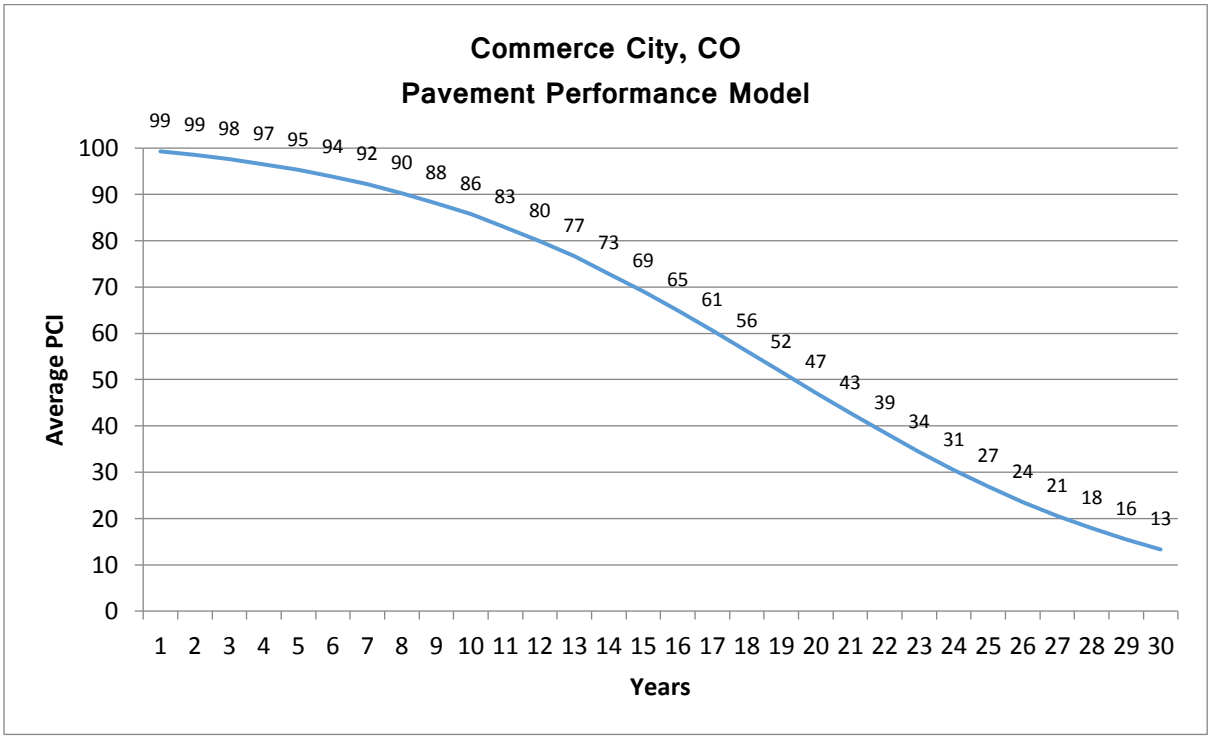


Figure A-1 - Asphalt Pavement Performance Model

Appendix B

Pavement Condition Index (PCI) Formula

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

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

Where

PCI_s = PCI of a pavement section

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

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

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

R = total number of inspected random sample units

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

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

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

PCI_a = area weighted average PCI of additional sample units

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

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

A_s = total section area

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