California Rural Counties Task Force

2015 Rural Counties Pavement Needs Assessment

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Executive Summary

The 26 rural counties included in this study own and maintain over 24,000 centerline miles of local roads and streets, and over 5,000 centerline miles of unpaved roads. They cover 41.5 percent of the total land area and maintain approximately 14.2 percent of the total lane-miles of the local road network. However, they contain only 5.6 percent of the state's population and have 9.4 percent of the available funding for pavement expenditures.

The main objectives of this project were to develop the following information for each county:

1. Provide a comparison of revenues versus pavement maintenance needs.
2. Provide three funding scenarios:
    a. Impacts of existing funding ($3.08 billion) with preventive maintenance first
    b. Impacts of existing funding ($3.08 billion) with worst first
    c. Funding required to reach PCI targets (average 68)

The average PCI for rural roads is only 58, significantly lower than the statewide average of 66. It will require more than $9.8 billion over the next 20 years to make all necessary repairs and bring the local road condition to what is considered to be best management practices. In addition, the state highway system will require an additional $732 million over the next ten years.

However, the existing funding available is only $3.08 billion over the next 20 years for local roads. Of this, more than 50 percent comes from the gas tax, which is a decreasing revenue source. The first two scenarios indicate that the average PCI will reach 42 by 2034; however, they differ in their deferred maintenance results. Scenario 1 results in a deferred maintenance of $6.7 billion compared to $8.1 billion for Scenario 2. Clearly, the latter is not recommended.

In order for all the counties to reach their target PCIs (average of 68), a total of $7.3 billion will be required for local roads alone. This results in a funding shortfall of $4.2 billion.

Finally, this report recommends using the PCI as the most appropriate performance measure for rural roads. The PCI is in widespread use nationally as well as in California. This means that most agencies have a historical database of PCI data, and agencies and industry have knowledge of the data collection methods as well as interpretation of results.

1. Introduction

1.1. Background

The State of California contains 26 rural counties[1], which generally have populations of less than 250,000 and do not have a single urbanized area greater than 50,000. Rural counties provide food, fiber, timber, and mineral products for California industry and residents, as well as recreation for urban residents and tourists.

In order to provide a direct opportunity for the small counties to remain informed, have a voice, and become involved with changing statewide transportation policies and programs, a task force was formed in 1988 as a joint effort between the California Transportation Commission (CTC) and the rural counties. There are 26 rural county Regional Transportation Planning Agencies (RTPAs) or Local Transportation Commissions represented on the Rural Counties Task Force (RCTF) as shown in Figure 1.1. Table 1.1 lists the members.

Figure 1.1 Rural Counties

Table 1.1 Members of California Rural Counties Task Force

Alpine County Transportation Commission	Modoc County Transportation Commission
Amador County Transportation Commission	Mono County Local Transportation Commission
Calaveras Council of Governments	Transportation Agency for Monterey County
Colusa County Transportation Commission	Nevada County Transportation Commission
Del Norte Local Transportation Commission	Placer County Transportation Planning Agency
El Dorado County Transportation Commission	Plumas County Transportation Commission
Glenn County Transportation Commission	Council of San Benito County Governments
Humboldt County Association of Governments	Santa Cruz County Regional Transportation Commission
Inyo County Local Transportation Commission	Sierra County Local Transportation Commission
Lake County/City Area Planning Council	Siskiyou County Transportation Commission
Lassen County Transportation Commission	Tehama County Transportation Commission
Mariposa County Local Transportation Commission	Trinity County Transportation Commission
Mendocino Council of Governments	Tuolumne County Transportation Council

[1] http://www.ruralcountiestaskforce.org/

With the implementation of Senate Bill (SB) 45 in 1997, demands on transportation systems and the responsibilities of small local planning agencies expanded significantly. More effort is now being applied in the areas of project specific planning, programming and monitoring. Under SB 45, the value and purpose of the RCTF expanded as well. Specifically, the RTPAs have the responsibility to work with Caltrans and the community to identify transportation needs, propose solutions, and assist in implementing projects to create a balanced regional transportation system. This includes administration of regional, state, and federal funding for projects related to roadways, bridges, public transportation services, railways, airports, bicycle facilities, and pedestrian amenities.

1.2. Objectives of Project

In 2014, the RCTF agreed on the need to develop a method to coordinate performance measures with the goals of their Regional Transportation Plans (RTPs), and to improve monitoring and reporting of performance measurement. The Nevada County Transportation Commission (NCTC) was selected as the Project Leader on behalf of the RCTF.

The main objectives of this project are to develop the following information for each RTPA:

1. Provide a comparison of revenues versus pavement maintenance needs.
2. Provide three funding scenarios including:
    - Impacts of current funding level with a focus on preventative maintenance.
    - Impacts of current funding level with focus on worst roads.
    - Funding needed to achieve specific performance goals for each RTPA.

Concurrently with this project, the 2014 update of the *California Statewide Local Streets and Roads Needs Assessment*[2] (Statewide) was also underway. Since the Statewide study included an online survey of all 540 cities and counties in California, it was the goal of this project to use the data collected from that effort so as to minimize costs. In addition, the methodology developed in the Statewide report was utilized with some "tweaks."

The Statewide report provides a systematic needs assessment of the transportation system. However, the needs of rural counties have been averaged with the urban cities and counties, and thus the pavement needs are masked and a complete picture of the rural counties is not provided. For instance, typical differences between rural and urban roads include the following:

- Paving construction costs on rural roads are, on average, approximately 86% of urban counties.
- Different types and unit cost of maintenance treatments are often applied to rural roads, such as rejuvenators and chip seals; these are not common on urban roads.
- Rural roads do not have many of the associated assets such as sidewalks, streetlights, signals and storm drains that are typical for an urban street.
- Rural counties have lower traffic volumes in most cases, and therefore, different pavement performance models for roads.

[2] California Statewide Local Streets and Roads Needs Assessment – 2014 Update, October 2014. www.SaveCaliforniaStreets.org

- The standards for an acceptable performance measure may be different.

These differences between rural roads and urban streets lead to differences in the transportation needs. Therefore, the goal was to better assess the needs of the transportation system (including highways as well as local roads) for rural counties.

1.3. Rural Counties Overview

The rural counties own and maintain over 24,000 centerline miles of local roads and streets, and over 5,000 centerline miles of unpaved roads. Figure 1.2 summarizes some key characteristics in terms of maintained roads, land area, population and pavement funding for the rural counties compared to the rest of California.

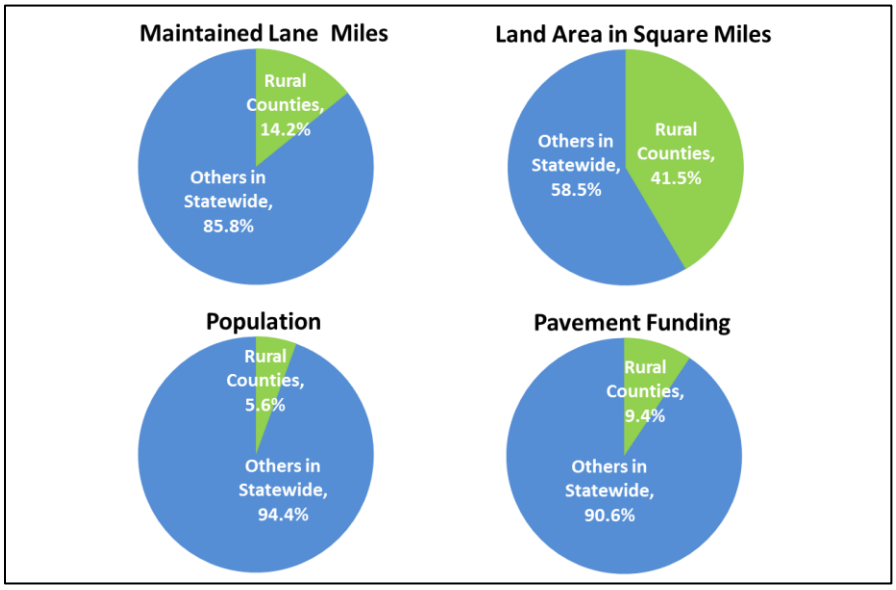


Figure 1.2 Key Characteristics of Rural Counties

As can be seen, Figure 1.2 indicates that rural counties own 41.5 percent of the total land area and maintains approximately 14.2 percent of the total lane-miles of the local road network. However, they contain only 5.6 percent of the state's population and have 9.4 percent of the available funding for pavement expenditures. We can conclude that:

- A resident in a rural county has to maintain almost three times as many lane-miles; and
- Available pavement funding per mile available is approximately 60 percent when compared to the rest of California.

Clearly, this reflects a disproportionate burden that is being shouldered by the rural counties when compared with the rest of the state.

Rural roads are also much more spread out, which is to be expected. However, when coupled with the lower population density, this leads to not just roads that have very low traffic volumes but also accessibility issues in terms of emergency response, safety or other reasons.

Figure 1.3 Example of Rural County Road

Figure 1.4 Example of Rural County Road

2. Pavement Condition and Treatment Cost Data

In this chapter, the methodologies and assumptions used for the needs assessment are discussed, and the results of pavement conditions are presented.

2.1. Statewide Online Survey Responses

As was previously mentioned, this project occurred at the same time as the 2014 Statewide update, which included an online survey conducted between January 20th and April 7th, 2014. All 540 cities and counties in California were contacted and asked to participate in the survey. A total of 399 agencies (74 percent) responded. When these were added to the agencies who responded in 2008, 2010 and 2012, they represented 99 percent of the total centerline miles of local streets and roads, and 98 percent of the state's population.

The Statewide survey included questions regarding the pavement management system used, distress survey procedures, sustainable pavement practices, road inventory and conditions, pavement treatment strategies, their costs, as well as complete streets policies. Other sections included safety, traffic and regulatory components, funding and expenditure data. More details are included in Appendix A.

Of the 26 rural counties, 79 of 98 cities and counties (81 percent) responded to the statewide survey at least once between 2008 and 2014. In addition, special efforts were made by both NCTC and NCE to obtain more information from each RTPA through April 2014. Ultimately, 99.6 percent of the total centerline miles are represented in rural counties. In addition, NCE updated Mariposa County's pavement management system in July 2014, and this updated information was included.

2.2. Study Assumptions

There were some important assumptions that were made during the analyses of the data received from cities and counties. Most are consistent with those used in 2014 Statewide study. The assumptions include (see Table 2.1):

- The analysis period is 20 years.
- All numbers reported in this study are in constant 2014 dollars – this is consistent with the 2014 Statewide study.
- In the Statewide study, the pavement condition goal was to reach a condition where best management practices (BMP) can occur. This translates to a PCI in the low 80s (on a scale of 0 to 100, where zero is failed and 100 is excellent) and where there are no failed pavements. However, for this study, the goal was determined by the individual counties, and they ranged from a PCI goal of 50 to 80.

- It is assumed that no new streets or roads are added within the analysis period. In addition, capital improvement or expansion projects are not included, e.g. realignments, widenings, grade separations etc. This is also consistent with the statewide study.
- Safety, traffic and regulatory components of the roadway system such as sidewalks, ADA ramps, storm drains were not included. Bicycle and pedestrian facilities were also not included.
- Bridges were not included.

Table 2.1 Summary of Assumptions Used in RCTF Study and 2014 Statewide Study

Assumptions	RCTF Study	2014 Statewide Study
Analysis Period	20 years	10 years
Cost Basis	2014 dollars	2014 dollars
Goals	Varies by County	Best management practices (PCI = low 80's & no failed pavements)
Total Scenarios Evaluated	3 per County	3
Capital Improvement Projects	No	No
Essential Components	No	Yes
Bridges	No	Yes
Performance Measures	PCI, Percent Failed Streets, Deferred Maintenance	PCI, Percent Failed Streets, Deferred Maintenance

2.3. Methodology

Since not all 98 cities and counties responded to the survey, a methodology had to be developed to estimate the pavement needs of the missing agencies. The following paragraphs describe in detail the methodology that was used in the study (note that this is consistent with previous updates).

2.3.1 Filling in the Gaps

Inventory Data

Briefly, this process determines the total miles (both centerline and lane-miles) and pavement areas for an agency, as this is crucial in estimating the pavement needs. Missing inventory data were populated based on the following rules:

- If no updated inventory data were provided, then previous statewide survey data (2008, 2010 or 2012) were used.
- If the inventory data provided was incomplete, Table 2.2 was used to populate the missing information. The average number of lanes and average lane width are summarized from agencies who submitted complete inventory data in the statewide previous surveys.

Table 2.2 Assumptions for Populating Missing Inventory Data

Functional Class	Average Number of Lanes	Average Lane Width (feet)
Urban Major Roads	2.8	15.5
Urban Residential/Local Roads	2.1	15.5
Rural Major Roads	2	13.2
Rural Residential/Local Roads	2	11.7
Unpaved Roads	1.8	11.4

Pavement Condition Data

To assist those agencies who had no pavement condition data, the online survey provided a table with the average pavement condition index (PCI) collected in the 2012 study. They were then encouraged to look at the data from neighboring cities or counties to make their best estimate of the pavement condition in their agency.

The surveys also asked for condition data for different functional classifications, and additional rules were developed to populate the missing data:

- If the PCI is provided for one but not the other functional classes, the same PCI was used for all functional classes.
- If no pavement condition data were provided in 2014, the last PCI provided was used, but it was extrapolated based on the statewide PCI trend i.e. if the statewide average deteriorated one point, then it was also assumed to have deteriorated one point. Based on the 2014 statewide survey database, the overall PCI is 66, which is the same as in 2012.

2.3.2 Pavement Needs Assessment Goal

The same needs assessment goal from the statewide study was used. To reiterate, the goal is for pavements to reach a condition where best management practices (BMP) can occur, so that only the most cost-effective pavement preservation treatments are needed. Other benefits such as a reduced impact to the public in terms of delays and environment (dust, noise, energy usage) would also be realized.

In short, the BMP goal is to reach a PCI in the low 80s and the elimination of the unfunded backlog. The deferred maintenance or “unfunded backlog” is defined as work that is needed, but is not funded. To perform these analyses, the StreetSaver® pavement management system program was used. This program was selected because the analytical modules were able to perform the required analyses, and the default pavement performance curves were based on data from California cities and counties. This process is described in detail in Appendix B.

2.4. Maintenance and Rehabilitation Treatment Types and Unit Cost

2.4.1 Maintenance and Rehabilitation Treatment Types

Assigning the appropriate maintenance and rehabilitation (M&R) treatment is a critical component of the needs assessment. It is important to know both the ***type*** of treatment, as well as ***when*** to apply it. This is typically outlined in an M&R decision tree.

Figure 2.1 summarizes the types of treatments assigned in this study. Briefly, good to excellent pavements (PCI>70) are best suited for pavement preservation techniques, (e.g., preventive maintenance treatments such as chip seals or slurry seals). These are usually applied at intervals of five to seven years depending on the type of road and their traffic volumes.

As pavements deteriorate, treatments that address structural adequacy are required. Between a PCI of 25 to 69, hot mix asphalt (HMA) overlays are usually applied at varying thicknesses. This may be accompanied by milling or recycling techniques.

Finally, when the pavement has failed (PCI<25), reconstruction is typically required. Note that if a pavement section has a PCI between 90 and 100, no treatment is applied. The descriptions used for each category are typical of most agencies, although there are many variations on this theme. For example, it is not unusual for residential roads to have slightly lower thresholds indicating that they are held to lower standards. The PCI thresholds shown in Figure 2.1 are generally accepted industry standards.

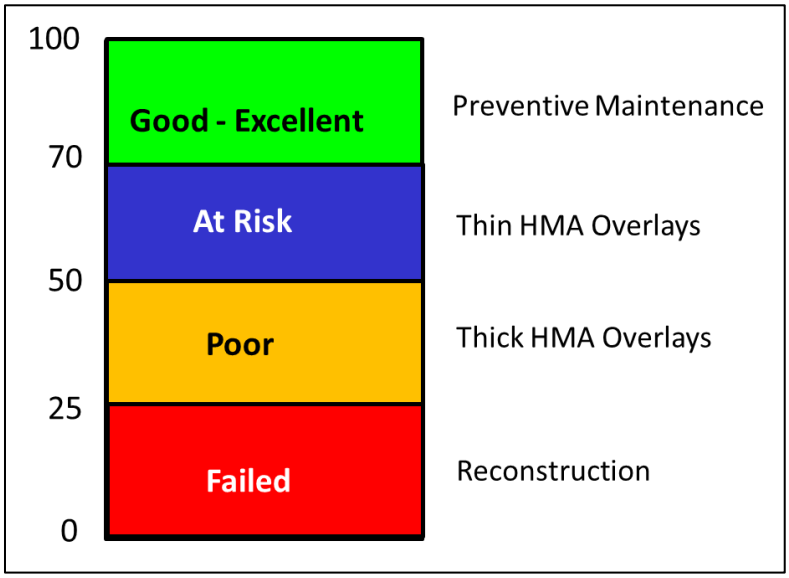


Figure 2.1 PCI Thresholds & Treatments Assigned

2.4.2 Treatment Unit Costs

From the 2014 Statewide Study, 177 agencies provided unit cost data, and the averages were used in the analysis. However, as noted before, different treatments and unit costs are applied on rural roads

and urban roads. In the statewide study, the unit costs were averaged across both rural and urban agencies. Rural roads had unit costs that ranged from 7 to 27 percent lower than the statewide costs. Therefore, a more accurate analysis was desired for this study. Two comparisons were made; the averages between the rural counties and the statewide, and between different regions within the rural counties.

To determine if there were any differences between rural counties, the 26 rural counties were first divided into four geographical regions i.e. Coast, Sierras/Eastern Sierras, Foothills, and North California, as shown in Figure 2.2. The intent of this regional aggregation was to see if there were commonalities in the cost of maintenance. For instance, the counties in the Sierras may have similar issues with regards to the type of maintenance treatments i.e. pavements that undergo colder winters will manifest distress types that are different from milder coastal climates, and therefore require different treatment strategies and costs.

Each region is composed of the following counties:

- **Coast:** Del Norte, Humboldt, Mendocino, Monterey, San Benito, and Santa Cruz
- **Eastern Sierra:** Inyo, Lassen, Modoc, Mono, Plumas, and Sierra
- **Foothills:** Alpine, Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, and Tuolumne
- **North California:** Colusa, Glenn, Lake, Tehama, Trinity, and Siskiyou

A total of 49 out of 98 agencies (or 50 percent) of member RCTF counties provided pavement treatment unit costs. From Figure 2.2, all regions provided some data, with the Coast and Foothill regions providing the most. The average unit cost for the statewide, RCTF and regions are summarized in Table 2.3. The range in unit costs by treatments are shown in Figures 2.3 to 2.6.

Table 2.3 Number of Responses and Average Unit Costs by Regions

Pavement Treatment Types		Statewide	RCTF Total	Coast	Eastern Sierra	Foothills	North California
Preventive Maintenance	# of responses	264	46	13	7	16	11
	Average cost ($/sy)	$4.74	$3.46	$3.06	$5.40	$3.24	$3.31
Thin overlay	# of responses	255	46	13	6	16	12
	Average cost ($/sy)	$19.52	$18.17	$17.19	$26.52	$16.25	$17.72
Thick overlay	# of responses	243	40	13	6	13	9
	Average cost ($/sy)	$30.14	$27.12	$26.33	$35.16	$26.81	$23.53
Reconstruction	# of responses	247	44	13	7	16	9
	Average cost ($/sy)	$66.13	$53.94	$66.53	$49.67	$50.20	$41.20

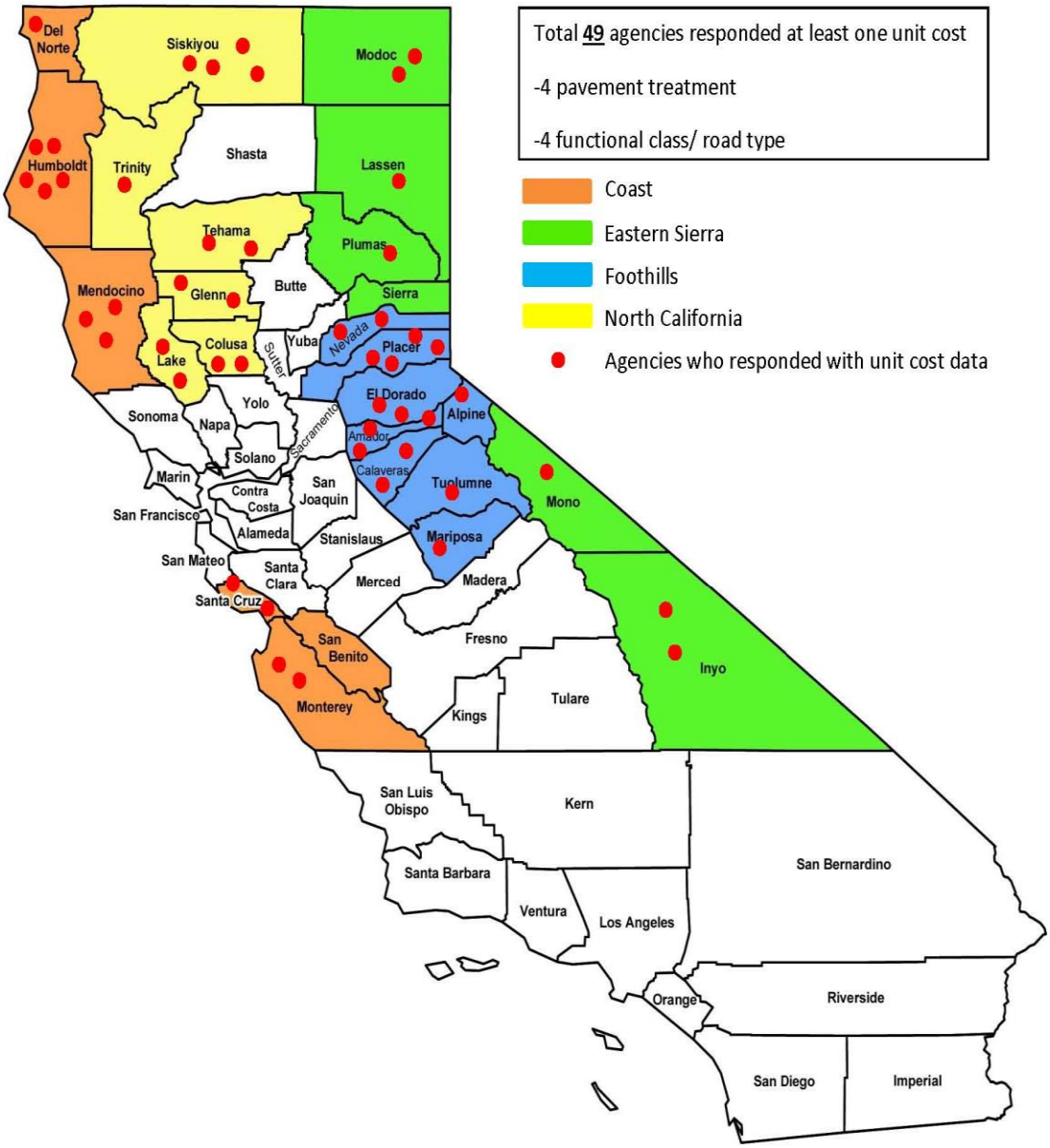
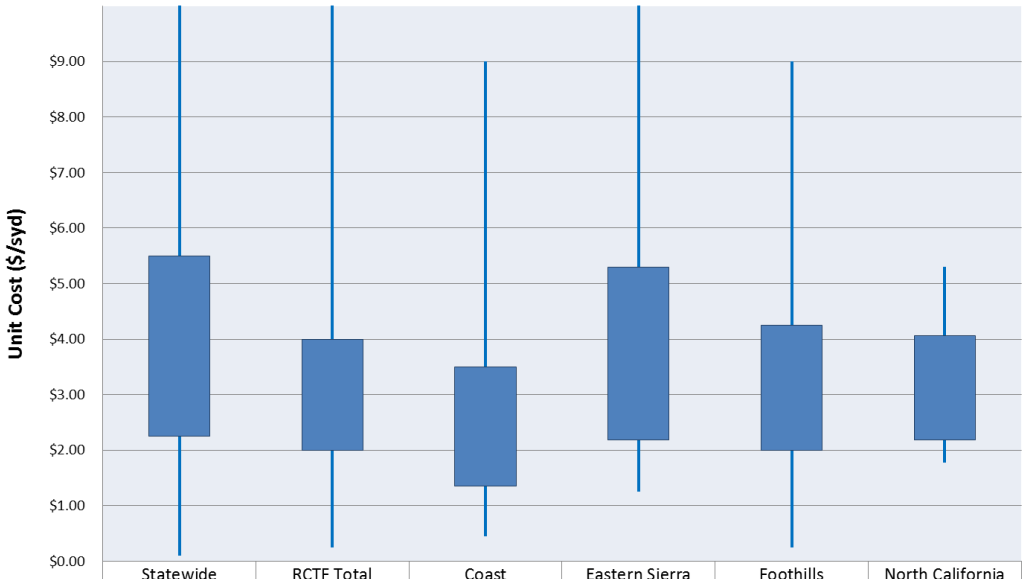
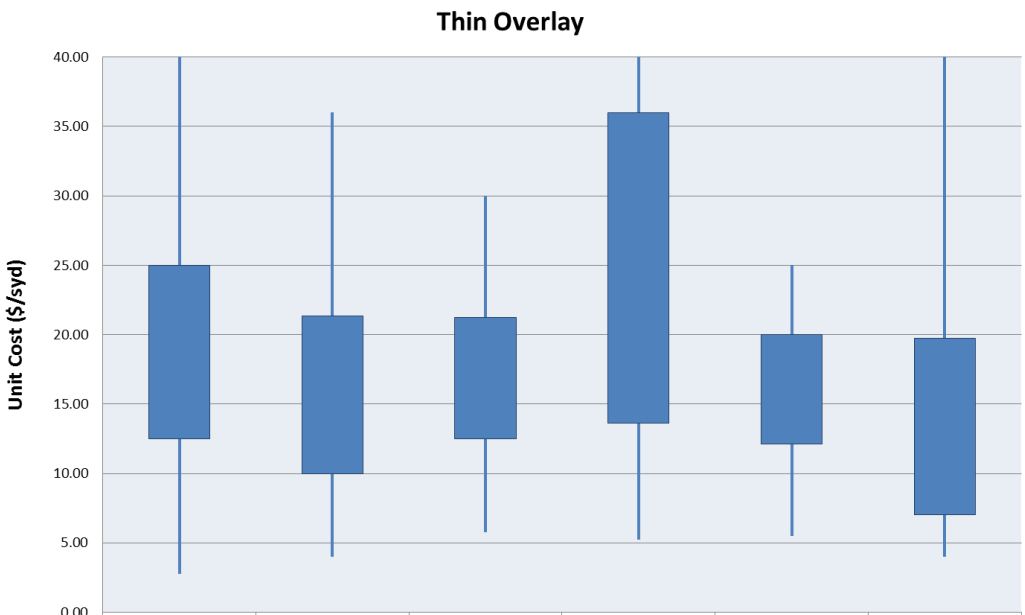


Figure 2.2 Rural County Four Regions with Agencies Who Responded With Unit Cost Data



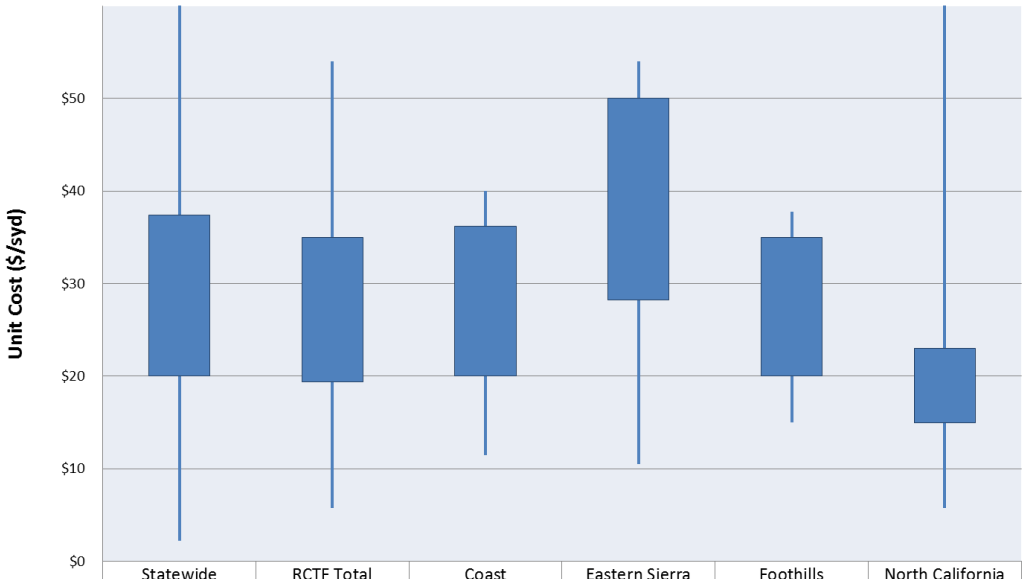
	Statewide	RCTF Total	Coast	Eastern Sierra	Foothills	North California
Q3 (75%)	5.50	4.00	3.50	5.30	4.25	4.06
Max	54.53	32.00	9.00	32.00	9.00	5.30
Min	0.10	0.25	0.45	1.25	0.25	1.77
Q1 (25%)	2.25	2.00	1.35	2.19	2.00	2.19

Figure 2.3 Unit Cost Distribution by Region (Preventive Maintenance)



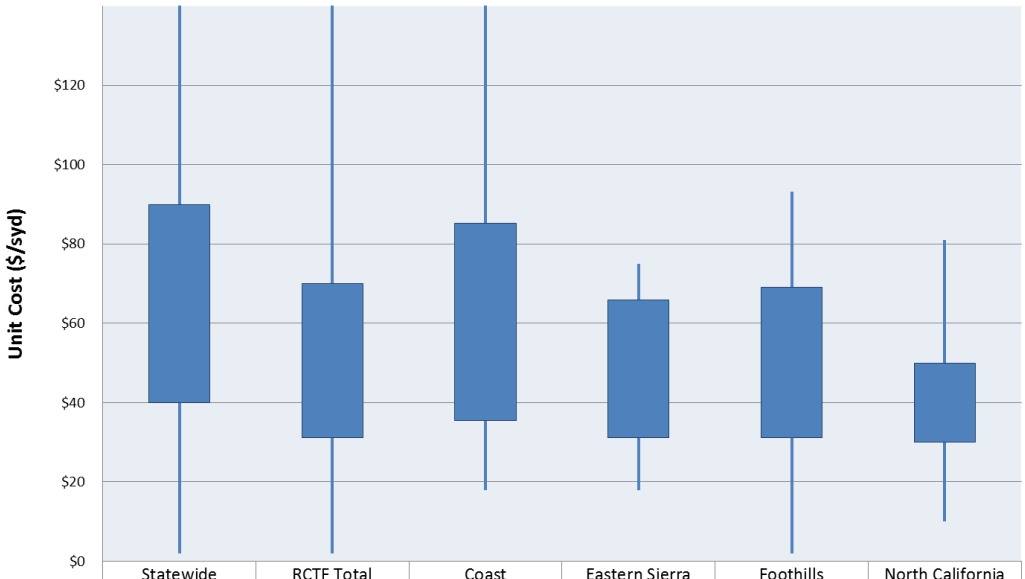
	Statewide	RCTF Total	Coast	Eastern Sierra	Foothills	North California
Q3 (75%)	25.00	21.35	21.25	36.00	20.00	19.75
Max	96.00	36.00	30.00	46.00	25.00	96.00
Min	2.75	4.00	5.75	5.22	5.50	4.00
Q1 (25%)	12.50	10.00	12.50	13.60	12.10	7.05

Figure 2.4 Unit Cost Distribution by Region (Thin Overlay)



	Statewide	RCTF Total	Coast	Eastern Sierra	Foothills	North California
Q3 (75%)	37.40	35.00	36.20	50.00	35.00	23.04
Max	108.00	54.00	40.00	54.00	37.80	100.00
Min	2.25	5.75	11.50	10.50	15.00	5.75
Q1 (25%)	20.00	19.36	20.00	28.24	20.00	14.95

Figure 2.5 Unit Cost Distribution by Region (Thick Overlay)



	Statewide	RCTF Total	Coast	Eastern Sierra	Foothills	North California
Q3 (75%)	90.00	70.00	85.23	65.87	69.00	50.00
Max	250.00	150.00	150.00	75.00	93.17	81.00
Min	2.06	2.06	18.00	18.00	2.06	10.00
Q1 (25%)	40.00	31.23	35.50	31.23	31.25	30.00

Figure 2.6 Unit Cost Distribution by Region (Reconstruction)

To determine whether there was a statistically significant difference between the mean unit costs from the four regions, an independent t-test was performed for each pavement treatments with significance levels (alpha value) of 0.05. When the t-value is less than 0.05, this indicates that the two groups have significantly different means. If not, it means there is no significant difference between two groups of data.

The t-test results are shown in Table 2.4. It indicates that there are significant differences between the reconstruction unit cost between the Coastal and other regions, as well as in the thin overlay unit cost between the Eastern Sierras and Foothills. There were no significant differences for any other unit costs in the other regions.

A second t-test was performed to determine if there were significant differences in the unit costs between the Statewide and the RCTF agencies. These results are shown in Table 2.5; they indicated that there were significant differences for preventive maintenance, thick overlay and reconstruction but not for thin overlays.

Table 2.4 t-Test Results Between Regions For Each Pavement Treatment

		Coast	Eastern sierra	Foothills	North California
Preventive Maintenance	Coast	--	0.2897	0.7714	0.5855
	Eastern sierra		--	0.3209	0.3382
	Foothills			--	0.8309
	North California				--
Thin Overlay	Coast	--	0.0788	0.5339	0.9058
	Eastern sierra		--	0.0496	0.2270
	Foothills			--	0.7402
	North California				--
Thick Overlay	Coast	--	0.2305	0.8199	0.5931
	Eastern sierra		--	0.2719	0.2081
	Foothills			--	0.5312
	North California				--
Reconstruction	Coast	--	0.0323	0.0316	0.0019
	Eastern sierra		--	0.7547	0.3387
	Foothills			--	0.1378
	North California				--

Table 2.5 t-Test results Between Statewide and RCTF Unit Costs

Unit Cost	RCTF	Statewide	% Difference	t-value (<0.05)
Preventive Maintenance	$3.46	$4.74	-27%	0.0010
Thin Overlay	$18.17	$19.52	-7%	0.2929
Thick Overlay	$27.12	$30.14	-10%	0.0495
Reconstruction	$53.94	$66.13	-18%	0.0002

From the statistical analyses described above, the unit costs for the RCTF agencies are significantly lower than the Statewide averages, and therefore will be used for the analyses. However, there were insufficient data to distinguish between the data by geographical regions; therefore, only the average unit costs from all RCTF agencies are utilized in this study.

Table 2.6 shows the unit costs that are used for each treatment by functional class and pavement treatment. As can be seen, the major roads have a higher cost than local roads.

Table 2.6 Unit Cost Used by Pavement Treatments and Road Classifications

Pavement Treatment	Unit Cost ($/sy)	
	Major Roads	Local Roads
Preventive Maintenance	$3.85	$3.15
Thin Overlay	$17.50	$15.75
Thick Overlay	$27.50	$24.85
Reconstruction	$57.10	$50.95

2.4.3 Unpaved Roads

As noted earlier, the agencies within the 26 rural counties own and maintain 24,017 centerline-miles of local streets and roads. Unpaved roads (gravel or dirt surfaced) comprise 16.1% of the total area. In some rural counties, the percentage of unpaved pavement is more than 50%, such as in Alpine County (61% unpaved) and Mono County (66% unpaved).

From the responses in the statewide survey, the average cost for unpaved road maintenance is $9,800 per centerline mile per year. Since pavement management software like StreetSaver™ only analyzes paved roads, the average cost of unpaved roads form the survey was used separately for the needs assessment.

2.5. Average Network Condition

Based on the results of the statewide survey and Mariposa County's data, the current pavement condition of rural counties is 58. This is in contrast with the statewide average of

The average PCI for the rural counties is 58, which is lower than the statewide average of 66.

66. To illustrate what PCIs really mean, Figure 2.7 includes photos of various roads with a range of PCIs.

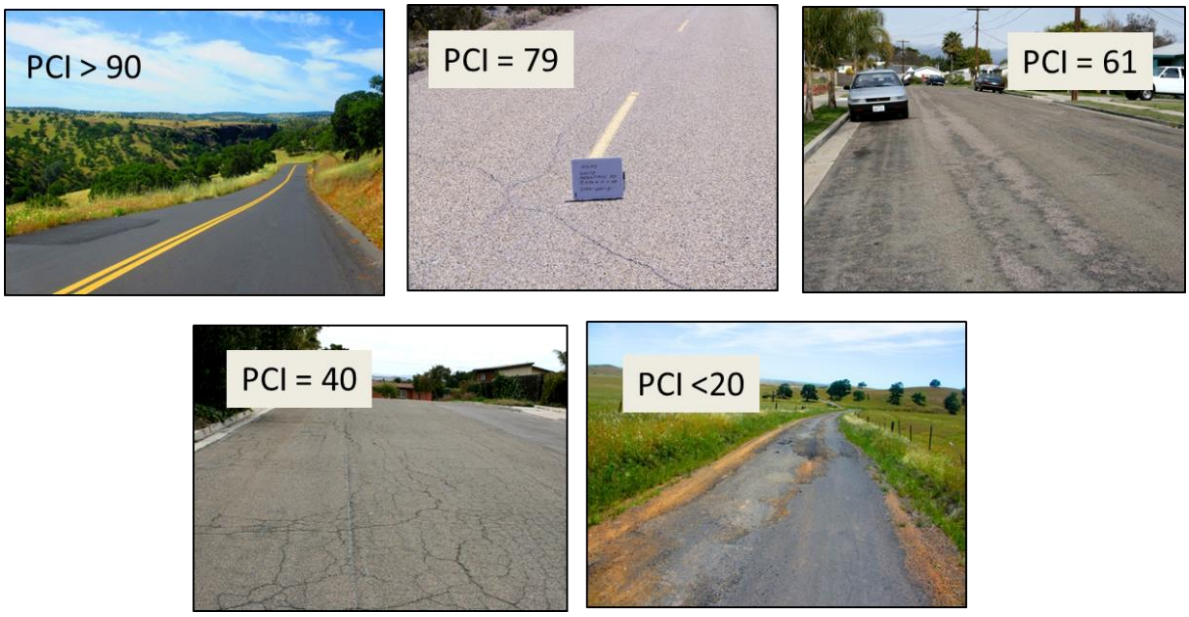


Figure 2.7 Examples of Roads with Different PCIs

Table 2.7 includes centerline miles, total lane miles, total area, and the average pavement condition index (PCI) for each county (includes cities and within the county). This is weighted by paved pavement area, i.e., longer roads have more weight than short roads when calculating the average PCI. Nevada County has the best pavements, with an average of 71. Unfortunately, Amador County remains the lowest ranked county, with an average PCI of 33. Appendix C includes maps of each county that illustrates the average PCI for each city and county.

Again, it should be emphasized that the PCI reported is only the ***weighted average*** for each county and ***includes*** the cities within the county. This means that Amador County and the cities may well have pavement sections that have a PCI of 100, although the average is 33. The map in Figure 2.8 illustrates the average PCI for each county.

Table 2.7 Summary of Inventory & Condition Data by County (including Cities)

County	Centerline Miles	Total Lane Miles	Total Areas (Square Yard)	Average Weighted PCI*
Alpine	135	270	1,900,800	44
Amador	478	958	6,485,201	33
Calaveras	717	1,333	8,937,332	51
Colusa	987	1,524	12,503,304	62
Del Norte	324	644	5,334,695	63
El Dorado	1,253	2,508	21,671,673	63
Glenn	910	1,822	13,917,626	68
Humboldt	1,471	2,933	24,234,864	64
Inyo	1,135	1,803	13,700,999	62
Lake	753	1,494	9,997,345	40
Lassen	431	879	6,282,324	66
Mariposa**	1,122	561	3,949,440	53
Mendocino	1,124	2,256	16,004,034	35
Modoc	1,491	2,983	17,545,534	46
Mono	727	1,453	10,071,369	67
Monterey	1,779	3,726	33,599,361	50
Nevada	802	1,617	10,370,868	71
Placer	1,986	4,194	34,182,680	69
Plumas	704	1,409	11,409,902	64
San Benito	452	916	5,951,814	48
Santa Cruz	874	1,790	14,190,207	57
Sierra	398	799	3,669,765	45
Siskiyou	1,519	3,050	20,519,624	57
Tehama	1,197	2,401	15,834,143	62
Trinity	693	1,114	11,757,354	60
Tuolumne	553	1,116	8,200,702	47
Totals	**24,017**	**45,551**	**342,222,958**	**58**

*PCI is weighted by area

**Mariposa County has updated data from 2014 surveys

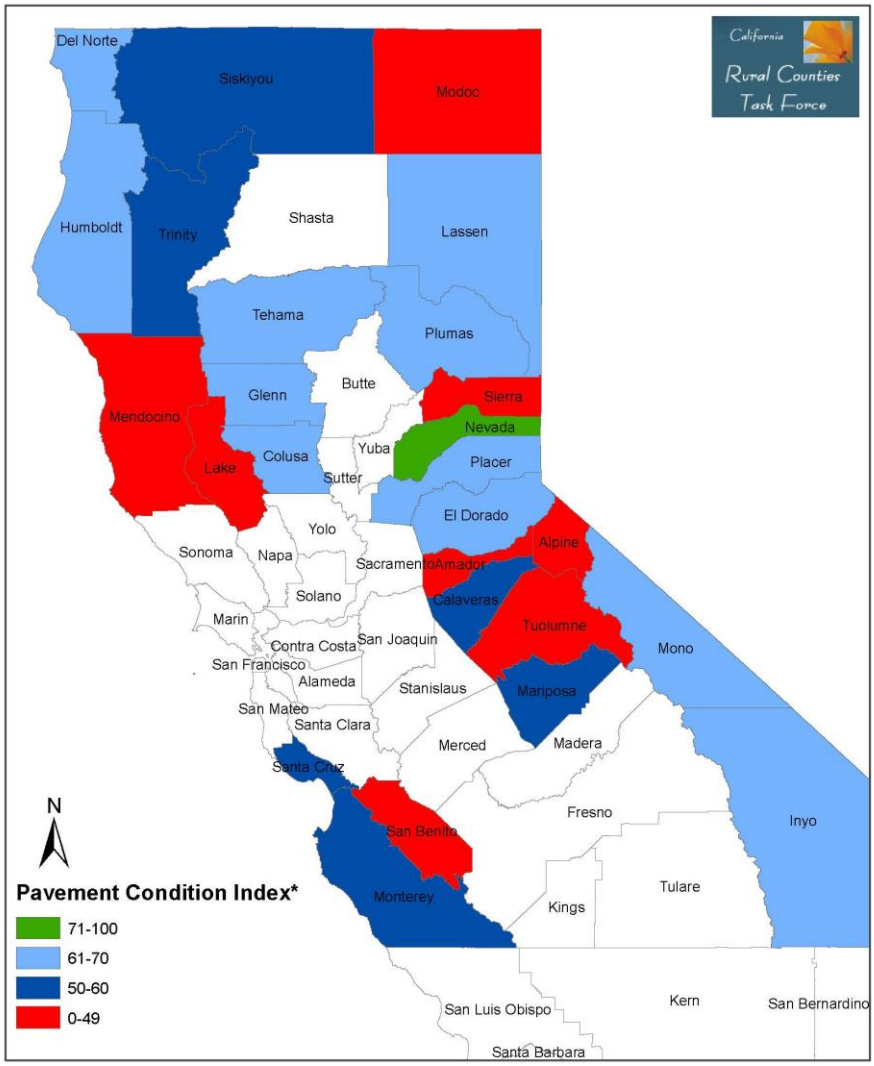


Figure 2.8 Average Weighted PCI By County

Figure 2.9 illustrates a generalized pavement deterioration curve. In general, an average pavement condition of 58 is in the "At Risk" category. At this point, the pavement life cycle will deteriorate rapidly; if repairs are delayed by just a few years, the costs of the proper treatment will increase significantly, as much as five times. The financial advantages of maintaining pavements in good condition are many, including saving the taxpayers' dollars with less disruption to the traveling public, as well as environmental benefits.

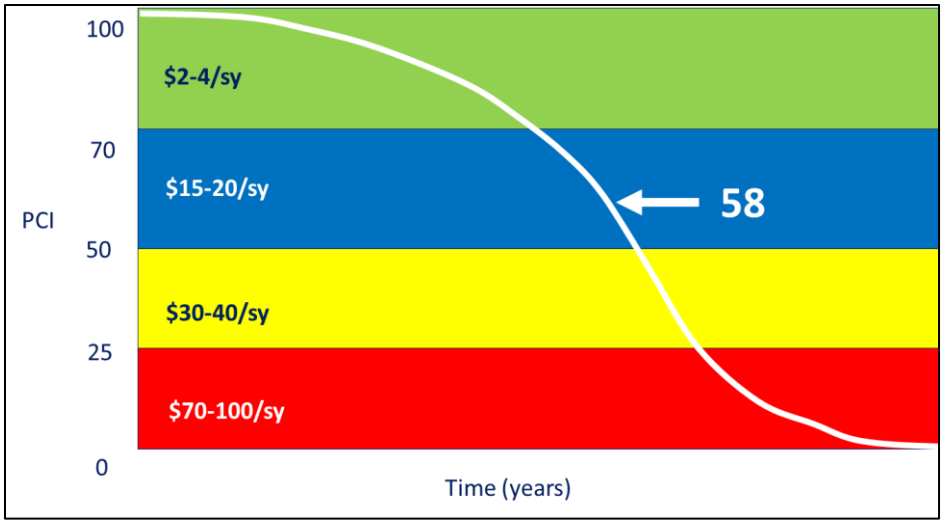


Figure 2.9 Generalized Pavement Life Cycle Curve

Many factors contribute to this rapid deterioration in pavement condition and they include:

- More traffic and heavier vehicles;
- More transit and more frequent bus trips, including heavier buses;
- Heavier and more garbage collection trucks (recycling and green waste trucks are new weekly additions to the traditional single garbage truck);
- More street sweeping for National Pollutant Discharge Elimination System (NPDES) requirements; and
- More freight and delivery trucks when the economy is thriving.

2.6. Pavement Management Software

A total of 67 agencies indicated that they used a pavement management system (PMS), which covers approximately 96 percent of the total centerline miles of rural counties. The remaining four percent indicated that they did not use a PMS. The main reason cited was that either no funding or staff were available. Figure 2.10 shows the types of PMS software used; 55 percent use StreetSaver, 19 percent use MicroPaver and 8 percent use Cartegraph.

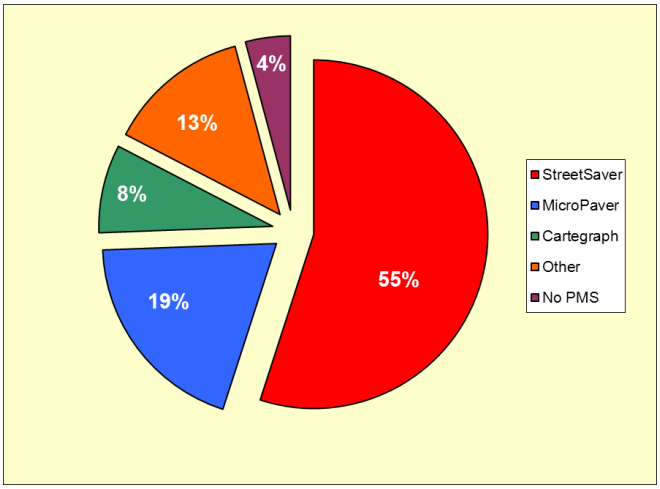


Figure 2.10 PMS Software Used in Rural Counties

3. Pavement Needs

3.1. Local Roads

The methodology for determining the pavement needs and the unfunded backlog is conceptually simple and is detailed in Appendix B. Essentially, four main elements are required in the analysis:

- Existing condition, i.e., PCI;
- Appropriate treatment(s) to be applied from decision tree and unit costs;
- Performance models; and
- Funding available during analysis period.

Once the PCI of a pavement section is known, a treatment and unit cost can be applied. This is performed for all sections within the 20-year analysis period. A road section may receive multiple treatments within this time period, e.g., Main Street may be overlaid in Year 1, and then sealed in Year 5 and again in Year 10.

The deferred maintenance or "unfunded backlog" is defined as work that is needed, but is not funded. It is possible to fully fund ***all*** the needs in the first year, thereby reducing the backlog to zero. However, the funding constraint for the scenario is to achieve the best management practices (BMP) goal within 20 years. Assuming a constant annual funding level for each scenario, the unfunded backlog will gradually decrease to zero by the end of 20 years.

The needs calculation also includes maintenance of unpaved roads. As noted in Section 2.4.3, the average cost to maintain unpaved roads is estimated to be $9,800 per centerline mile per year. The unpaved road needs were added to the paved road needs.

The results are summarized in Table 3.1 and indicate that $9.8 billion is required to achieve the BMP goal in 20 years. Again, this is in constant 2014 dollars. Detailed results by agency are included in Appendix D.

The maps in Figure 3.1 illustrate the needs by county as well as by population. The map on the left highlights the total ten- year paving needs for every county in California – the darker the color, the higher the needs. (Ten year needs was used for comparison as this data was available for the other counties from the 2014 Statewide Needs[3] report.)

The map on the left shows that rural counties, overall, have lower needs than the rest of the state – they range from $47 million to $1.2 billion, compared to needs of more than $10 billion for Los Angeles County. However, when compared on a per capita basis (see map on right), a rural resident shoulders a much greater burden of the needs, as much as 14 times as an urban resident! This is a trend that is a result of the mileage and population distribution previously discussed in Section 1.3.

[3] California Local Streets & Roads Needs Assessment – 2014 Update. Available at www.SaveCaliforniaStreets.org.

Table 3.1 Summary of Local Pavement Needs by County (20 Years)

County	Total Centerline Miles	Total Lane Miles	Total Area (sq. yards)	2014 Average PCI	Pavement Needs ($ million over 20 years)
Alpine	135	270	1,900,800	44	**$47.6**
Amador	478	958	6,485,201	33	**$292.9**
Calaveras	717	1,333	8,937,332	51	**$318.3**
Colusa	987	1,524	12,503,304	62	**$316.9**
Del Norte	324	644	5,334,695	63	**$130.1**
El Dorado	1,253	2,508	21,671,673	63	**$566.4**
Glenn	910	1,822	13,917,626	68	**$348.6**
Humboldt	1,471	2,933	24,234,864	64	**$614.8**
Inyo	1,135	1,803	13,700,999	62	**$344.0**
Lake	753	1,494	9,997,345	40	**$371.7**
Lassen	431	879	6,282,324	66	**$171.9**
Mariposa**	1,122	561	3,949,440	53	**$195.2**
Mendocino	1,124	2,256	16,004,034	35	**$557.4**
Modoc	1,491	2,983	17,545,534	46	**$541.2**
Mono	727	1,453	10,071,369	67	**$189.0**
Monterey	1,779	3,726	33,599,361	50	**$1,175.4**
Nevada	802	1,617	10,370,868	71	**$240.0**
Placer	1,986	4,194	34,182,680	69	**$766.4**
Plumas	704	1,409	11,409,902	64	**$230.7**
San Benito	452	916	5,951,814	48	**$216.3**
Santa Cruz	874	1,790	14,190,207	57	**$431.3**
Sierra	398	799	3,669,765	45	**$124.3**
Siskiyou	1,519	3,050	20,519,624	57	**$587.1**
Tehama	1,197	2,401	15,834,143	62	**$430.4**
Trinity	693	1,114	11,757,354	60	**$331.4**
Tuolumne	553	1,116	8,200,702	47	**$308.0**
Totals	**24,017**	**45,551**	**342,222,958**	**58**	**$ 9,847.4**

*PCI is weighted by area

**Mariposa County data from 2014 inspections.

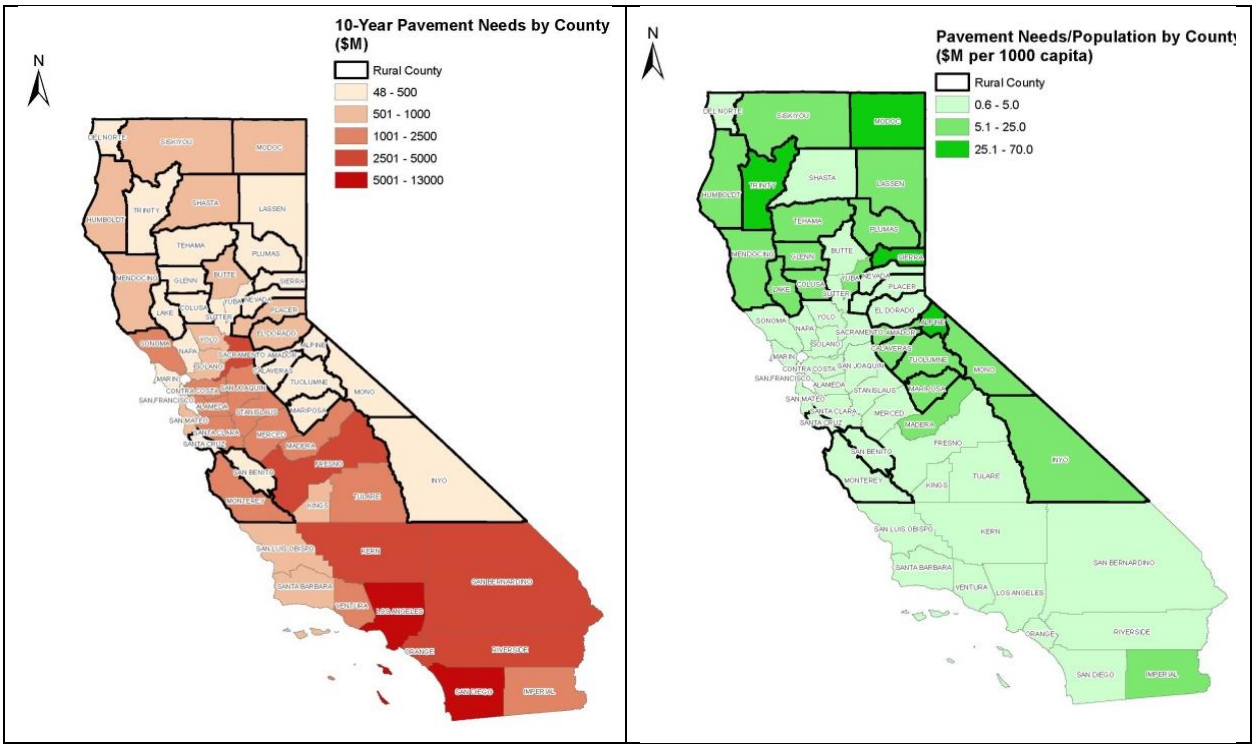


Figure 3.1 Pavement Needs by County and Per Capita

3.2. State Highways

The state highway system is an integral component of the transportation system in rural counties. In many cases, they provide the only access for isolated communities to commercial centers such as grocery stores or schools.

The California Department of Transportation (Caltrans) is responsible for maintaining and operating the state highway System. Caltrans monitors highway system conditions and performance through periodic inspections, related traffic studies, and system analysis. Information obtained from these studies is used to prepare the Ten-Year State Highway Operation and Protection Program Plan (SHOPP Plan). The SHOPP plan is released annually and provides input for funding distribution in the State Transportation Improvement Program (STIP) fund estimate.

The pavement needs for state highways in rural counties were provided by the Caltrans Division of Maintenance. Since the SHOPP is based on ten year analysis period, only ten year needs were available and these are summarized in Table 3.2. A total of $732.1 million is required for the 26 rural counties; approximately 22 percent are allocated for rehabilitation projects, and 78 percent for preventive maintenance.

Table 3.2 Summary of State Highway Needs by County (Ten Years)

County	Ten Year Pavement Needs ($ Million)		
	Rehabilitation Needs	Capital Preventive Maintenance Needs	Total Needs
Alpine	$ 1.4	$ 26.3	$ 27.7
Amador	$ 9.1	$ 17.9	$ 27.0
Calaveras	$ 35.6	$ 17.9	$ 53.5
Colusa	$ -	$ 27.7	$ 27.7
Del Norte	$ -	$ 4.1	$ 4.1
El Dorado	$ 4.7	$ 34.8	$ 39.5
Glenn	$ -	$ 22.2	$ 22.2
Humboldt	$ -	$ 58.0	$ 58.0
Inyo	$ -	$ 8.2	$ 8.2
Lake	$ -	$ 0.6	$ 0.6
Lassen	$ 20.2	$ 27.4	$ 47.6
Mariposa	$ 21.3	$ 13.2	$ 34.5
Mendocino	$ 23.2	$ 107.6	$ 130.8
Modoc	$ 0.2	$ 5.7	$ 5.9
Mono	$ 4.3	$ 34.1	$ 38.3
Monterey	$ -	$ 12.4	$ 12.4
Nevada	$ -	$ 5.3	$ 5.3
Placer	$ -	$ 5.2	$ 5.2
Plumas	$ 24.0	$ 25.9	$ 49.9
San Benito	$ 3.7	$ 28.9	$ 32.6
Santa Cruz	$ 1.2	$ -	$ 1.2
Sierra	$ 3.0	$ 4.4	$ 7.4
Siskiyou	$ -	$ 42.6	$ 42.6
Tehama	$ -	$ 6.7	$ 6.7
Trinity	$ 10.5	$ 27.8	$ 38.3
Tuolumne	$ -	$ 4.7	$ 4.7
Total	**$ 162.5**	**$ 569.6**	**$ 732.1**

3.3 Sustainable Pavement Practices

Finally, as a side note, sustainability is a growing factor to be considered for many local agencies, particularly if it saves costs. Cities and counties were asked for information on any sustainable pavement practices employed and the estimated cost savings, if any. The types of sustainable practices that were mentioned included:

- Reclaimed asphalt pavement (RAP)
- Cold-in-place recycling (CIR)
- Full depth reclamation (FDR)
- Pavement preservation strategies
- Warm mix asphalt (WMA)
- Rubberized hot mix asphalt (RHMA)
- Porous/pervious pavements

A total of 60 rural agencies responded with some information on different types of sustainable practices (see Table 3.3). However, of the agencies who responded, very few provided information on cost savings or additional costs. Therefore, the average cost savings in Table 2.8 should be used with caution, as they may not be representative of the counties as a whole.

However, it is worth noting that in the statewide update, over 300 agencies provided information on sustainable pavement strategies. Cold in-place recycling (CIR), full depth reclamation (FDR) and pavement preservation strategies were reported to have the highest cost savings when compared with conventional treatments, in the order of 30 percent, 32 percent and 35 percent, respectively. This trend is similar to rural counties.

Table 3.3 Summary Responses on Sustainable Pavement Strategies

Sustainable Pavement Strategies	No. of Agencies			Average % Savings	Average % Additional costs
	No. of Responses	Savings	Add'l Costs		
Reclaimed AC Pavement (RAP)	16	2	-	5%	-
Cold in place recycling (CIR)	12	4	-	26%	-
Full depth reclamation (FDR)	20	2	-	10%	-
Pavement Preservation	29	3	4	30%	-
Warm mix asphalt (WMA)	16	1	-	10%	-
Rubberized HMA (RHMA)	13	1	3	20%	40%
Porous/Pervious pavements	4	-	-	-	-

4. Performance Measures

This report would not be complete without a section that discusses performance measures. Since MAP-21 was signed in 2012, many discussions with the FHWA, Caltrans and among RTPAs have been held around performance measures. While no definitive guidelines have yet been released, it is worthwhile to include some background on typical measures that are applicable (or not) to local road networks.

4.1. Overview of Performance Measures

This section discusses pavement performance measures in general, and includes recommendations for performance measures that are applicable to local agencies in California.

The most recent Federal Highway Bill, known as MAP-21, introduced the concept of "performance measures", by which highway agencies would periodically measure conditions within their highway network, set performance targets, and asses their progress towards meeting those targets. Performance measures that are applicable to state highway agencies were to be established by the Federal Highway Administration (FHWA) in 2014. In January 2015, the FHWA published a notice of proposed rulemaking (NPRM) for comments. This is further discussed in Section 4.2.8.

In order to be of use for planning decisions, a performance measure must be:

1. **Meaningful**: The performance measure must be closely related to either the user's experience of the road (e.g. in terms of safety, comfort or vehicle operating costs) or agency maintenance costs. Ideally the performance measure can also be used, either by itself or in combination with other performance measures, to predict future conditions.

2. **Repeatable and Reproducible:** Repeatability is the ability of a single rater (or equipment) to consistently measure the same value for the same condition. Reproducibility is the ability of different raters (or equipment) to independently measure the same value for the same condition. Both are important for pavement performance measures, and need to be evaluated in the context of the sensitivity of the measure as used in the decision making process. Repeatability is related to the accuracy of the measurement technique, and has two important effects:
   - How likely will error in the measurement result in an incorrect management decision? For example, can the level of error result in incorrectly assigning a rehabilitation treatment to a section that only requires preventative maintenance.
   - How likely will error in the measurement mask important trends over time? If the level of error is large compared to the expected change in performance over time, a section that is rapidly deteriorating may be overlooked. Conversely, a section that is performing well may be incorrectly assessed as deteriorating.

Reproducibility adds in several other effects:

- Are conditions being measured uniformly throughout the agency's network?
- Is data being collected consistently over time, so that trends in condition can be evaluated?
- Can the one agency's data be compared to another agency's?

3. **Economical:** Even very small local agencies may be responsible for dozens of lane-miles of roadway, and the average network size for local agencies in California is 595 lane-miles. Clearly, any selected performance measure must be able to be measured at a reasonable cost per mile in order to be affordable when applied to the entire network.

Pavement data collection has traditionally been categorized as "project-level" and "network-level". Project-level data collection is focused on design. Network-level data collection is focused on project selection, as well as monitoring overall network health. While the same or similar performance measures may be used at both project and network levels, often the sampling interval, reporting interval or other factors are varied to reflect differences in the usage of the data as well as funds available for data collection.

The *AASHTO Pavement Management Guide*[4] discusses three general categories of performance measures:

1. *Distress: observations of visible conditions on or along the pavement surface provide either direct identification of the cause of performance problems or are indications of underlying performance problems. Distress information is particularly helpful in selecting specific pavement preservation and rehabilitation treatments and in planning long-term management programs.*

2. *Surface characteristics: measurements of a pavement's longitudinal profile or smoothness, surface texture (for frictional purposes) and noise are all performance measures that relate to customer concerns. A pavement may be free from most visible distresses and have good structural capacity but still exhibit surface characteristics warranting some sort of surface repair.*

3. *Structural capacity: the load-carrying capability of a pavement can be determined several different ways. Available tools measure a pavement's response to applied loads, identify sub-surface conditions that may lead to structural problems (such as sub-surface voids or moisture and poor load transfer), and provide indirect measurements of intrinsic strength/stiffness properties. Poor structural capacity indicates that major rehabilitation or reconstruction is needed.*

[4] *Pavement Management Guide*, American Association of State Highway and Transportation Officials (AASHTO), 2nd Edition, 2012.

4.2. Examples of Performance Measurements

4.2.1. Pavement Distress

The most common types of pavement performance measures are based on pavement distress. These measures can include direct use of distress quantities, such as total length of cracking, or an *index* computed from weighted quantities of multiple distress types.

The most commonly used distress index is the Pavement Condition Index (PCI). It should, however, be noted that while there is an ASTM standard method for measuring PCI (ASTM D6433[5]), other methods exist which also use the term PCI. Some, such as the Metropolitan Transportation Commission (MTC StreetSaver) and Department of Defense methods, are similar to the ASTM method, while others are not.

A manual ASTM PCI survey is relatively labor-intensive, and involves precise measurement of the observed quantities of 20 or more different distress types. This labor is somewhat offset by the use of a sampling methodology, so that the entire pavement surface need not be surveyed if conditions are relatively uniform. The labor required is semi-skilled – while an engineering or technical background is not required, training is required in order to properly identify distresses and measure them appropriately. Manual PCI surveys of multi-lane facilities can be problematic, requiring either lane closures or estimation of distress quantities with a lower degree of precision. Night-time PCI surveys require artificial lighting – this is generally only performed for airports.

Direct measurement of cracking quantities is currently reported in the FHWA Highway Performance Monitoring System (HPMS). Total "cracking length" is reported in feet per mile. This is only reported for asphalt-surfaced pavements, and is measured as the combined length of transverse and reflective cracks. HPMS also includes "cracking percent", which for asphalt surfaced pavements is the percent of the pavement area that is affected by fatigue cracking. For concrete pavements this is reported as the percent of slabs with cracks. While simple and economical to measure, these HPMS measures are very lacking in utility compared to a PCI survey. Cracks are measured without regard to severity levels, whereas in a PCI survey, cracking quantities are measured separately for each of three different severity levels. In addition, the HPMS data set is lacking important and common distress types such as longitudinal cracking, patching, potholes and raveling.

In addition to field distress surveys, by which a human rater directly observes and measures distresses in the field, there are several digital imaging and machine vision technologies that have been developed for surveying pavement distresses. All of these involve taking a continuous digital image of the pavement surface from a moving vehicle. Newer systems typically use a linescan camera, although some systems take pictures with a conventional digital camera and stitch the images together. This image may be augmented with a high-resolution digital elevation profile, measured using a scanning laser mounted on the same vehicle.

[5] ASTM D6433-11, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys.

Analysis of these digital images can be performed manually, semi-automatically, or automatically. An example of digital images and analysis was shown in Figure 4.1. Manual analysis involves a human rater identifying and classifying distresses observable in the image. Automated analysis involves a computer algorithm identifying and classifying distresses observable in the image. Semi-automated analysis involves a human rater closely reviewing the algorithm's output and correcting and/or adjusting algorithm parameters as necessary. Semi-automated analysis may also include automated detection of some distresses, and manual detection of others.

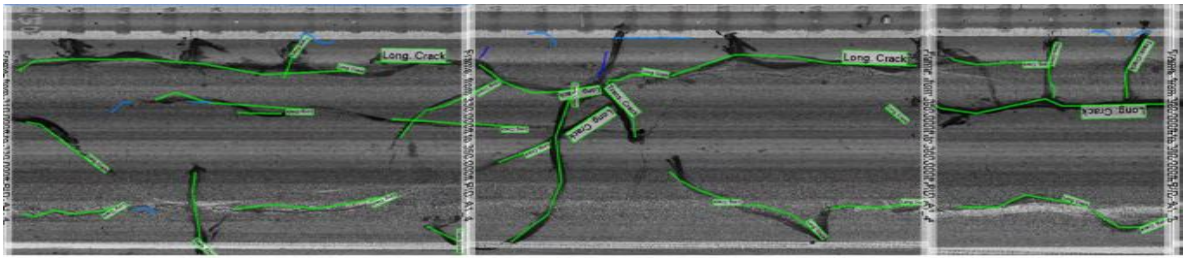


Figure 4.1 Example of Digital Image and Distress Analysis

The development of automated pavement distress detection, classification and measurement systems is an active area of research, and improvement in equipment and algorithms is ongoing. However performing a PCI survey using digital images still requires manual analysis or semi-automated analysis with significant human intervention. Some distresses, such as raveling, are difficult or impossible to perform using digital images, regardless of the degree of human involvement.

Rutting can be considered a distress or a surface characteristic. Rutting is included as a distress in most distress survey methods, including the ASTM and MTC PCI methods. In these methods, rutting is rated as low, medium or high severity. Rutting can also be measured quantitatively by high speed equipment, often in concert with roughness measurements. Rutting is surprisingly difficult to objectively define, and different equipment and/or analysis techniques (such as virtual straight edge versus virtual string line) can yield different answers.

4.2.2. Surface Characteristics

Surface characteristics relate to the geometry of the pavement surface, and its deviation from a true planar surface. This geometry is generally known as "texture". These characteristics are responsible for the functionality of a pavement and how it serves the traveling public through effects such as friction, noise, tire and vehicle wear and ride quality.

Different classifications of texture are defined based on wavelength. Common classifications include microtexture, macrotexture, megatexture and roughness. An illustration of these classifications and their effect on vehicles is shown in Figure 4.2.

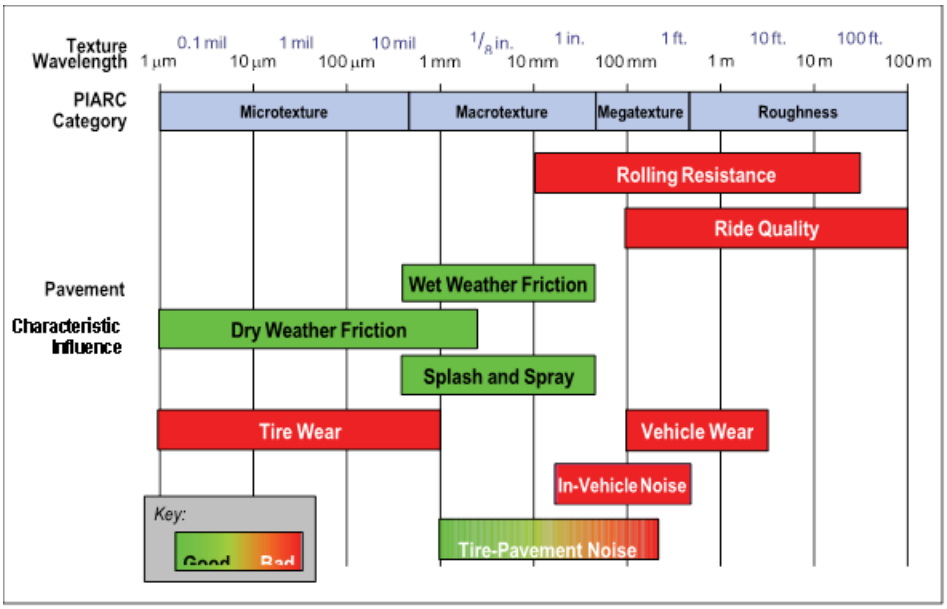


Figure 4.2 Texture Definitions and Their Influence on Functionality (*Rasmussen et al. 2011*)

Texture can be directly measured using a profilometer; however not all profilometers are capable of measuring all relevant wavelengths of texture. Profilometers are most commonly used to measure roughness, and calculation methods and indices such as the International Roughness Index (IRI) for determining roughness based on pavement texture are well established. The measurement of shorter texture wavelengths requires higher sampling rates and more tightly focused lasers than most profilometers' capabilities. Texture can also be measured by static system (Sand Patch Test, ASTM Standard E965) or dynamic system (Circular Track Texture Meter, ASTM Standard E2157). The index to evaluate texture at a specific spot is Mean Texture Depth (MTD). In addition, methods for determining friction and noise characteristics of pavements based on texture measurements are currently not well established.

4.2.3. Roughness

Pavement roughness measurement devices can be categorized as response-type devices and profile measurement devices. Response-type devices directly measure vertical motion of a vehicle as it travels down the road, typically in terms of accumulated suspension travel. Response-type devices are simple and intuitive, but the measurements are highly vehicle dependent and are therefore poorly reproducible, and even vary over time for the same vehicle due to wear in the suspension system, tire pressure variations and other factors. Response-type devices have been largely supplanted by profile measurement devices.

Profile measurement devices measure the elevation of the pavement surface, typically along the wheel paths. This profile can be used to determine roughness using an algorithm. Profile can be measured using low-speed devices such as a rod-and-level, dipstick, California Profilograph or various walking profilers. These devices may be used for construction quality acceptance or calibration of high-speed profilers, but are impractical for network evaluation.

Figure 4.3 High Speed Profiler

High speed profilers measure profile using lasers or ultrasonic sensors to measure the distance from the vehicle body to the pavement surface, and accelerometers to subtract out suspension movement. The upper speed limit for laser-based systems is only limited by the speed of the data acquisition system – for modern computer hardware this speed limit is far in excess of highway speeds, unless the system is collecting very high-frequency microtexture data. High speed profilers do have difficulty collecting accurate data at slow speeds, and 15 mph is usually considered the minimum speed for data collection. This can cause problems in urban areas with traffic lights or stop signs. This can also cause problems with short road sections, especially those in residential areas with cul-de-sacs.

Highly textured surfaces such as chip seals or open graded friction courses can also pose problems for profilers. Ultrasonic height sensors can experience significant problems due to poor sound reflection or multiple echoes. These problems are considered unavoidable with ultrasonic sensors. Laser height sensors can have difficulties due to aliasing effects. Solutions to this problem for laser sensors include increasing the sampling rate or increasing the image size.

Highly cracked surfaces can also pose problems for profilers. The image projected by a laser is small enough to enter a crack. With a longer sampling interval, the crack may be miss-interpreted as a wider depression that has far more effect on roughness than the actual crack. Even with a very short sampling interval, the commonly used filtering algorithms will still result in cracks being interpreted as depressions, with the effect of overestimating the contribution of the crack to roughness.

By far the most common method for computing roughness based on profile is the International Roughness Index (IRI). IRI is the roughness index used in the FHWA HPMS. It was originally developed by the World Bank specifically for measuring and comparing conditions in developing nations. This required an index capable of being used over a very broad range of conditions. IRI is computed by simulating a specific vehicle (the “golden car”) driving over the measured profile, and calculating the accumulated suspension movement. In the US, this movement is typically expressed in inches per mile (i.e. inches of body movement per mile driven). In most other countries, IRI is reported in meters per kilometer. As this car is simulated, its properties can be exactly duplicated, allowing for far better reproducibility than real vehicle responses.

Ride Number (RN) is another roughness index used by some agencies in the US. RN was developed to better predict how the public would rate a pavement on a 0 to 5 scale, with 0 being the worst and 5 being the best. This scale, which is often called *Present Serviceability Rating,* is highly relevant to the AASHTO empirical pavement design methodology. Unlike IRI, RN is not an open-ended scale, and differences between rough pavements appear much smaller on the RN scale than on the IRI scale. In addition, as RN is the result of a non-linear transform, averaging RN data is problematic. For example, the RN computed for a 1 mile segment is not the same as the average of RN computed for the first 0.5 mile and the last 0.5 mile.

4.2.4. Friction

Friction between a tire and pavement can be directly measured with various devices. The mostly common used device on highways in the US is the locked-wheel skid trailer, with a test method defined in ASTM E274. Different agencies test at different intervals, but between 1 and 10 tests per mile is typical. This test is relatively slow and requires traffic control. Although approximately half of the state highway agencies in the United States regularly test their networks, they are generally reluctant to share data due to potential liability issues. Friction data is not reported to the FHWA HPMS.

Figure 4.4 Locked-Wheel Skid Trailer

Profile-based friction indices are an active area of research. These have the potential of providing continuous, faster and cheaper measurements compared to skid testing. However, as of yet there are no widely accepted indices.

4.2.5. Noise

Pavement noise is generally measured with off-the-shelf microphones and sound meters. While this data can be collected quickly and cheaply, there are some vehicle and especially tire-related dependencies that have yet to be addressed through standardization. As with friction, profile-related noise indices are an area of active research, but have not yet resulted in any accepted methods. Noise data is not reported to the FHWA HPMS.

Figure 4.5 Noise Measurement Device

4.2.6. Pavement Structure

Pavement structure performance parameters, such as pavement stiffness, may be considered primarily as a way to improve the prediction of future conditions. In and of themselves, they are not useful for describing network health. Pavements are designed for specific traffic and environmental conditions, and a pavement with a high structural capacity should not necessarily be considered to be performing better than a pavement with a lower structural capacity. It may be that the stronger pavement is under-designed for its specific conditions while the weaker pavement is adequately designed for its conditions.

The primary non-destructive tools for evaluating pavement structure are Falling Weight Deflectometer (FWD) and ground-penetrating radar (GPR). Neither is typically considered a network-level testing tool, although a few state highway agencies perform network-level FWD testing. An FWD must stop to perform testing, requiring traffic control and resulting in a low rate of production. GPR is typically used to measure the thickness of pavement layers, which do not change appreciably as a pavement deteriorates. GPR can also be used to detect sub-surface cracking and moisture damage; however this currently requires interpretation by an expert, and is not suitable for high-volume applications.

Figure 4.6 High Speed Deflectometer

There are currently two different types of high-speed deflectometers undergoing evaluation by FHWA. Both of these devices are tractor-trailer units, which measure pavement deformation in front the trailer axle. Ideally, these devices will be used in the future to produce pavement stiffness data similar to that

produced by an FWD, but continuously and at high speed, with no need for traffic control. At the network level, the results may be used to improve predictive models for other performance parameters or to track changes in structural condition over time.

4.2.7. Proposals from Other Agencies

While there has been much discussion of MAP-21 performance measures in general, there has been remarkably little discussion of specific performance measures for pavements.

4.2.7.1. San Diego Association of Governments

The San Diego Association of Governments (SANDAG) has produced a report on proposed performance measures for MAP-21[6]. For pavement condition for local streets and roads, this report states the following:

- *Pavement condition for local streets and roads: the Pavement Condition Index (PCI) can be used as a metric for distressed lane miles on local streets and roads.*
- *The process for calculating the PCI involves dividing the total pavement section into sample units, selecting certain sample units for testing using an industry standard. This method produces the PCI, which is a way of calculating the distressed quantities and the distressed densities for each tested unit. These values are used to determine a deduct value and this deduct value is subtracted from 100 to give the PCI value. A PCI value below 80 falls in the "at risk" or "poor" categories.*
- *Data Source: The California Statewide Local Streets and Roads Needs Assessment reports on the condition of local streets and roads by county using the PCI, which is calculated on a scale of 0 (failed) to 100 (excellent). This is weighted by the pavement area, which means that longer roads have more weight than shorter roads when calculating the average PCI. The report is updated every two years. Pavement monitoring systems currently in place that help manage PCI rankings are StreetSaver and MicroPaver.*

These recommendations appear to envision using a single weighted average PCI value to represent the entirety of each local agency's pavement network. They also appear to allow data collection using either the StreetSaver (MTC) or the MicroPaver methods.

4.2.7.2. AASHTO

AASHTO as an organization has not publically released recommendations for performance measures. However, the AASHTO Standing Committee on Performance Management has developed a list of recommended performance measures[7,8] for highways. The recommended performance measures are IRI (to be reported in 0.1 mile segments) and a Pavement Structural Health Index. The Pavement Structural Health Index is not defined, however the November 2012 report states that "AASHTO estimates that a Pavement Structural Health Index measure will be ready for implementation in the next 3 to 5 years".

[6] http://www.dot.ca.gov/hq/tpp/offices/ocp/ATLC/documents/august_15_2013/document_links/indicator.pdf
[7] http://scopm.transportation.org/Documents/SCOPM%20Task%20Force%20Findings%20on%20National%20Level%20Measures%20FINAL%20%2811-9-2012%29.pdf
[8] http://scopm.transportation.org/Documents/SCOPM%20Task%20Force%20Findings%20on%20Performance%20Measure%20Target-Setting%20FINAL%20v2%20%283-25-2013%29.pdf

With regards to standards and procedures, the report refers to "generally require[ing] HMPS protocols", indicating that this index may be computed from existing HPMS data types. The relevant HPS data types are:

- Rutting: Average rut depth to the nearest 0.1 inch (asphalt surfaced pavement only)
- Faulting: Average joint fault to the nearest 0.1 inch (jointed concrete pavement only)
- Cracking Length: Total length of transverse and reflective cracking in feet per mile (asphalt surfaced pavement only)
- Cracking Percent: Percent of pavement with fatigue cracking (asphalt surfaced pavement only), or percent of slabs with cracks (concrete pavement only)

Note that HPMS data is reported at 0.1 mile intervals for each highway in the network.

On the subject of IRI, it is relevant to note that the March 2013 report states that "Because IRI testing is not appropriate at low traffic speeds and may be adversely impacted by utilities, we do not recommend establishing targets for urban environments without further study."

4.2.8. MAP-21 Proposed Measures

In January 2015, the FHWA released the proposed rules for assessing pavement and bridge conditions for the National Highway Performance Program[9]. As described, the rule seeks to "[*establish] new requirements for performance management to ensure the most efficient investment of Federal transportation funds. …. As part of performance management, recipients of Federal-aid highway funds would make transportation investments to achieve performance targets that make progress towards national goals. The national performance goal for bridge and pavement condition is to maintain the condition of highway infrastructure assets in a state of good repair."*

Briefly, the proposed measures will apply to all highways and roads in the National Highway System (NHS). California has approximately 8,900 miles of Interstate highways and another 5,100 miles of local roads on the NHS. This rule will establish national measures for the pavement condition on the both the Interstate system as well as non-Interstate NHS. Four condition metrics have been proposed:

1. International Roughness index (IRI)
2. Percent of cracking
3. Rut depth
4. Faulting (for jointed Portland cement concrete)

The four condition metrics are already being collected by Caltrans for the Highway Performance Monitoring System (HPMS), and the NPRM proposes that this data be collected biennially for the non-Interstate NHS.

[9] *National Performance Management Measures: Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program; Proposed Rule,* Department of Transportation - Federal Highway Administration, Federal Register Vol. 80, No. 2, Released January 5, 2015.

Three additional data elements (through lanes, surface type and structure type) will also be collected.

Roughness or IRI, was previously discussed in Section 4.2.3 and will pose challenges on local roads, particularly those with chip sealed surfaces. It is possible that a newly chipped road will, under the proposed rule, be identified as in "poor condition". The next two metrics (cracking and rut depth) are usually collected on local roads but not in the same manner nor or the results calculated in the same fashion as those identified in the NPRM. The fourth (faulting) will affect few, if any, rural agencies since PCC pavements are uncommon.

If the state does not meet targets that have been set for the percent of roads in "good" or "poor" condition for two consecutive years, they will be subjected to financial penalties that include the transfer of Surface Transportation Program (STP) funds.

The NPRM states that the State DOT shall collect and report this required data; however, it is unclear if Caltrans will continue to collect this information for all local agencies.

4.3. Recommended Measures

4.3.1. Distress

The pavement condition index, or PCI, is in widespread use nationally as well as in California. This means that most agencies have a historical database of PCI data, and agencies and industry have knowledge of the data collection methods as well as interpretation of results. In California, approximately 64 percent of the agencies in California use PCI as their primary or only form of condition assessment (see table below). This represents almost 68 percent to the total miles.

Table 4.1 Local Agencies Using PCI Method for Condition Assessment

Pavement Condition	# of Local Agencies	% Local Agencies	Centerline Miles	% Miles
PCI method	346	64%	97,665	68%
Non-PCI measure	82	15%	37,748	26%
No PMS	75	14%	5,859	4%
No Response/Unknown	36	7%	2,439	2%
Totals	**539**	**100%**	**143,712**	**100%**

In the context of local agencies in California, PCI is the obvious choice for a pavement performance measure, although it should be noted that different areas of the State use slightly different methods of measuring PCI.

Care should be taken in assigning how agencies report PCI data. Use of a single agency-wide average value may mask underlying trends and promote poor maintenance decisions. Options include reporting PCI value by functional class, and reporting percentage of network with a PCI of 0-20, 20-40, 40-60, 60-80 and 80-100. A key network health measure is the trend in percent of network with a PCI of 80-100, indicating that the agency is implementing a preventative maintenance program.

4.3.2. Roughness

IRI has great value as an objective and rapidly collected measure that is closely related to the user's perception of a road's quality. However, profile measurements are currently not commonly performed on local agency roads in California. Very few local agencies are knowledgeable about profile measurements, and very few local contractors possess profilometers. In addition, profile measurement and analysis procedures have been mostly developed for large highway agencies, and urban roads, highly distressed roads and chip-sealed roads are known to be problematic.

At this time, use of IRI as a performance measure for local agency networks in California is impractical and not recommended. The only exception where it may be considered are rural arterials and major collectors.

5. Funding Analysis

5.1. Funding Sources

In the statewide survey, both revenue sources and pavement expenditures were provided by agencies for FY 2012-2013, FY-2013-2014, as well as estimates of an annual average for future years. A total of 59 agencies from the rural counties responded with financial data.

Cities and counties identified a myriad of sources of funds for their pavement expenditures, broadly categorized into federal, state, or local. They included the following:

Federal Funding Sources

- Community Development Block Grants (CDBG)
- Congestion Mitigation & Air Quality Improvement (CMAQ)
- Secure Rural Schools and Community Self-Determination Act
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- HSIP High Risk Rural Roads Set-Aside (HR3)
- Safe Routes to School (SRTS)
- Transportation Alternatives Program (TAP)
- Others such as emergency relief

State Funding Sources

- Gas taxes (Highway User Tax Account or HUTA)
- Bicycle Transportation Account (BTA)
- Proposition 1B: Local Streets and Roads Program
- State Transportation Improvement Program (STIP)
- AB 2766 (vehicle surcharge)
- Safe Routes to School (SR2S)
- AB 1546 Vehicle License Fees (VLF)
- CalRecycle grants
- Prop 1B: State Local Partnership Program (SLPP)
- State Water Resource Control Board
- Transportation Development Act (TDA)
- Traffic Safety Fund
- Transportation Uniform Mitigation Fee (TUMF)

Local Funding Sources

- Development Impact Fees (DIF)

- General Fund
- Local Transportation Fund (LTF)
- Redevelopment fees
- Local Sales Taxes

5.2. Pavement Funding

The financial data provided was first reviewed to ensure that the description matched the funding source (i.e. federal, state or local). In cases where the source did not match the description, the source was modified appropriately. Funds were also further categorized as gas tax, sales tax, general fund or other, based on the description. Funds and expenditures were then summed by agency and year. Agencies that reported funding or expenditures for some years but not others were further reviewed, and the data for reported years was used to estimate the data for unreported years.

Funds and expenditures for each agency were then divided by the number of lane-miles of roadway in that agency. The funding and expenditures data per lane-mile results were then reviewed for outliers. With the outliers removed, funding and expenditure data per lane mile were then averaged for cities and counties. These averages were used to determine the estimated total funds and expenditures for all cities and counties. Then the total expenditures and funds for these categories were then summed to determine pavement funding available for all counties.

Table 5.1 summarizes the percentage of funding sources from the different categories for FY 2008/09 to FY 2013/14 and the estimated funds available for future years.

Table 5.1 Funding Sources for Pavements

	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	Future
Federal	10%	23%	18%	16%	10%	11%	13%
State	62%	49%	53%	53%	52%	50%	54%
Local	28%	27%	29%	30%	38%	38%	34%

Note that federal funding was a significant component in 2009/10 and 2010/11, reflecting the influx of American Recovery and Reinvestment Act (ARRA) funding which occurred during the recession. Since then, the percentage of federal funds has fluctuated between 10 to 13 percent. This is an important item to note since it indicates that cities and counties, in general, do not rely heavily on federal funds. Rather, state and local funds typically make up almost 90 percent of pavement funding, with state funds as the predominant source at more than 50 percent.

The gas tax is the single largest funding source for cities and counties, yet this is projected to decline statewide and nationally.

The Highway User Tax Account (HUTA), more commonly known as the state gas tax, is by far the single largest funding source for cities and counties. Table 5.2 shows an increasing dependence on a revenue source that is projected to decline. Part of this is because of declining gas consumption due to more gas-efficient and electric vehicles,

and partly this is due to the additional responsibilities for most cities and counties e.g. compliance with the American Disabilities Act (ADA) in the form of curb ramps and sidewalk, which reduces the amount of funding available for pavements.

The rural counties are estimated to have $3 billion available in pavement funding over the next 20 years.

The resulting funding available for the rural counties is was determined to be approximately $3.08 billion over the next 20 years, or $154 million a year. The breakdown by county is shown in the next section.

5.3. Funding Scenarios

As noted before, databases were established in StreetSaver for each rural county. Based on an county's pavement condition and road characteristic (percentage of urban roads and rural roads), a total of 26 databases were utilized to perform three funding scenarios:

1. Impacts of existing funding (assuming preventive maintenance first)
2. Impacts of existing funding (assuming worst first)
3. Funding required to improve current PCI level

These scenarios are only for the local roads and do not include the state highways.

Scenario 1: Existing Funding (Preventive Maintenance First)

In this scenario, the existing funding is estimated to be $154 million a year for the next 20 years. The first two years funding was applied on preventive maintenance or preservation strategies, such as seals. The results of each county was aggregated, and the pavement condition is expected to deteriorate to 42, while the unfunded backlog or deferred maintenance increases to $6.7 billion. Table 5.2 summarizes the budget, PCI in 2034 and deferred maintenance for each county.

As an example, Figure 5.1 graphically illustrates the trends for the average PCI and deferred maintenance over the analysis period for Nevada County. Similar graphs for each county are included in Appendix E.

Scenario 2: Existing Funding (Worst Sections First)

Scenario 2 has the same funding level as Scenario 1 but assumes that the worst roads are repaired first. The average pavement condition for all rural counties will also drop to 42 by 2304; however, the deferred maintenance will increase to $ 8.1 billion, 21 percent more than in Scenario 1. Figure 5.2 shows these results for Nevada County.

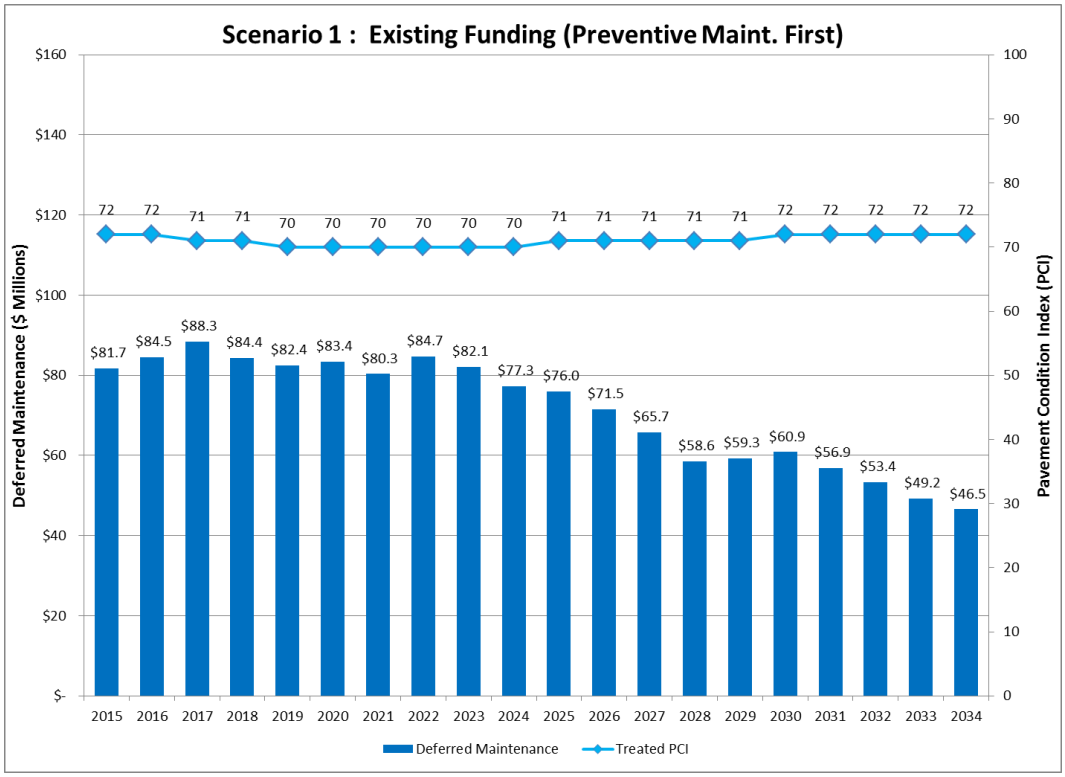


Figure 5.1 PCI and Deferred Maintenance for Scenario 1 (Nevada County)

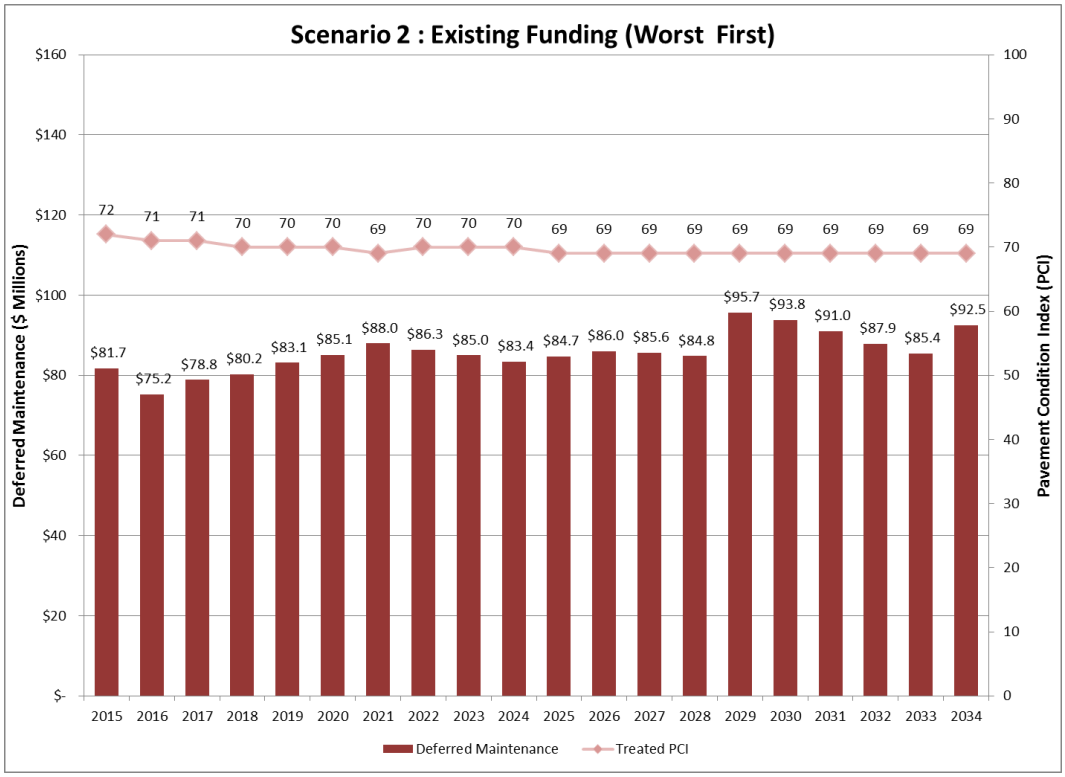


Figure 5.2 PCI vs Deferred Maintenance for Scenario 2 (Nevada County)

Scenario 3: Funding Required to Improve PCI

In Scenario 3, a total funding level of $7.3 billion ($364 million/year) over 20 years will be required to improve the network PCI to the recommended targets for each county (see Table 5.1 and note that the PCI goals range from 50 to 80, with about half the counties indicating a goal of 70.) As a result, the average PCI for all the rural counties will increase to 68, and the deferred maintenance will be $2.5 billion by 2034. This funding level is more than twice what is currently available, or to put it another way, the funding shortfall is $4.2 billion.

Approximately $7.3 billion is required for the rural counties to reach their PCI goals (average 68). This is a funding shortfall of $4.2 billion.

Figure 5.3 indicates the results for Nevada County, which has a target PCI of 75.

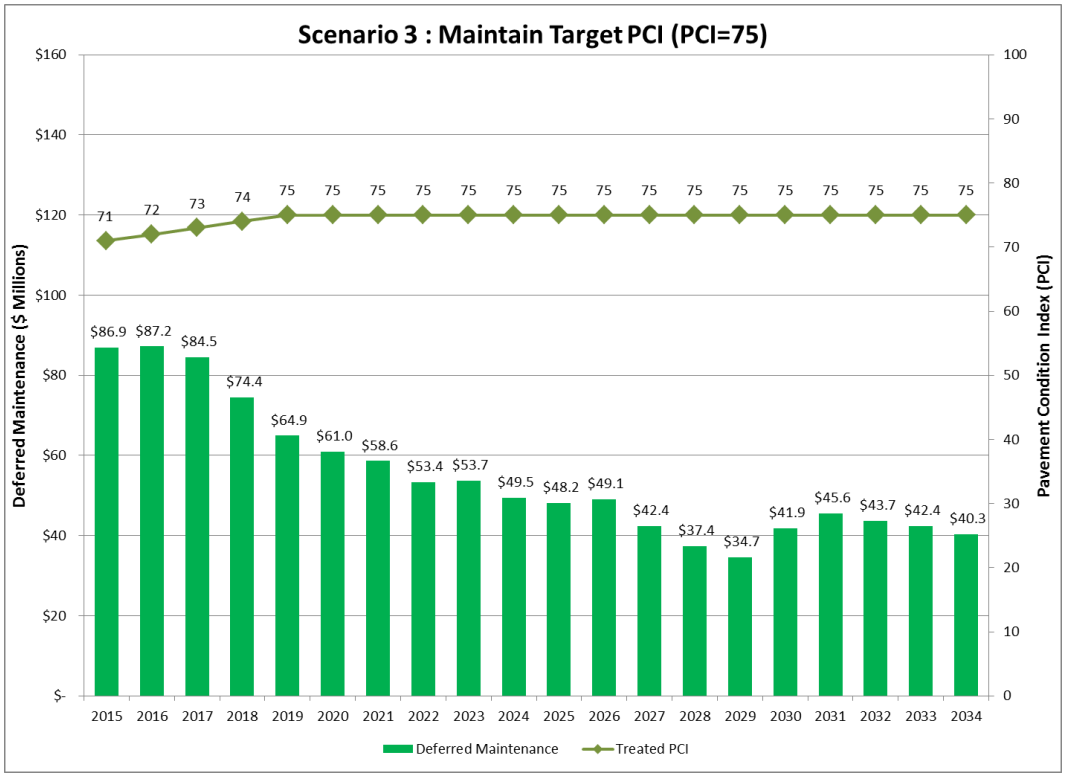


Figure 5.3 PCI vs Deferred Maintenance for Scenario 3 (Nevada County)

Table 5.2 Summary of Scenario Results by County

County	2014 Overall PCI	Scenario 1			Scenario 2			Scenario 3		
		Total Budget ($M)	2034 PCI	2034 Deferred Maintenance ($M)	Total Budget ($M)	2034 PCI	2034 Deferred Maintenance ($M)	Total Budget ($M)	Target PCI	2034 Deferred Maintenance ($M)
Alpine	44	11.8	40	20.6	11.8	39	22.5	28.4	70	5.4
Amador	33	8.8	9	292.6	8.8	9	302.3	188.4	50	121
Calaveras	51	33.9	24	278.5	33.9	24	322.5	205.9	60	109.5
Colusa	62	102.5	46	201.1	102.5	42	261.5	232.3	70	67.2
Del Norte	63	11.5	29	109.8	11.5	29	139	89.1	70	27.4
El Dorado	63	137.9	37	512	138.0	35	653.9	493.8	70	143.1
Glenn	68	98.2	43	248.5	98.3	41	364.9	312.9	75	55.4
Humboldt	64	218.4	44	474.7	218.7	42	609.9	524.7	70	151.6
Inyo	62	58.6	38	179.7	58.5	37	236.5	190.5	70	52.9
Lake	40	89.7	31	263.7	89.7	31	276.7	205.4	50	158.4
Lassen	66	62.7	45	125.9	62.6	44	166.9	143.6	70	44.4
Mariposa	53	29.8	35	90.9	29.5	35	91.8	72.6	60	37.8
Mendocino	35	99.0	24	414.2	99.1	23	431.5	304.9	50	221.6
Modoc	46	38.5	19	441.5	38.6	19	486.9	398.5	70	82.6
Mono	67	51.9	56	51.3	52.0	55	70.8	78.5	70	24
Monterey	50	303.2	35	998.3	302.8	33	1107.2	821.2	60	455.5
Nevada	71	170.3	72	46.5	170.3	69	92.5	181.5	75	40.3
Placer	69	839.6	81	0	839.6	77	185.3	828.6	80	18.4
Plumas	64	203.7	79	0	203.7	77	37.9	161.8	70	48.2
San Benito	48	51.2	33	178.9	51.3	32	190.1	153.3	60	76.7
Santa Cruz	57	149.6	42	346.4	149.8	41	399.8	380.6	70	100.9
Sierra	45	11.3	27	59.1	11.2	25	64.8	49.2	60	22.8
Siskiyou	57	88.2	31	470.4	88.2	30	539.6	432.3	70	107
Tehama	62	121.5	42	302.7	121.7	40	390.3	323.2	70	102.6
Trinity	60	28.4	25	298.5	28.4	25	373.9	250.5	70	70.8
Tuolumne	47	60.0	28	278.3	60.0	27	298.1	223.3	60	109.2
Total	**58**	**3,080**	**42**	**6,684**	**3,081**	**41**	**8,117**	**7,275**	**68**	**2,455**

6. Summary

The results of this study are sobering. The average PCI for rural roads is only 58, significantly lower than the statewide average of 66. This is still considered to be in the "at risk" category. Although the costs for pavement maintenance are lower than for the urban agencies, nonetheless, it will require more than $9.8 billion over the next 20 years to make all necessary repairs and bring the local road condition to what is considered to be best management practices. In addition, the state highway system will require an additional $732 million over the next ten years.

However, the existing funding available is only $3.08 billion over the next 20 years for local roads. Of this, more than 50 percent comes from the gas tax, which is a decreasing revenue source.

Three scenarios were performed:

1. Impacts of existing funding ($3.08 billion) with preventive maintenance first
2. Impacts of existing funding ($3.08 billion) with worst first
3. Funding required to reach PCI targets (average 68)

The first two scenarios indicate that the average PCI will reach 42 by 2034; however, they differ in their deferred maintenance results. Scenario 1 results in a deferred maintenance of $6.7 billion compared to $8.1 billion for Scenario 2. Clearly, the latter is not recommended.

In order for all the counties to reach their target PCIs (average of 68), a total of $7.3 billion will be required for local roads alone. This results in a funding shortfall of $4.2 billion.

Finally, this report examined a variety of performance measures used for roads and highways. During the preparation of this report, the FHWA released their proposed performance measures for roads that are part of the non-Interstate NHS. In California, approximately 5,100 miles of local roads will be affected. The proposed measures include the IRI and measures of cracking, rutting and faulting. For local agencies, IRI is rarely collected; cracking and rutting are collected but not in the same manner. Faulting will probably not affect most rural agencies since very little of the road network is composed of PCC. Currently, Caltrans collects these measures for the NHS.

We recommend using the PCI as the most appropriate performance measure for rural roads. The PCI is in widespread use nationally as well as in California. This means that most agencies have a historical database of PCI data, and agencies and industry have knowledge of the data collection methods as well as interpretation of results.