2020 Pavement Management Report

for

Metropolitan Planning Organization
Urbanized Area

Prepared by

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2020 Pavement Management System Report

Executive Summary

The nation's highways represent an investment of billions of dollars by Local, state and federal governments. To protect this investment, the Missoula Metropolitan Planning Organization (MPO) hired Transmap Corporation to assist in the development of a Network Pavement Management System to incorporate the Missoula County and City roads. This program is designed to preserve and extend the useful life of paved surfaces throughout the region and optimize the available funds to meet the network condition needs.

The Missoula Urbanized Area encompasses a mix of Missoula City and County maintained roads consisting of approximately 401.01 miles of asphalt paved roads. This represents an investment of roughly $625.6M, when factoring in a replacement (reconstruction) cost of approximately $1.56 million per mile, and a "fix-all" cost of $115.8M (See Tables 2.1 & 2.2). The $1.56 million per mile is a national estimate obtained from the American Public Works Association (APWA).

TransMap utilizes MicroPAVER (ver. 7.0.10) to perform the analysis of clients' roads. MicroPAVER, a pavement management system (PMS), is a decision-making tool for the development of cost-effective maintenance and repair alternatives for roads and streets, parking lots and airfields. Developed and maintained by the US Army Corp of Engineers Research and Development Center, it provides a Network-Level, systematic approach to pavement management to insure optimum return on investment.

MicroPAVER employs a Pavement Condition Index (PCI) condition rating for each segment of roadway (intersection to intersection) in its assessment, on a 0 (Failed) to 100 (Excellent) scale. The inspection criteria and PCI determination is governed by ASTM Standard D6433-11, "Standard Practice for Roads and parking Lots Pavement Condition Index Surveys" making it an objective and, just as important, repeatable means of assigning a condition rating to the roadways.

Below are graphs of the distribution of the square yardage of the City of Missoula roads and County roads within the Urbanized Area (UZA) that comprise the total population of road segments within the UZA, by PCI range's that was presented at the May 4, 2020 Boot Camp meeting.

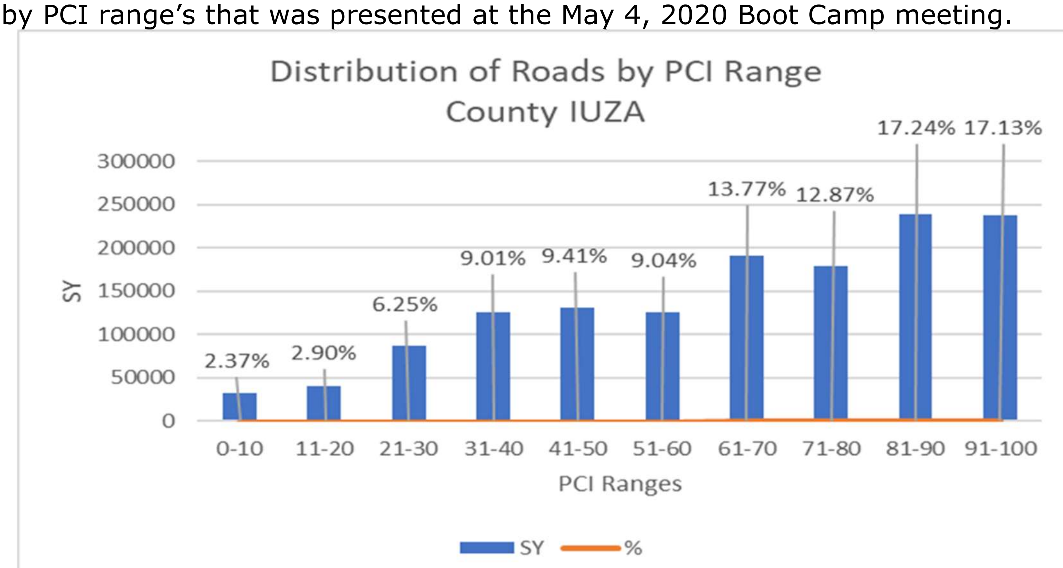


Figure ES-1 Missoula County IUZA Distribution of Roads by PCI Range

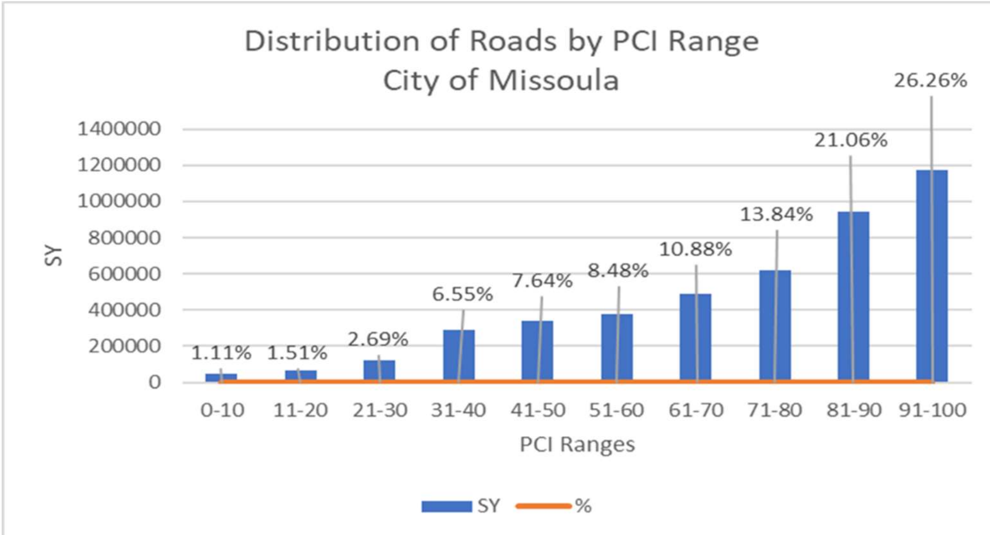


Figure ES-2 City of Missoula Distribution of Roads by PCI Range

Using the City of Missoula's historical information (dates of past roadway treatments) and similar pavement performance models, specific models (See Appendix A) were constructed for Missoula's Arterial/Collector and Local roads. This information coupled with the City and County's approach to pavement maintenance, consisting of a list of Maintenance and Repair (M&R) treatments and their costs, (Table 1.1) tied to PCI ranges within the PCI scale provides the data necessary for MicroPAVER to conduct its analysis.

The following 5-year scenarios were constructed based on information obtained during the Boot Camp meeting, and preceding discussions with the City and County, divided by Arterial/Collectors and Local Roads, followed by tabular and graphical representations.

- Cost to "Fix-All"
  - **$25.5M – Arterial/Collectors and $90.3M Local**

- Do Nothing Consequences
  - **5 Year Ending PCI's of 54 – Arterial/Collectors and 49 – Local**

- Consequences of existing $4,400,654 Budget
  (This was derived by adding the City budget of $4,244,654 to the percentage of the County $400K budget allocated to IUZA which is 39% or $156,000. Similarly, the Arterial/ Collector budgets consist of $1,056,003 (24.9% of $4,244,654) plus $64.428 (41.3% of $156K) equaling $1,123,431 and Local Roads as $3,185,651 (75.1% of $4,244,654) plus $85,572 (58.7% of $156K) equaling $3,271,223.
  - **5 Year Ending PCI's of 63 – Arterial/Collectors and 56 – Local**

- Budgets to maintain the existing PCI's of 75 – Arterial/Collectors and 68-Local
  - **$3.603M – Arterial/Collectors and $8.699M Local**

- Budgets to Achieve PCI of 71 – Arterial/Collectors and 71 - Local
  - **$3.138M – Arterial/Collectors and $10.479M Local**

One method of comparing the effectiveness of the scenarios, in reaching overall savings, is by comparing the Cost of M&R and the Loss (Deferred/Backlog Cost or depreciated Value) at the end of the 5 year period to the Total Loss (Deferred Cost) of the Do-Nothing scenario. This comparison should provide a difference indicating the savings realized at the end of the 5 years. Thus, the scenario providing the greatest savings would be the most desirable. Of course, this has to ultimately be balance by practical concerns related to the availability of funding.

The tables on the following page, illustrates this comparison with the overall savings shown in the far-right columns. (The deferred costs can be seen in Section 2 of this report). It demonstrates what is often difficult to illustrate but is intuitively understood; that money spent on maintenance equates to overall savings in the long run. Highlighted below is the scenario that provides the greatest savings.

Table ES.1 –Missoula UZA
Estimated 5-Year M&R Budget Cost Savings Comparisons
Arterial/Collectors

Budget Scenario	Total 5-Year M&R Costs $ Millions (2020-2024)	Deferred M&R Backlog (1) $Millions (2024)	Total 5-Year Cost(2) $Millions	Cost Difference/ Savings $Millions
Do Nothing	0	56.3	56.3	0
Current Budget $1.123M/ Yr	5.62	48.5	54.12	2.18
Maintain Current PCI $3.603M/ Yr	18.02	28.7	46.72	9.58
Achieve PCI 71 $3.138M/ Yr	15.69	33.9	49.59	6.71

1) M&R Backlog is defined as the Fix All Cost
2) Total of 5-Year M&R costs plus Deferred Costs

Table ES.2 –Missoula UZA
Estimated 5-Year M&R Budget Cost Savings Comparisons
Local

Budget Scenario	Total 5-Year M&R Costs $ Millions (2020-2024)	Deferred M&R Backlog (1) $Millions (2024)	Total 5-Year Cost(2) $Millions	Cost Difference/ Savings $Millions
Do Nothing	0	152	152	0
Current Budget $3.271M/ Yr	16.36	142.3	132.4	19.6
Maintain Current PCI $8.699M/ Yr	43.5	89.7	133.2	18.8
Achieve PCI 71 $10.479M/ Yr	52.395	77.2	129.595	22.405

1) M&R Backlog is defined as the Fix All Cost
2) Total of 5-Year M&R costs plus Deferred Costs

1.0 - Missoula UZA, MT – All Asphalt (AC) Pavements

The following unit prices for (M&R) treatments were obtained from discussions during the boot camp meeting and preceding correspondence with County Staff (See Appendix E). Initially it consisted of a mix of City and County pricing till later is was decided to use the City of Missoula prices only. Transmap translated the information and placed it into the M&R Category ranges and unit prices shown in Tables below**.** The column titled "Expected Result" reflects the extended life of the pavement as experienced by the City.

Table 1.1 – Missoula UZA – Treatments, PCI Ranges and Costs Arterial/Collectors

M&R Category	M&R Treatment	Price per Square Yard	Expected Result
Rejuvenation (PCI 86-100)	Chip Seal	$2.14	5 Years
Global (PCI 71-85)	Crack Seal/ Chip Seal	$2.82	7 Years
Conventional (PCI 66-70)	Thin Overlay/ Chip Seal	$18.97	10 Years
Conventional (PCI 60-65)	Mill/ Overlay/ Chip Seal	$26.52	15 Years
Critical (PCI 40-59)	Structural Mill/ Overlay/ Chip Seal	$33.85	20 years
Reclamation (PCI 0-39)	Reconstruct w/ full base gravel stabilization	$52.46	25 Years

The Pavement Performance models and Treatment PCI Ranges and Costs for the Urbanized Area (UZA), which is a combination of the City and County roads (City + County IUZA), were not able to be analyzed together while maintaining their individual family traits within Micropaver. They are combined utilizing the City of Missoula family traits.

The following sections will consist of budget scenarios for each using the performance models as shown in **Appendix A**, and Boot Camp information in **Appendix B**.

It is important to note that MicroPAVER is designed to optimize and determine a levelized budget based on the treatment cost provided above, the existing conditions and the deterioration model. Its methodology is not a worst-first approach but instead assigns treatments in a manner that may not be intuitively obvious. For example, it will apply preventative treatments early on, letting many of the worst segments get worse or let segments within the range of needing only global treatment drift into requiring conventional treatment or reconstruction before addressing them. It also often applies conventional treatments to segments within a Global range if structural distresses are detected, such as alligator cracking.

One aspect of its logic that is immediately noticeable when analyzing small data sets (i.e. roughly less than 500 segments) are significant peaks in the overall PCI over time. This will generally occur in the first few years when more preventative measures are recommended and concentrating later, on segments requiring more costly treatments.

1.1 - UZA Road Characteristics, Missoula, MT

The table below illustrates the mileage distribution by surface type, number of miles, number of square yards and the overall weighted average Pavement Condition Index (PCI).

Table 1.2 – Missoula UZA
Distribution of Roads by Pavement Type

Pavement Type	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
Asphalt	4,685	401.01	6,864,403	100%	70
Concrete	1	0.07	990	0%	91
Total	**4,686**	**401.08**	**6,865,393**	**100%**	**70**

There is only one section of concrete roadway which will not be considered in the remainder of this report.

The tables below show the mileage distribution of asphalt pavement by Functional Classification detailing the number of sections, the number of miles, the number of square yards, and the weighted average Pavement Condition Index (PCI).

Table 1.3 – Missoula UZA
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/ B	116	8.63	211,764	3.1%	81
Collector C	1,159	107.54	1,841,246	26.8%	75
Local E	3,410	284.84	4,811,393	70.1%	67
Total	**4,685**	**401.01**	**6,864,403**	**100.0%**	**70**

Table 1.4 – Missoula UZA
Distribution of Asphalt Roads

Pavement Type	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
City of Missoula	3,735	302.12	5,447,865	79.4%	71
County IUZA	950	98.89	1,416,538	20.6%	64
Total	**4,685**	**401.01**	**6,864,403**	**100%**	**70**

Table 1.5 – Missoula UZA
Distribution of Asphalt Arterial/ Collector Roads

Pavement Type	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
City of Missoula	877	75.29	1,465,487	71.4%	78
County IUZA	398	40.89	587,522	28.6%	68
Total	**1,275**	**116.18**	**2,053,009**	**100%**	**70**

Table 1.6 – Missoula UZA
Distribution of Asphalt Local Roads

Pavement Type	# of Sections	# of Miles	# of Square Yards	% by # of Square Yards	Weighted Average PCI
City of Missoula	2,858	226.82	3,982,378	82.8%	69
County IUZA	552	58.01	829,016	17.2%	61
Total	**3,410**	**284.83**	**4,811,394**	**100%**	**70**

2.0 - Missoula UZA, MT – Budget Scenarios

The table below summarizes the number of square yards of pavement into each M&R Category by PCI range. The cost column shows the result of the multiplication of the number of square yards times the unit price. The numbers shown in this table represent the cost to "fix everything".

2.1 - Missoula UZA, MT – Fix-All Scenarios

Table 2.1 UZA Roads, Missoula
Cost for Repair All Asphalt Arterial/ Collector Roads

PCI Range	# of Miles	# of SY	Unit Cost per SY	Total Cost
Rejuvenation (PCI 86-100)	41.04	773,438	$2.14	$1,655,157
Global (PCI 71-85)	34.46	614,253	$2.82	$1,732,193
Conventional (PCI 66-70)	7.79	130,080	$18.97	$2,467,618
Conventional (PCI 60-65)	7.81	131,194	$26.52	$3,479,265
Critical (PCI 40-59)	16.84	270,719	$33.85	$9,163,838
Reclamation (PCI 0-39)	8.23	133,326	$52.46	$6,994,282
Total	**116.17**	**2,053,010**		**$25,492,353**

Table 2.2 – UZA Roads, Missoula
Cost for Repair All Asphalt Local Roads

PCI Range	# of Miles	# of SY	Unit Cost per SY	Total Cost
Rejuvenation (PCI 86-100)	87.26	1,446,432	$2.14	$3,095,364
Global (PCI 71-85)	64.76	1,104,356	$2.82	$3,114,284
Conventional (PCI 66-70)	15.67	266,409	$18.97	$5,053,779
Conventional (PCI 60-65)	24.39	410,946	$26.52	$10,898,288
Critical (PCI 40-59)	46.58	803,987	$33.85	$27,214,960
Reclamation (PCI 0-39)	46.18	779,263	$52.46	$40,880,137
Total	**284.84**	**4,811,393**		**$90,256,812**

Results from MicroPAVER analyses take the following parameters into consideration:

- network cost optimization,
- the performance curve,
- the Critical PCI,
- the application of Preventative and Global Maintenance treatments,
- and a cost by PCI condition.

The following scenarios illustrate the annual major and global recommended budgets for a 5-year period, as determined by MicroPAVER, and the resulting PCI. Major treatments would be those indicated in tables 2.1 & 2.2 as those treatment below PCI 71, where Global would be those treatments above. The last column is the deferred maintenance which consists of the cost of those treatments on sections of road that fall below the Critical PCI, and those above where MicroPaver has identified structural related deficiencies or where it has determined that there is enough remaining budget to address sections of road that are close to dropping to lower state of condition and it would be advantageous to alleviate. Part of MicroPaver's strategy is to begin by tackling those road where preventative treatments will do the most good maintenance and letting major work go till later in the work plan. It is not a worst-first approach and can often appear counter-intuitive.

2.2 - Missoula UZA Roads – Do Nothing Consequences

Table 2.3 – Missoula UZA – Arterial/ Collector Roads
Do Nothing Budget Consequences

Year Beginning September 2020	Annual Budget (Major)	PCI at Year End	Deferred Maint.
2020	$0	72	$ 29,700,000
2021	$0	68	$ 35,200,000
2022	$0	63	$ 41,200,000
2023	$0	59	$ 48,200,000
2024	$0	54	$ 56,300,000

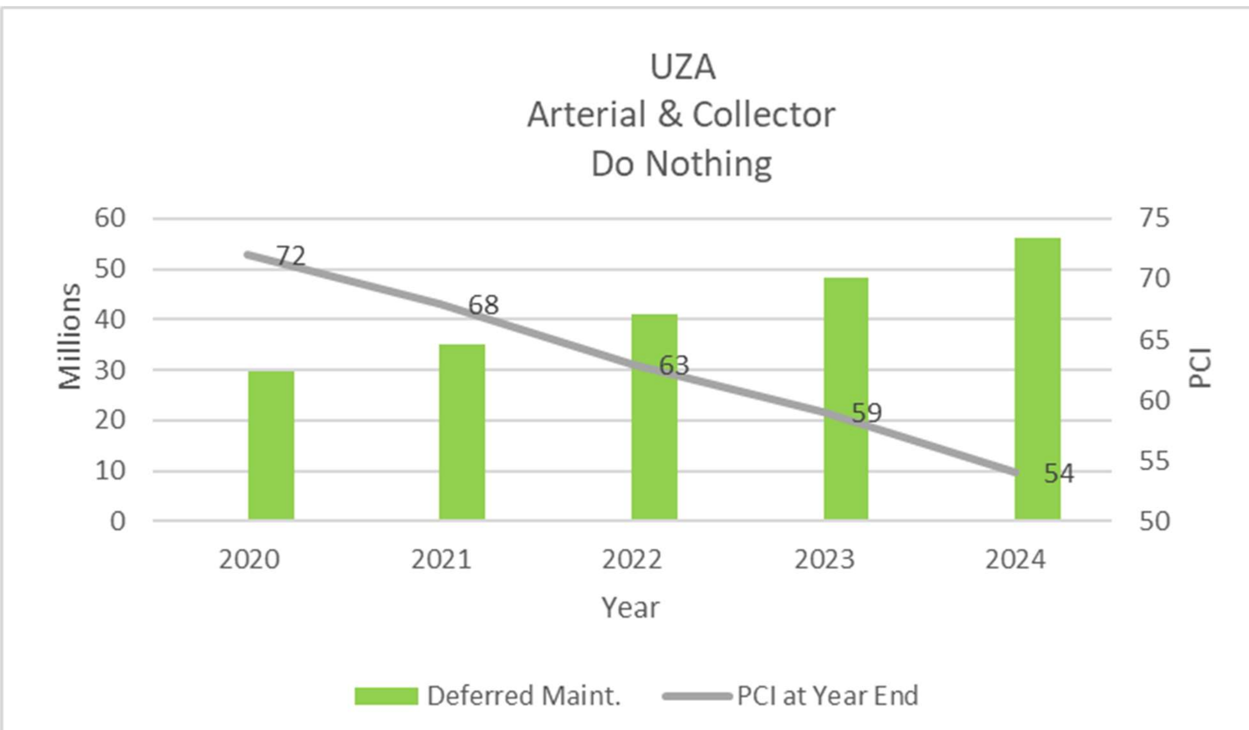


Figure 2-1 – Missoula UZA – Arterial/ Collector Roads
Do Nothing Budget Consequences

Table 2.4 – Missoula UZA – Local Roads
Do Nothing Budget Consequences

Year Beginning September 2020	Annual Budget (Major)	PCI at Year End	Deferred Maint.
2020	$0	64	$ 101,200,000
2021	$0	61	$ 113,800,000
2022	$0	57	$ 125,600,000
2023	$0	53	$ 138,200,000
2024	$0	49	$ 152,000,000

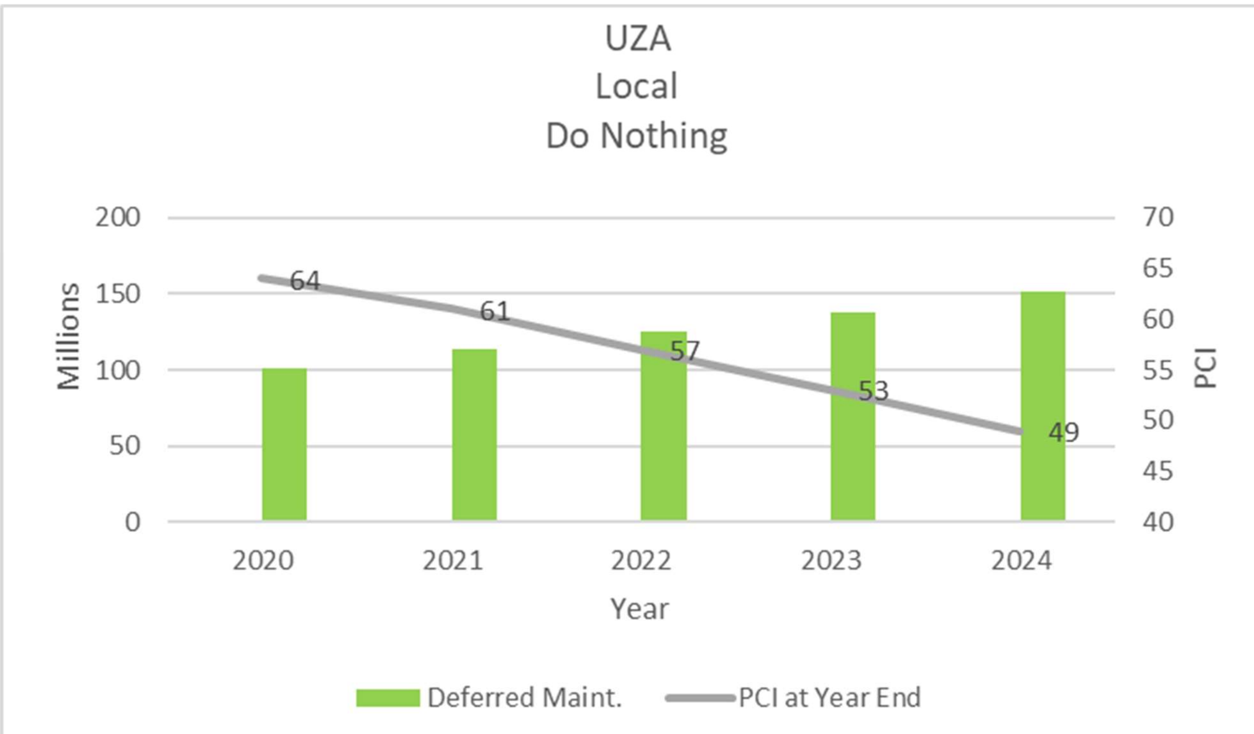


Figure 2-2 – Missoula UZA – Local Roads
Do Nothing Budget Consequences

2.3 - Missoula UZA Roads – Consequences of Existing $4.242M Budget

Table 2.5 – Missoula UZA – Arterial/ Collector Roads
Consequences of Existing $1.123M Budget

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$0	$1,123,000	74	$ 28,700,000
2021	$500,000	$623,000	72	$ 33,100,000
2022	$1,067,000	$56,000	69	$ 37,900,000
2023	$1,079,000	$44,000	66	$ 42,900,000
2024	$988,000	$135,000	63	$ 48,500,000

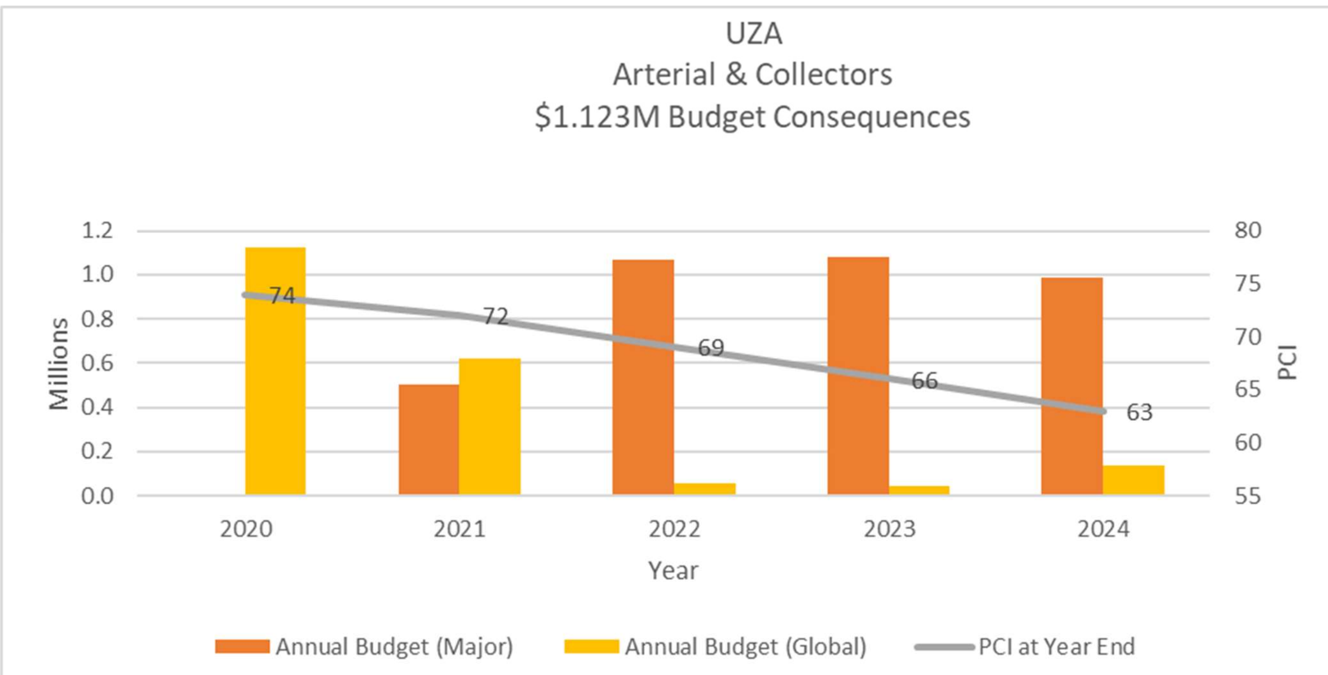


Figure 2-3 – Missoula UZA – Arterial/ Collector Roads
Consequences of Existing $1.123M Budget

Table 2.6 – Missoula UZA – Local Roads
Consequences of Existing $3.271M Budget

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$585,000	$2,686,000	66	$ 98,000,000
2021	$3,211,000	$60,000	64	$ 107,300,000
2022	$3,211,000	$60,000	61	$ 115,000,000
2023	$3,056,000	$215,000	59	$ 123,500,000
2024	$2,961,000	$310,000	56	$ 132,400,000

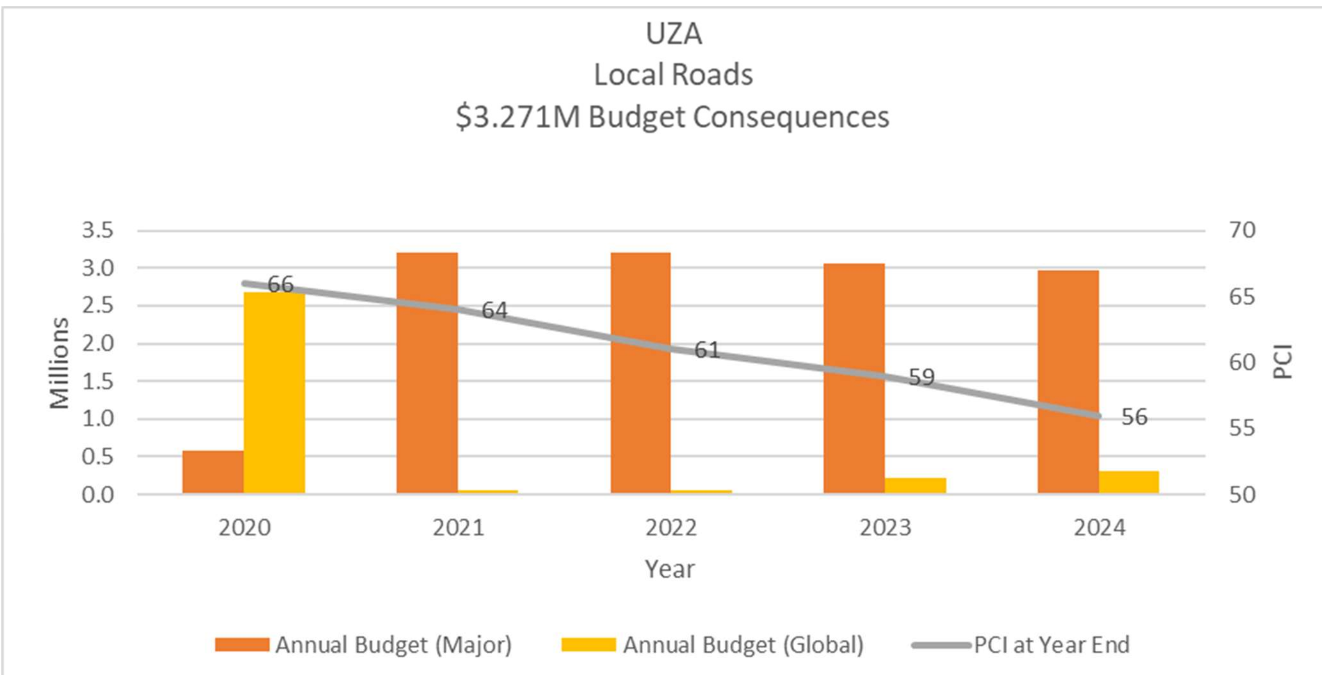


Figure 2-4 – Missoula UZA – Local Roads
Consequences of Existing $3.271M Budget

2.4 - Missoula UZA Roads – Budget to Maintain Existing PCI's

(Tables 1.3 & 1.4 – Arterial/ Collector Roads PCI = 75, Local Roads = 68)

Table 2.7 – Missoula UZA – Arterial/ Collector Roads
$3.603M Budget to Maintain PCI 75

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$2,046,000	$1,557,000	77	$ 26,100,000
2021	$3,497,000	$106,000	76	$ 27,400,000
2022	$3,547,000	$56,000	75	$ 28,700,000
2023	$3,559,000	$44,000	75	$ 29,900,000
2024	$3,468,000	$135,000	75	$ 28,700,000

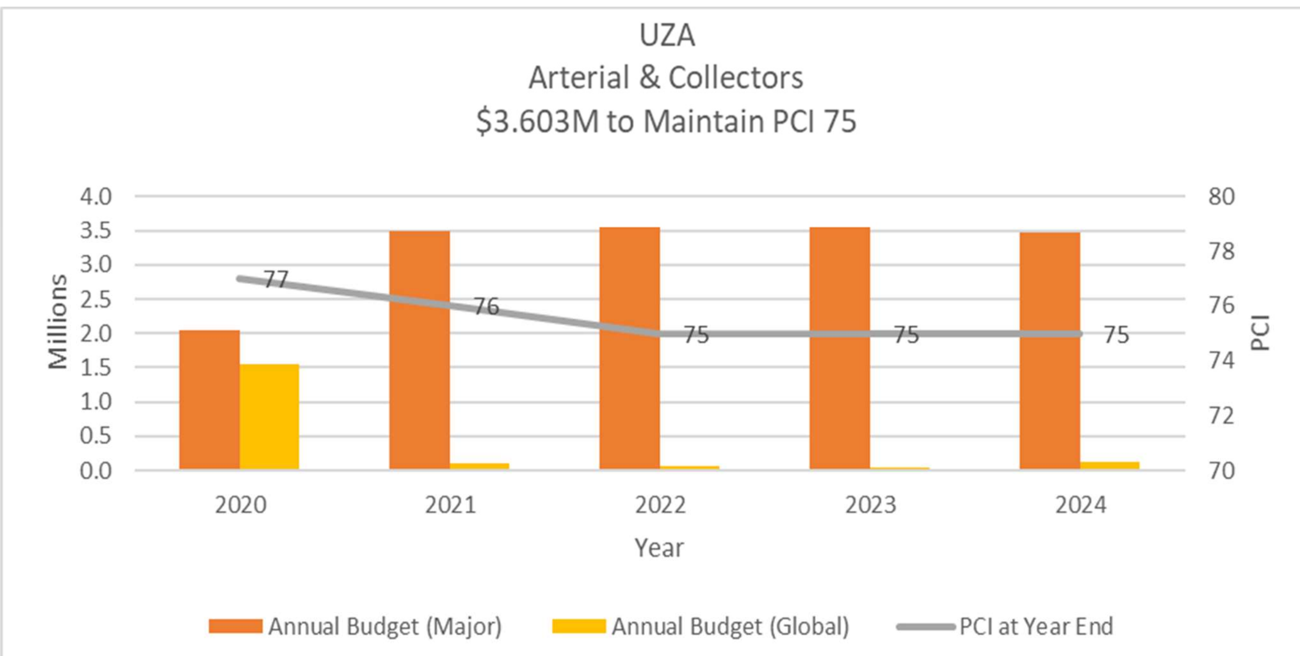


Figure 2-5 – Missoula UZA – Arterial/ Collector Roads
$3.603M Budget to Maintain PCI 75

Table 2.8 – Missoula UZA – Local Roads
$8.699M Budget to Maintain PCI 68

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$6,013,000	$2,686,000	68	$ 92,500,000
2021	$8,639,000	$60,000	67	$ 94,700,000
2022	$8,639,000	$60,000	68	$ 95,600,000
2023	$8,484,000	$215,000	68	$ 94,600,000
2024	$8,389,000	$310,000	68	$ 89,700,000

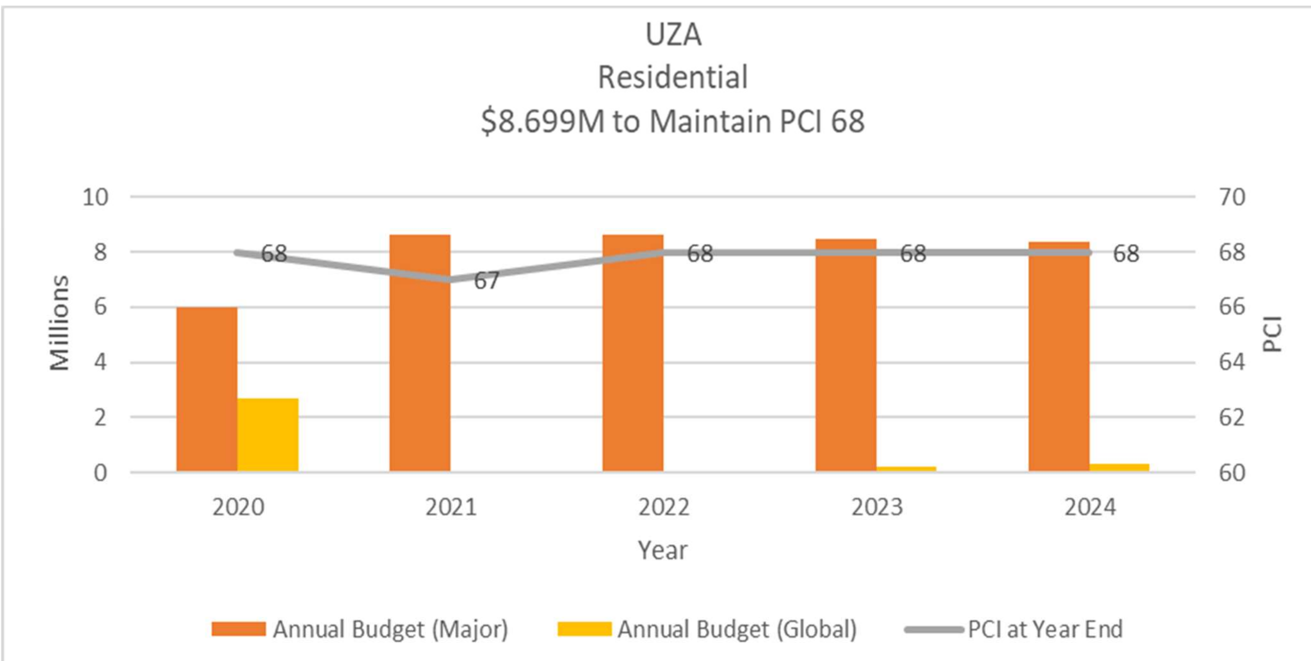


Figure 2-6 – Missoula UZA – Local Roads
$8.699M Budget to Maintain PCI 68

2.5 - Missoula UZA Roads – Budget to Achieve PCI 71

Table 2.9 – Missoula UZA – Arterial/ Collector Roads
$3.138M Budget to Achieve PCI 71

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$1,581,000	$1,557,000	77	$ 26,600,000
2021	$3,032,000	$106,000	75	$ 28,500,000
2022	$3,082,000	$56,000	74	$ 30,300,000
2023	$3,094,000	$44,000	72	$ 32,400,000
2024	$3,003,000	$135,000	71	$ 33,900,000

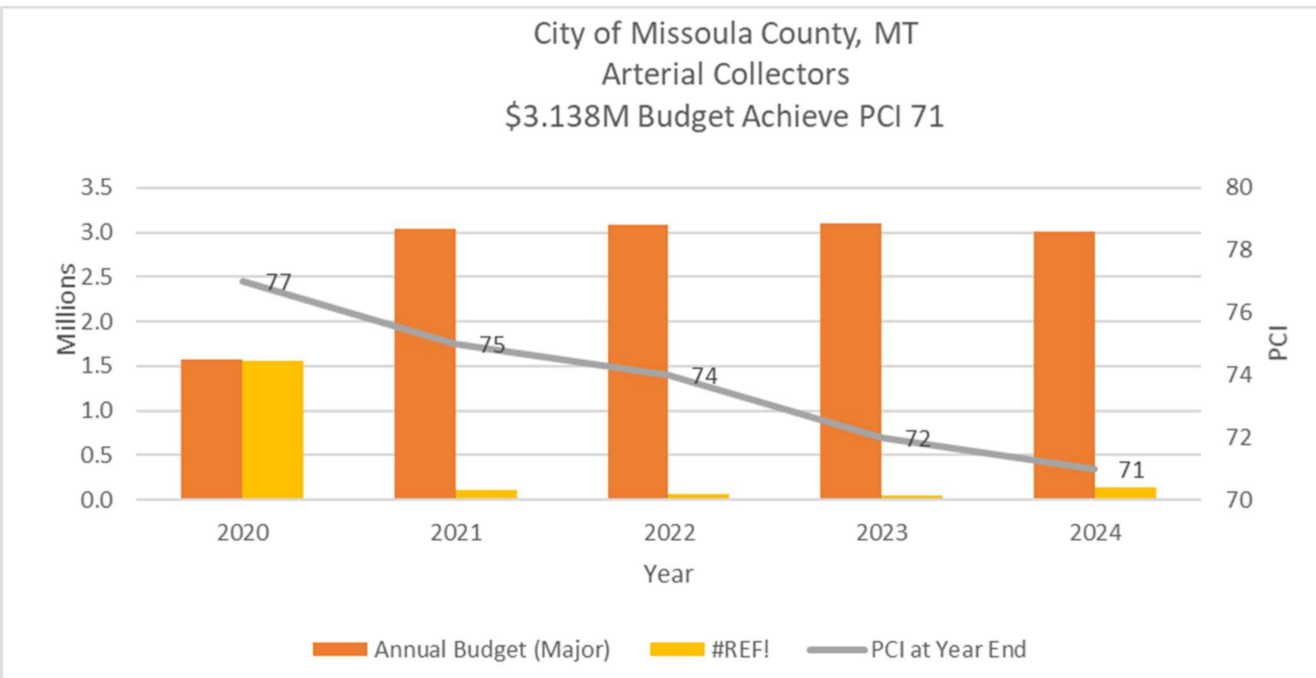


Figure 2-7 – Missoula UZA – Arterial/ Collector Roads
$3.138M Budget to Achieve PCI 71

Table 2.10 – Missoula UZA – Local Roads
$10.479M Budget to Achieve PCI 71

Year Beginning September 2020	Annual Budget (Major)	Annual Budget (Global)	PCI at Year End	Deferred Maint.
2020	$7,793,000	$2,686,000	68	$ 90,800,000
2021	$10,419,000	$60,000	69	$ 91,000,000
2022	$10,419,000	$60,000	71	$ 87,500,000
2023	$10,264,000	$215,000	71	$ 84,500,000
2024	$10,169,000	$310,000	71	$ 77,200,000

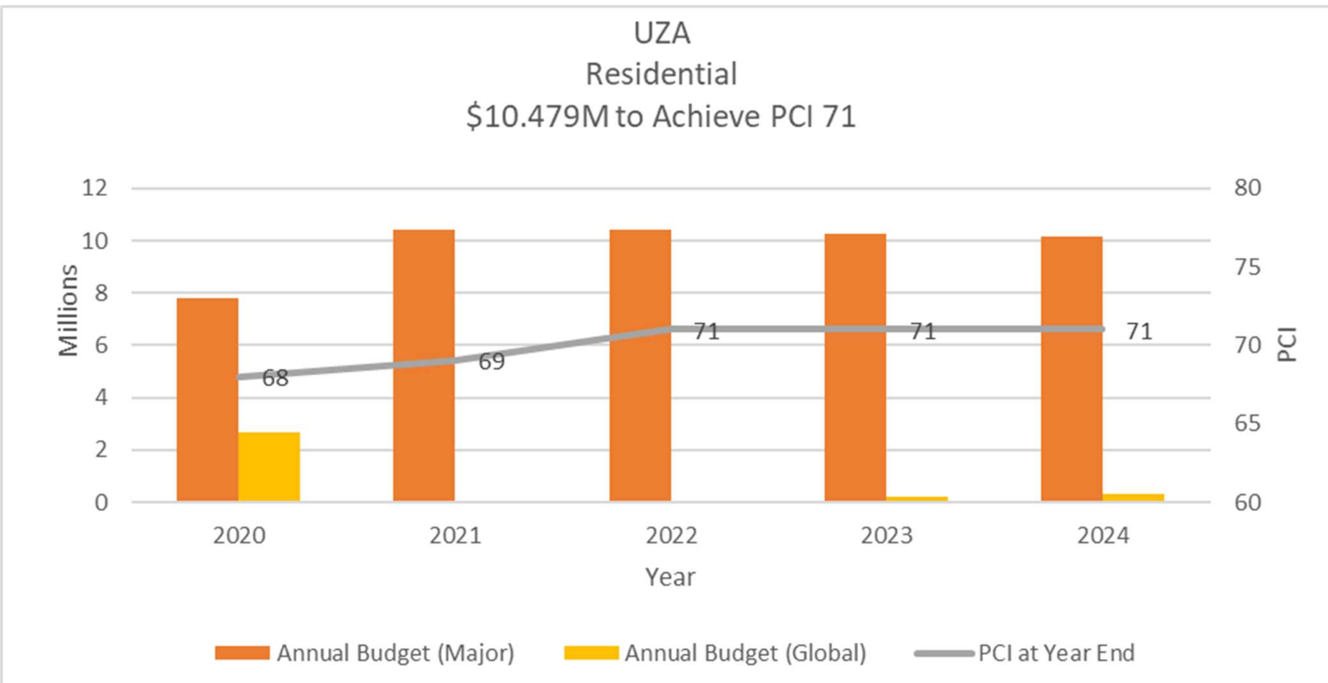


Figure 2-8 – Missoula UZA – Local Roads
$10.479M Budget to Achieve PCI 71

2.6 - UZA Roads, Missoula, MT – Scenario Summaries

Table 2.11 – Missoula UZA - Arterial/ Collector Roads Scenario Summary

Year Beginning September 2020	Do Nothing	$1.123M Budget Consequences	$3.603M to Maintain PCI 75	$3.138M to Achieve PCI 71
2020	72	74	77	77
2021	68	72	76	75
2022	63	69	75	74
2023	59	66	75	72
2024	54	63	75	71

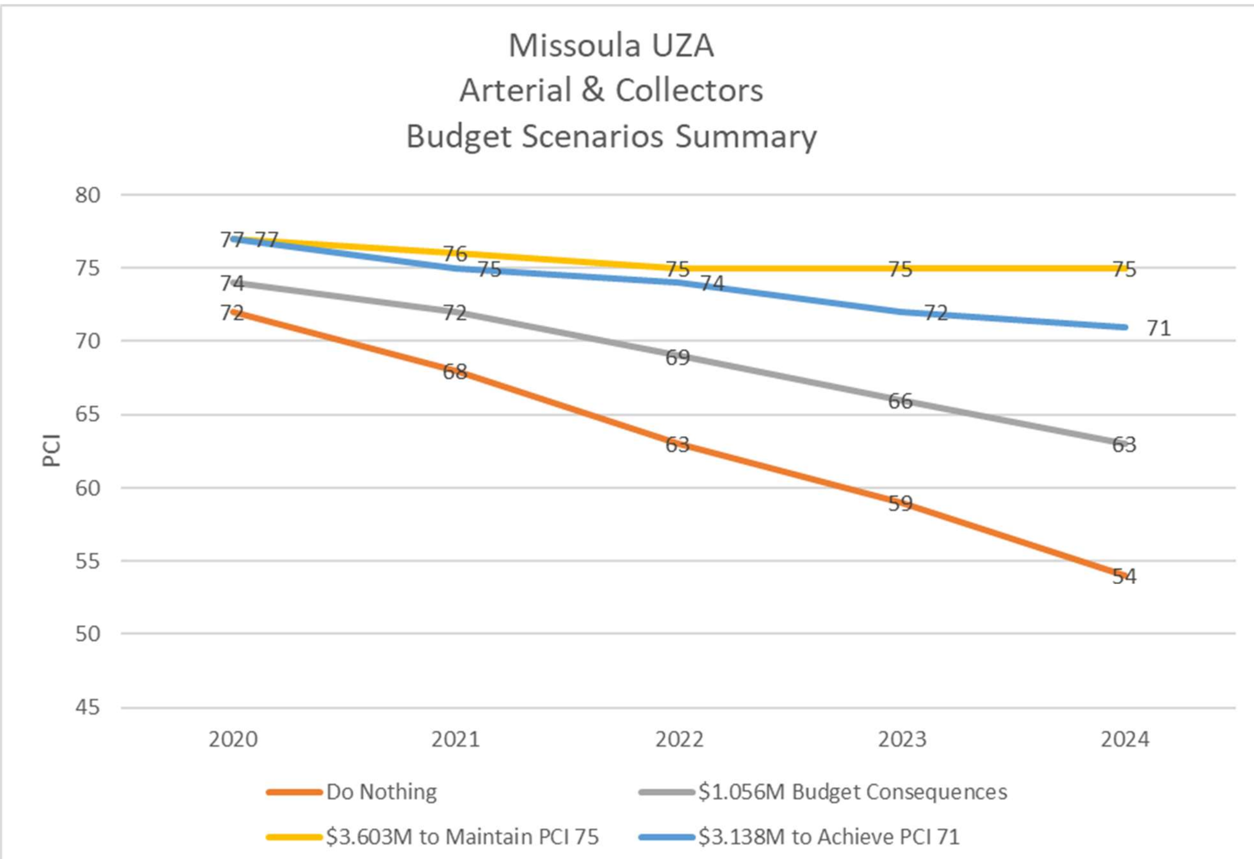


Figure 2-9 – Missoula UZA – Arterial/ Collector Roads Scenario Summary

Table 2.12 – Missoula UZA – Local Roads Scenario Summary

Year Beginning September 2020	Do Nothing	$3.271M Budget Consequences	$8.699 to Maintain PCI 68	$10.479M to Achieve PCI 71
2020	64	66	68	68
2021	61	64	67	69
2022	57	61	68	71
2023	53	59	68	71
2024	49	56	68	71

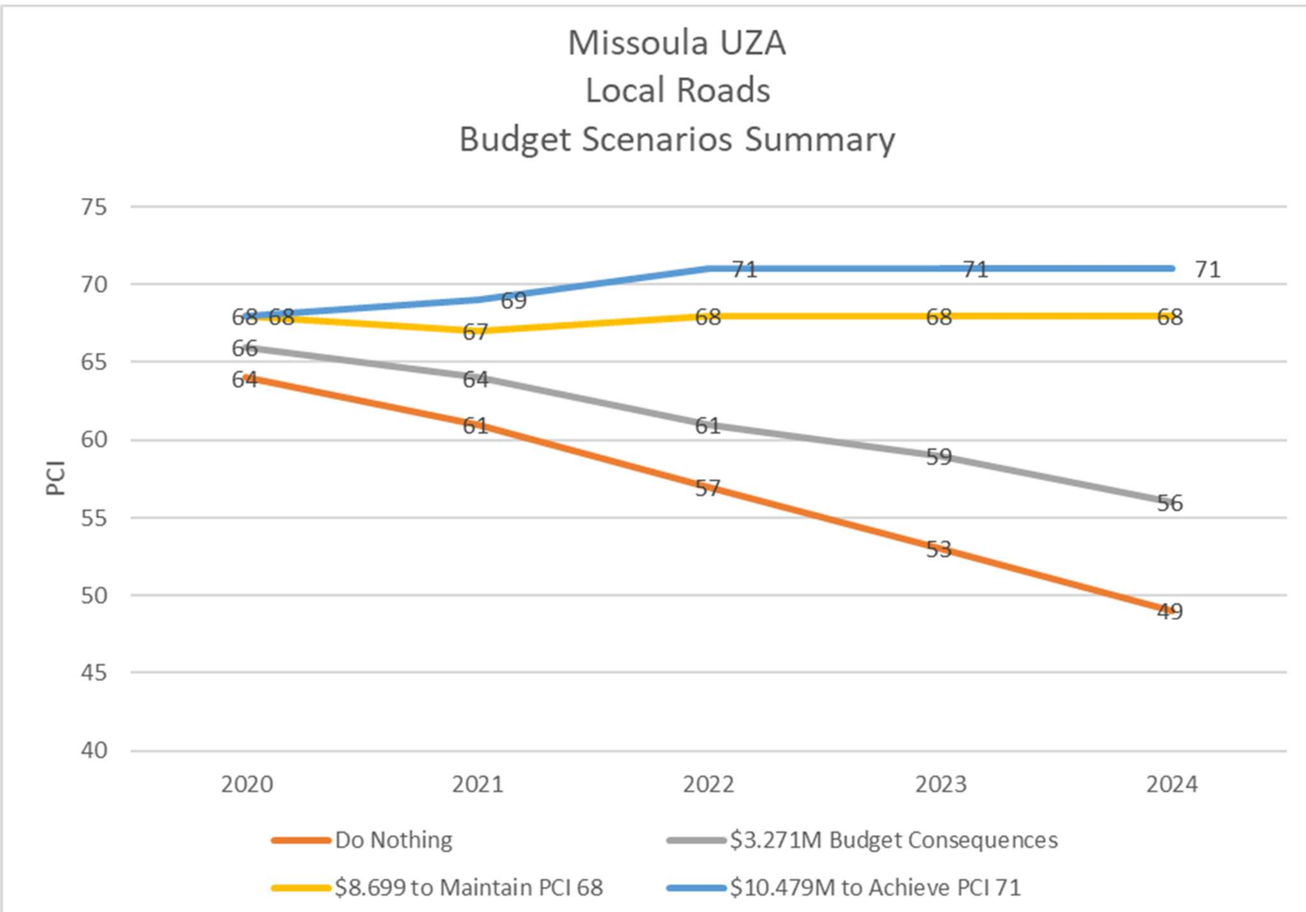


Figure 2-10 Missoula UZA – Local Roads Scenario Summary

Note:

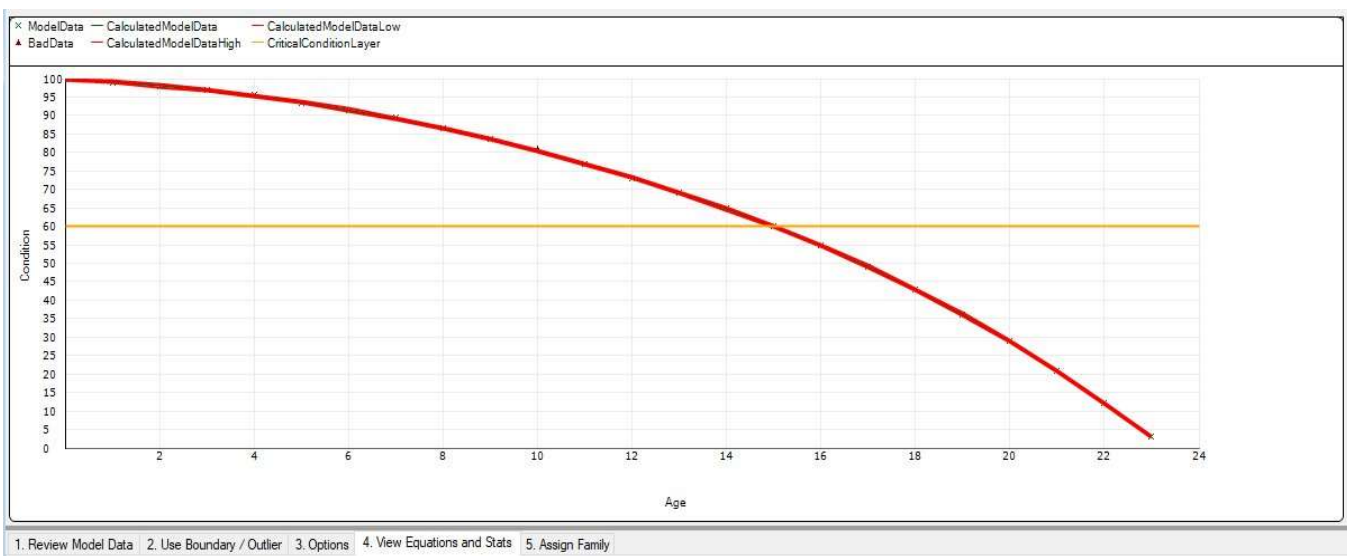
Detailed work plans for scenarios are provided within the separate County and City reports.

Appendix A
Asphalt Pavement Performance Curves for Missoula

The predictive modeling (family modeling) process 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 MicroPAVER, 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 but when analyzing over a short period of time, like 5 years, the change at any point, over that period, need only be close initially. Constructing models that can accurately predict the performance of any road is an iterative process that is refined from the results of multiple condition surveys. Historical maintenance data is useful but can be initially misleading because it will contain many outliers particularly if the data is not being collected specifically for this purpose.

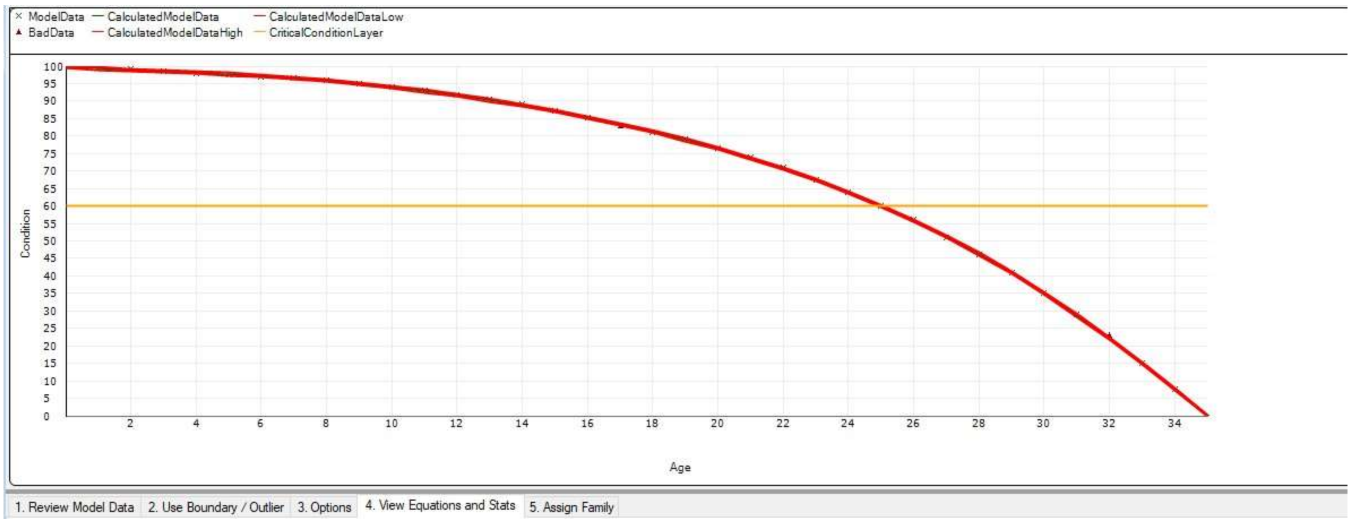
Figure A-1 shows the results from the asphalt performance model developed from the historical construction data provided by Missoula for Arterial/Collector Roads in MicroPAVER and the polynomial defining it.



100 - 0.925351619720459 X^1 + 0.0378412455320358 X^2 - 0.0331244915723801 X^3 + 0.00290213851258159 X^4 - 0.000117047391540837 X^5 + 1.67845541909628E-06 X^6

Figure A-1 Missoula Arterial/Collector Asphalt Pavement Performance Curve

Figure A-2 shows the results from the asphalt performance model developed from the historical construction data provided by Missoula for Local Roads in MicroPAVER and the polynomial defining it.



$$100 - 0.695520460605621\, X^1 + 0.113977126777172\, X^2 - 0.0173654947429895\, X^3 + 0.00091510167112574\, X^4 - 2.42969636019552E{-}05\, X^5 + 2.35055694020048E{-}07\, X^6$$

Figure A-2 Missoula Local Asphalt Pavement Performance Curve

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 management 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.

Appendix C

Principles of Pavement Management

Given the persistent shortage of funds for maintaining 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.

A Pavement Management System also 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.

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 pavement maintenance; the cost of rehabilitation will be prohibitively expensive.

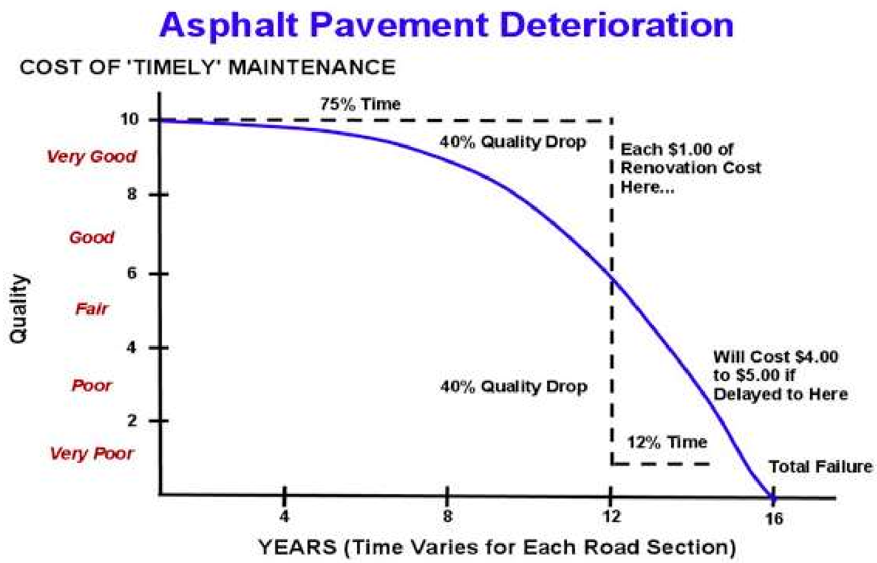


Figure 1-1 - Pavement Life Cycle Curve

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 the purpose of 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 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.

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 Distresses 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 Distresses 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), or linear feet (length of a specific crack) is 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 management 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.

3. Analysis and Reporting

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

Pavement Condition Index (PCI) is engineering terminology 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 destroyed

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 is used to calculate a single number representing the pavement condition. The higher numbers reflect better pavement. The formula used to calculate the PCIs is in **Appendix C**.

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.

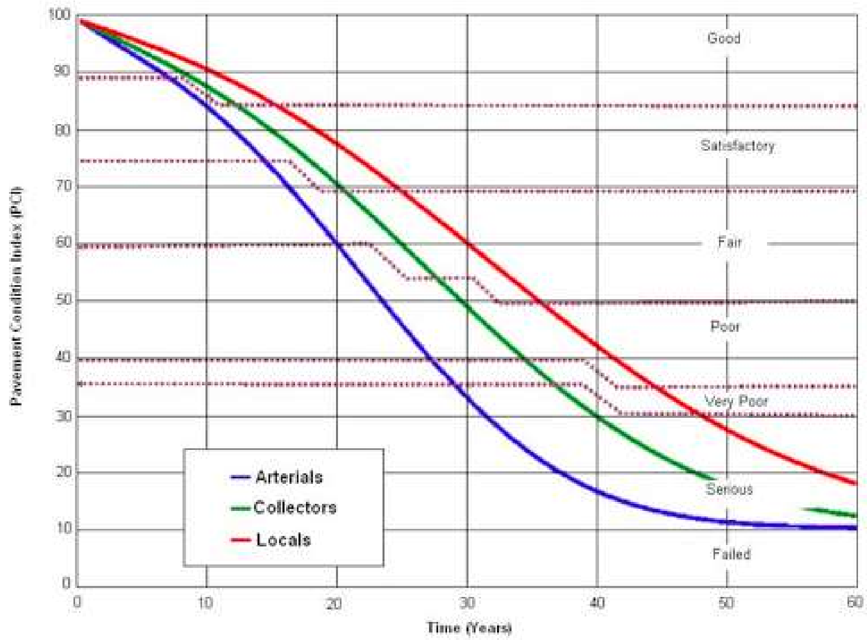


Figure 1-3 - Understanding the Pavement Condition Index Score

Table 1.2, an industry standard, defines the different PCI condition levels with respect to the remaining life of a pavement and typical rehabilitation options recommended.

Table 1.2 - Industry Standard for PCI Condition Levels

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

Boot Camp Notes can be seen in Appendix B of this report.

2.2 Pavement Preservation

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

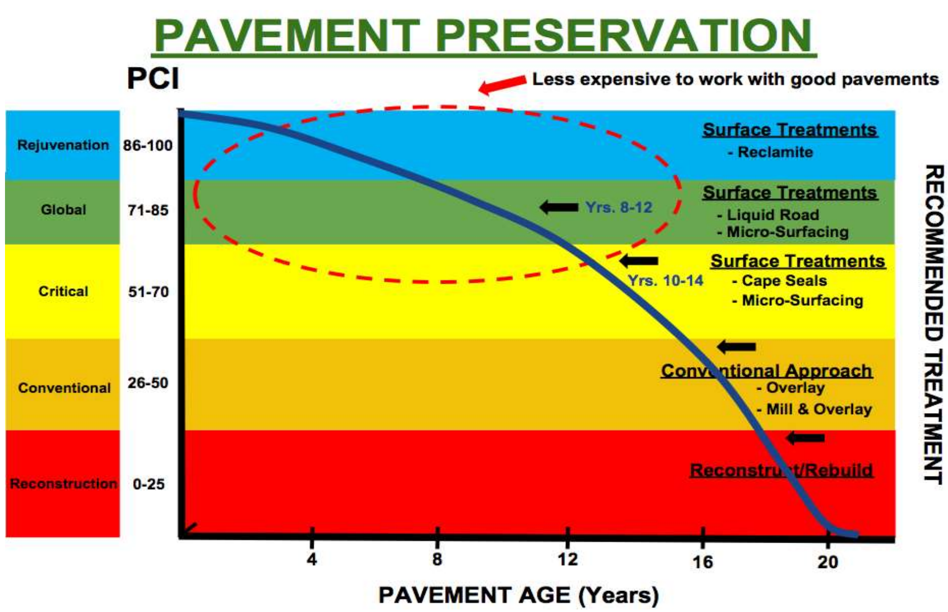


Figure 2-1 - Pavement Preservation

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).

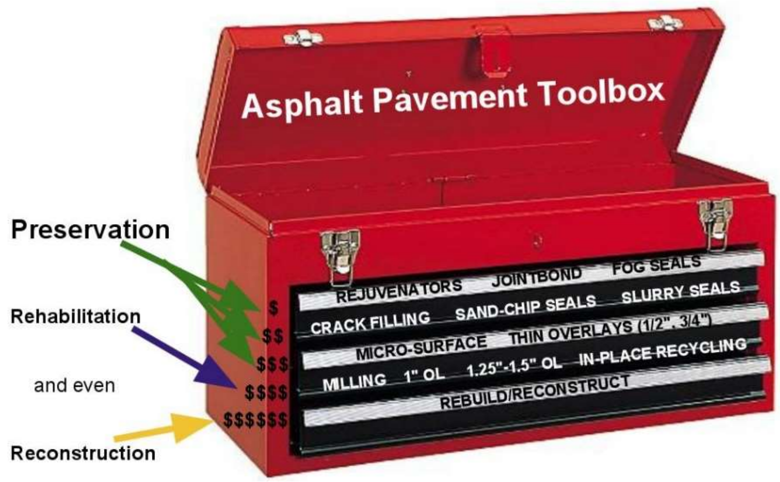


Figure 2-2 - Preservation Treatments

This hierarchical strategy ensures that roadways slated for reconstruction remain in the reconstruction pipeline, even if there is a funding shortfall. Available funds are used to preserve those streets that can be treated with slurries and overlays. No real equity is lost when those roads become unacceptable for use, since they were already scheduled for reconstruction.

Appendix E
Boot Camp Meeting Notes for Missoula and Correspondence

Meeting Description	**Missoula County & City of Missoula, MT** **Pavement Management Boot Camp Meeting Minutes**
Objective	Pavement Management Understanding & Best Practices
Location	Go-To Meeting
Date	May 4, 2020
Time	1:00 PM (MTZ)

Persons Attended –Missoula	Persons Attending - Transmap
Aaron Wilson **wilsona@missoula.mt.us** **David Gray, Transportation Planner** **grayd@ci.missoula.mt.us** **406-552-6669** **Erik Dickson, PE – County Engineer (Absent)** **edickson@missoulacounty.us** **406-258-3772** **Brian Hensel- Deputy Dir. Public Works-Streets** **BHensel@ci.missoula.mt.us** **Shane Stack** **sstack@missoulacounty.us** **Mary Gayle Padmos (emailed)** **mpadmos@mt.gov** **Lee Macholz – City GIS Manager** **MacholzL@ci.missoula.mt.us** **Jeremy Keene** **KeeneJ@ci.missoula.mt.us**	Craig Schorling, GISP, VP cschorling@transmap.com 614-537-6297 Chris Crocker, Operations Manager ccrocker@transmap.com 740-835-1223 Anthony J. Manch PE Senior Reporting Engineer tmanch@transmap.com 614-481-6799 Rob Little PE Senior Project Manager rlittle@transmap.com 813-390-2565

Discussion Topics
Introductions **Project Update**
GIS Data Review **Construction Dates** **Functional Class** **From-To Intersection Data (Transmap)** **Legacy Data Integration (Centerline files)**
Measuring **Distress Review** **Measuring ASTM standards**
Current Pavement Maintenance **Existing Paving Plan - Work Ongoing (3 to 5-year data)** **Treatments / Price / Expected Benefits** **Previous Reports** **CIP Plans**
Pavement Preservation Strategies **Goals** **Commissioners Objectives / Level of Service Analysis** **Discussion of Options** **Above Critical PCI Practices** **Below Critical PCI Practices** **Budget to Keep the PCI at Current Level** **Current Budget** **Family Creation in Micro-PAVER**
Next Steps **Network Re-Inspection - 3-year cycle**

Data Requests
• **Verify PCI ranges, costs and Expected Life for Treatments**

May 4, 2020 Boot Camp Meeting Notes

- Chris Crocker discussed the elements of the ArcGIS Online Site.
- Chris discussed the project viewer, Pavement Data Viewer, and the van images.
- Discussed the Laser Crack Measurement System (LCMS) features and capabilities. Can be thought of as a Crack Heat Map. Cracks are categorized by width.
- Discussed the Crack Intel Map Layer. Ranking from 0 to 8 using the total crack count.
- The rut depths (mm) are grouped into four (4) categories and then extrapolated and input into MicroPAVER.
- LCMS - Mr. SID files are included on the hard drive provided to the city.
- Chris updated the staff regarding Transmap standard project deliverables: PCI Map, and Section Report by unique section ID's.
- City/County requested a Data dictionary describing GIS elements
- Discussion regarding when and how the GIS data and images will be made available resulted in Chris coordinating effort to migrating data from Transmap server to City/ County servers.
- There are two M&R cost matrices, One for the City and a second for the County (See tables below).
- City of Missoula provided Transmap with construction work history that will be included in the MicroPAVER database.
- Network families will consist of Arterial/Collectors and Local for the City and County roads (4 total).
- Transmap will construct two performance models for Arterial/ Collectors and Local for both the City and the County, considering 20 to 25 year life spans for Local Roads and 15 years for Arterial/ Collectors and data from other projects.
- Current Maintenance Budget(s) to conduct Major Maintenance and Rehabilitation (M&R) treatments for the identified families are presently undefined. Transmap will produce Do-Nothing Consequences and Maintain Existing PCI Budget and send to attendees to assist in defining budgets.
- Critical Pavement Condition Index (PCI) will be PCI 60 for City and County.

Present Asphalt M&R Category Ranges, Unit Prices and Treatments

M&R Category	M&R Treatment	City Price per SY	County Price per Sy	Expected Result
Rejuvenation (PCI 86-100)	Crack seal/chip seal	$2.72	$0.68	
Global (PCI 71-85)	Crack seal/chip seal	$3.72	~~$2.73~~ $2.14**	
Critical (PCI 60-70)	Thin overlay/chip seal	$6.50	$8.82	
Conventional (PCI 40 - 59)	Structural overlay/chip seal	$9.15	$8.82?	
Reclamation (PCI 0 - 39)	Reconstruct	~~11.67~~ 18.35*	$18.35	

*Changed during Boot Camp Meeting

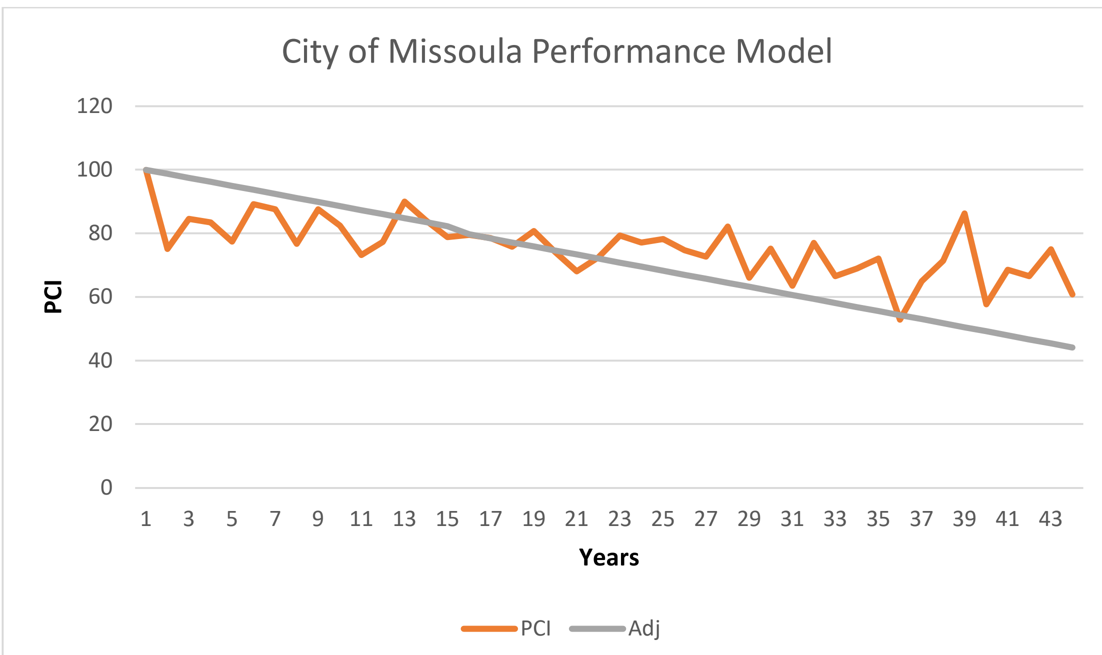
M&R Category	M&R Treatment	Price per Square Yard	Expected Result
Rejuvenation (PCI 86-100)	Crack seal/chip seal	2.72	
Global (PCI 71-85)	Crack seal/chip seal	3.72	
Critical (PCI 60-70)	Thin overlay/chip seal	6.50	
Conventional (PCI 40 - 59)	Structural overlay/chip seal	9.15	
Reclamation (PCI 0 - 39)	Reconstruct	11.67	

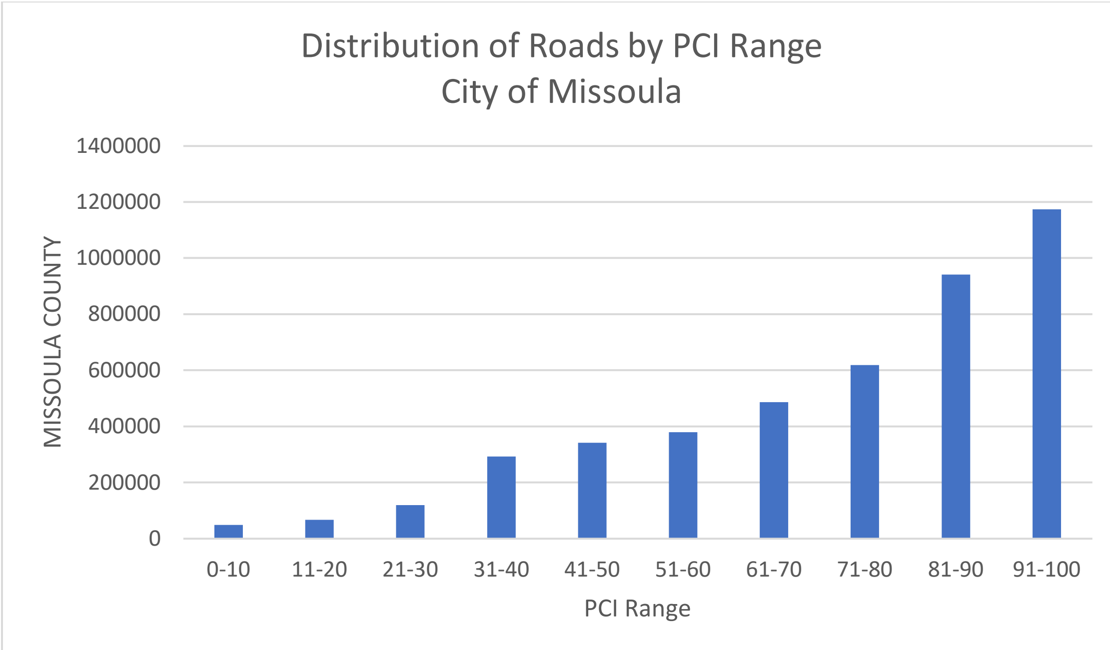
MicroPAVER Input Parameters

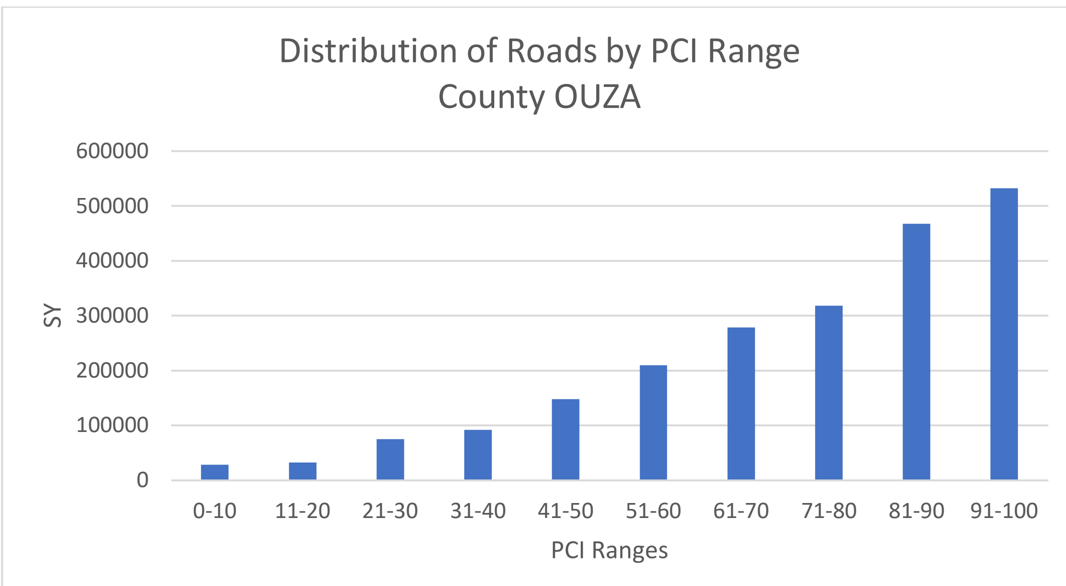
Item	Status
Network(s)	City, County IUZA, County OUZA
Construction History	Received and inputted
Format of Construction History Data	Digital
Number of Families	Arterial/Collectors & Local for City and County
M&R Category by PCI Ranges	See Treatment Table above
Pavement Performance Model	TBD for Arterial/Collectors and Local
Critical PCI Between PCI of 55 and 70. (Recommend PCI=55)	60
M&R Treatments (See Matrix)	See Treatment Table above
Unit Cost (Per Square Yard)	See Treatment Table above
Current Budget	TBD
Given Budget for Major	TBD
Given Budget for Global	TBD
Global PCI Ranges	TBD
Global Life Expectancy	TBD
Start Date for Work Plans	July 1, 2020

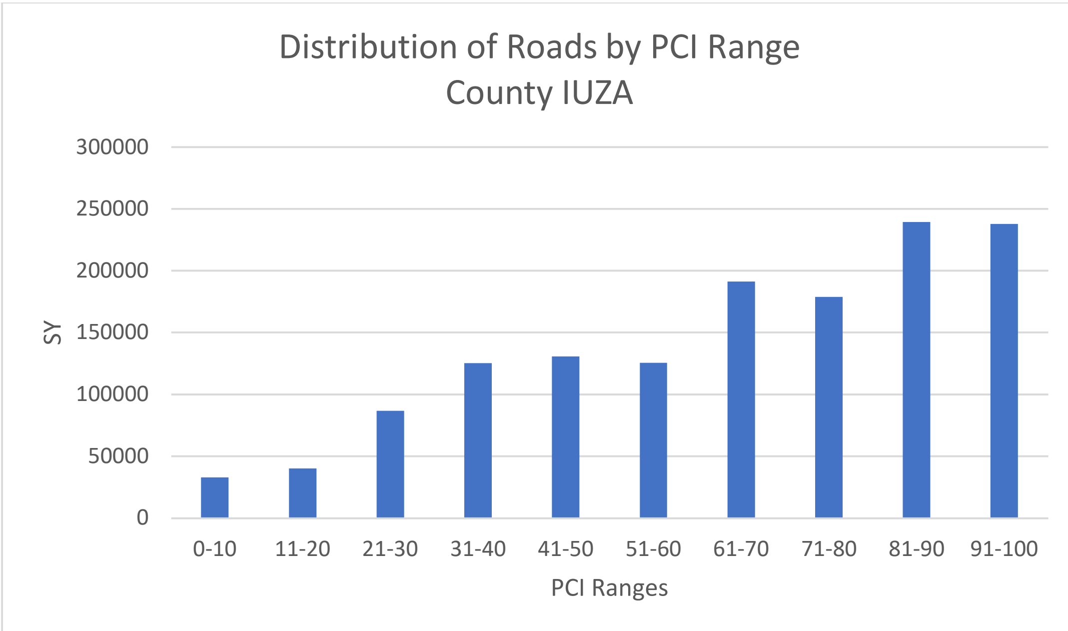
Number of Years for Work Plan (Planning Horizon)	5 years (maybe 10)
Recommended Budget Scenarios: 1- Do Nothing Budget 2- Budget to Maintain the Existing PCI – Using Major M&R Treatments 3- Given the current annual budget- show the resulting change in PCI over time.	Initially will run 1) Do Nothing and, 2) Budget to Maintain Existing PCI

2020 Pavement Performance Model for Asphalt roads




Distribution of Roads by PCI Range
City of Missoula
MISSOULA COUNTY
1400000
1200000
1000000
800000
600000
400000
200000
0
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
PCI Range


Distribution of Roads by PCI Range
County OUZA
SY
600000
500000
400000
300000
200000
100000
0
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
PCI Ranges


Distribution of Roads by PCI Range
County IUZA
300000
250000
200000
150000
100000
50000
0
SY
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
PCI Ranges