Economic Benefits of Pavement Preservation Applied to Flexible Pavements

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EXECUTIVE SUMMARY

One of the key concepts of pavement preservation is to apply the right treatment at the right time on the right pavement to extend the service life and delay costly rehabilitation. In California, the state and industry are actively involved in developing and applying various pavement preservation treatments to extend the pavement life and delay the need for rehabilitation or reconstruction. The primary benefits for using these treatments include:

- They are cost effective. Use of preservation treatments may cost from $1-6/sq. yd. while the cost to rehabilitate roads can be 6-10 times more expensive and the cost to reconstruct roads can be 15-30 times more expensive.
- They are “Green”. The selected treatments produce fewer emissions that could potentially impact global warming and reduce the energy used to produce the materials that maintain the roadways in the state.
- They are sustainable. The recycling strategies can save precious aggregates and binders which are becoming extremely scarce or expensive. This is true not only for preservation, but also for rehabilitation.

In addition to above mentioned benefits, other potential benefits associated with pavement preservation include the following:

- Reduced user costs. Keeping good roads in good condition have been shown to reduce annual user costs by as much as $500-700 per year per vehicle. This has likely resulted from smoother roads with fewer potholes to cause damage and wear to vehicles.
- Improved safety (to the public and the workforce). Use of pavement preservation treatments allow the contractor to get in and get out fast, minimizing the opportunities for work accidents during long work periods. Better road surfaces also provide for good drainage and skid resistance which improves safety to all users.
- Improved overall network health. Some agencies have shown the overall network health in their jurisdiction can improve by keeping good roads in good condition and finding ways to plan repairs for pavements in need of rehabilitation and reconstruction.

Caltrans has embarked on various efforts to determine the economic benefits of pavement preservation. These efforts include projects at the California Pavement Preservation (CP2) Center, MACTEC, the University of California at Davis (UCD) and the California Pavement Preservation Task Group (PPTG). The PPTG Subtask Group on Strategy Selection has identified expected lives and costs of treatments using the experience of industry providers and agencies.

In addition, work in progress for the Center by Sousa and Way (2007; vol 1 and 2) used an analytical approach to estimate treatment lives and the life extension associated with the treatment. They also look at the cost effectiveness of the treatments using an approach developed as a part of their study

The overall objectives of these combined efforts were to evaluate the cost effectiveness of a proactive pavement preservation program as compared with the reactive rehabilitation strategies currently employed by state and local agencies. The work done by the Center and UC Davis, the FHWA RealCost program (or equivalent) was used to determine the life cycle cost savings associated with the use of a proactive pavement preservation program. A discount rate of 4% and analysis periods of 25-35 years were used in the studies. The results of the studies indicated the following:

- For local agency's data, the life cycle cost savings with the proactive pavement preservation program compared to the traditional rehabilitation program could save up to 20% over the analysis period.
- For the Caltrans data, the life cycle cost savings when using pavement preservation varied from 20 to nearly 50%. Additionally, applying preservation treatments at a later stage of cracking results in life-cycle costs up to 14% higher than if treatments are placed at an earlier stage of cracking.
- Analytical studies performed for the Center indicate the life of the treatment, as well as the associated life extension, is affected by the condition of the pavement on which it is placed.

The initial studies did not include user costs. Follow-up studies for the local agencies did include user costs and the results were not significantly different for this particular study. The reported savings of 20-50% are very significant when one considers the size of the pavement budget for Caltrans. Additional work including user costs is needed. Additional savings are anticipated when true preservation activities (i.e., proper optimum timing for a given treatment) are used in the life cycle cost analyses.

The additional work performed by Sousa and Way (2007) for Caltrans, the findings were as follows:

- This research developed an analytical approach for comparing treatments called the Treatment Performance Capacity (TPC), which uses total binder content (including the tack coat), strain energy at failure of the binder used in the treatment, and the thickness of the treatment to calculate this value. Results presented by Sousa and Way showed that better treatments are those that have higher TPC values. In short, the results indicate treatments, perform better if they have more binder, are made with stiffer and more elastic binder, and the treatments are thicker.

- A model was developed to relate the treatment life function in terms of TPC, pavement condition, traffic level and temperature (actually only the reflective cracking temperature given by the difference between the Shell mean weighted average temperature and the lowest temperature representative of each region), for all asphalt based treatments. This model is able to explain the performance of 23 treatments, in three climatic zones, three pavement conditions levels and three traffic magnitudes (i.e. 621 observations) with only four variables, with a remarkably high R^2 of 0.84.

- Using the TPC values for each treatment and the price of each treatment, a cost effectiveness table for all treatments was developed (*simply dividing the TPC of a treatment by its cost per square yard*). Actually the concept to adopt is to start evaluating how much TPC /square yard does CALTRANS get for each $1 USD spent in a given treatment. The results indicate that there are huge differences in values between treatments currently used in California and that there appears to exist a great opportunity for Caltrans to optimize (i.e. minimize) its annual budget by applying only treatments with the highest cost-effectiveness at the correct time. Additional work is underway to refine the model.

- Structural and reflective cracking analyses from their studies indicate that the optimum time to apply a treatment is when the pavement cracking levels are in the range of 1 to 2% (Sousa and Way, 2007). It should be noted that other researchers believe that a level of between 5 and 10% are more reasonable (Lee et al, 2007; Zhou and Barrentees, 2008).
- There are significant structural benefits (structural pavement life extension) when a pavement has a waterproofing treatment applied by the time it reaches 4 to 5% cracking. Preventive maintenance treatments, if applied at the correct time, with long lasting 100% waterproofing capabilities, can provide life extensions for the underlying pavement as high as four years.

These results by Sousa and Way (2007) are preliminary, but still reveal some insight into the way preservation treatments behave. All in all, the results of the studies done as a part of this task show those pavement preservation treatments are very cost effective.

DISCLAIMER

ACKOWLEDGMENTS

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1 INTRODUCTION

1.1 BACKGROUND

Americans have grown accustomed to easy mobility in their daily lives and expect to travel on safe, smooth, and well-maintained roads. These same highways play a critical role in the nation's economy, by bolstering agriculture, industry, commerce and recreation. During the 90's, the nation experienced a 29% increase in usage, and more growth is expected over the next 10 years. During the same period, large commercial truck traffic increased by nearly 40% with continued growth projected at more than 3% per year during the next 20 years. Additionally, more than 95% of personal travel is made by automobile, making it clear that increasing highway capacity is important to meet the nation's needs (Galehouse et al. 2003). The question is: Can we finance future highway capacity improvements while addressing the needs of the existing pavement system? The answer has to be 'yes', by developing a strategic plan that includes pavement preservation.

Pavement preservation is a solution that gives highway agencies an alternative to address pavement needs in lieu of using rehabilitation. Further, it offers highway agencies the ability to improve pavement conditions and extend pavement life and performance without increasing expenditures. The focus is on preserving the pavement asset while maximizing the economic efficiency of the investment. It provides greater value to the highway system and improves satisfaction of highway users. Pavement preservation is not about a single treatment or one size fits all philosophy. Rather, pavement preservation should be tailored to each highway agency's system needs in the most cost-effective manner. This involves using a variety of treatments and pavement repairs to extend pavement life.

According to data compiled by the Federal Highway Administration (FHWA), there are nearly 4 million miles of public roads in the United States (FHWA, 2006). A tabulation of highway mileage by agency ownership is shown in Table 1.

Table 1. Highway mileage by agency ownership (FHWA, 2006)

Total Highway Centerline Miles					
	1995	**1997**	**2000**	**2002**	**2004**
Federal	172,050	168,830	118,191	120,595	122,436
State	771,124	772,356	775,303	776,588	816,388
Local	2,973,208	3,011,316	3,054,773	3,081,900	3,058,638
Total	3,916,382	3,952,502	3,948,267	3,979,083	3,997,462
Percent of Total Highway Miles					
Federal	4.4%	4.3%	3.0%	3.0%	3.1%
State	19.7%	19.5%	19.6%	19.5%	20.4%
Local	75.9%	76.2%	77.4%	77.5%	76.5%
Total	100%	100%	100%	100%	100%

Similar data for California is presented in Table 2.

Table 2. Highway mileage by agency ownership in California (centerline miles)- (Caltrans, 2007)

Agency	Mileage	Percentage of total
City	72,340	47
County	65,491	43
State	15,000	10
Total:	152,831	100

The problem facing California and other states today is that many roads are wearing out because of increased traffic, environmental effects, and a lack of proper maintenance. Every highway agency must deal with unique environmental factors for any given geographic region. These environmental differences combined with traffic variations have a profound effect on pavement performance. Pavement sections originally constructed to last for the designed life often accumulate distress at an alarming rate leading to premature failure. Most highway agencies have seen and understand these problems, but perhaps the most daunting issue confronting them is the lack of operating revenues to keep pace with needs.

1.2 PURPOSE OF DOCUMENT

The purpose of this white paper is to document the economic benefits of pavement preservation by delaying the need for costly rehabilitation and reconstructions. It first discusses the concept of pavement preservation along with the reported benefits of pavement preservation and identifies remaining issues or barriers. Then the white paper presents information on treatment lives (and life extension) and compares scenarios where pavement preservation is integrated into the design process with scenarios where it is not used. Through these analyses, the economic benefits of pavement preservation for agencies and users are clearly demonstrated.

2 PAVEMENT PRESERVATION DEFINITIONS

To describe the concept of pavement preservation as used across the United States, it is important that standard definitions be developed and adopted. Figure 1 shows a graphical depiction of what pavement preservation is about (keeping good roads good) and subsequent paragraphs describe various terms that define the differences between pavement preservation and other activities. It is clear from this figure that the concept of pavement preservation is to keep good roads good and to protect them from wearing out. The trigger for pavement preservation is higher, in terms of pavement condition, than it is for rehabilitation. That is, treatments are applied when the pavement condition is still high. Incremental applications of simple preservation treatments will continue to keep the pavement in consistently good condition, rather than allowing the condition to decline to a point where rehabilitation is the only alternative. In essence we are trying to keep good roads in good condition.

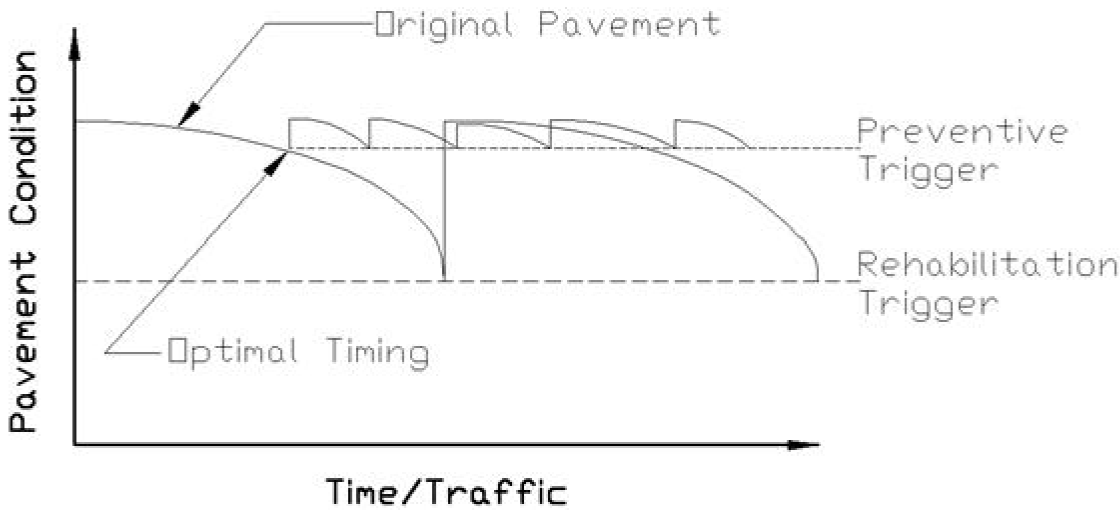

Figure 1. Typical pavement performance curve showing relation between various maintenance and rehabilitation activities

2.1 ASSET MANAGEMENT

As defined by the FHWA and the American Association of State Highway and Transportation Officials (AASHTO), asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively (FHWA, 1999a). It combines engineering principles with sound business practices and economic theory, and provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short-range and long-range planning.

Asset management is important to state and local governments because of policy statement 34, "Basic Financial Statements for State and Local Governments" issued in June, 1999 by the Government Accounting Standards Board (GASB-34) (FHWA, 2000). The statement encourages governmental agencies to promote asset management practices and further to report on the value of capital assets such as utilities, roadways, and other infrastructure items (FHWA, 1999b). The value of these assets and how they are being maintained will eventually affect the bond ratings of government agencies, which will in turn affect their ability to borrow money to repair and replace these investments. The objectives of an asset management program are to:

- Consider various investment strategies
- Provide a more rational decision process
- Improve the overall condition of the highway system at a lower cost

California agencies, therefore, must comply with this policy statement and improve the quality of their pavement and bridge systems. Preservation (or maintenance) of the infrastructure is an important part of this effort.

2.2 PREVENTIVE MAINTENANCE

Preventive maintenance, as defined by AASHTO (FHWA, 1999b), is a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without substantially increasing structural capacity.

Preventive maintenance is a tool for pavement preservation in which non-structural treatments are applied early in the life of a pavement in order to prevent them from further deterioration. In other words, it consists of applying the right treatment to the right pavement at the right time.

2.3 PAVEMENT PRESERVATION

California and the FHWA define pavement preservation as the sum of all activities undertaken to provide and maintain serviceable roadways; it includes corrective maintenance and preventive maintenance, as well as minor rehabilitation projects. It excludes new or reconstructed pavements and pavements requiring major rehabilitation or reconstruction.

Pavement Preservation (PP) is a program of activities aimed at preserving the investment in the pavement network, extending pavement life, enhancing pavement performance, ensuring cost-effectiveness, and reducing user delays – in other words, meeting customer needs.

2.4 REACTIVE (OR CORRECTIVE) MAINTENANCE

Reactive maintenance is an activity that must be done in response to events beyond the control of an agency (FHWA, 199b). Some events require response as soon as possible to avoid serious consequences because a present or imminent danger exists. Reactive maintenance cannot be scheduled because it occurs with little or no warning and often must be immediately addressed. Examples of reactive maintenance activities include pothole patching rut filling, or unplugging drainage facilities.

2.5 EMERGENCY MAINTENANCE

These activities are associated with treatments placed under extreme conditions where loss of life and property are at risk. Washouts, rigid pavement blow-ups, and rock or earth slides are examples of this type of maintenance.

3 BENEFITS OF PAVEMENT PRESERVATION

Pavement preservation is similar to maintaining an automobile or a house. The concept of paying for minor work now to prevent major work in the future is an important concept of pavement preservation. Caltrans has been describing the benefit of pavement preservation to that of pavement rehabilitation using a 6 to 1 ratio, meaning that the cost of pavement preservation treatments are about 1/6 of that for pavement rehabilitation (Caltrans, 5 year maintenance plan). This approach unfortunately does not consider the lives of the treatments, the life extension of the existing pavement associated with the treatments, and the other costs such as user and safety costs.

Caltrans has identified several potential benefits associated with implementing a pavement preservation program including the following:

- Life extension of the existing pavements (delay in pavement rehabilitation). This is an important benefit of pavement preservation. If timely low cost treatments can defer pavement rehabilitation or reconstruction, they will preserve funds now for use on other more urgent or needed activities (see Figure 2).
- Lower treatment costs. Pavement preservation treatments typically cost from $1-6/sq.yd while the cost to rehabilitation roads can be 6 to 10 times more expensive and the cost to reconstruct roads can be 15 to 30 times more expensive (Caltrans, , 2007).
- Reduced user costs. Keeping good roads in good condition has been shown to reduce annual user costs by as much as $500-700 per vehicle per year. This means the roads are smoother with fewer potholes to cause damage to vehicles (TRIP, 2009).
- Improved safety (to the public and the workforce). Pavement preservation treatments usually take less time to complete, therefore, the contractor can get in and get out faster minimizing the chances for work accidents during long work periods. Better roads surfaces also provide for good drainage and skid resistance which improves safety to road users.
- Improved overall network health. Some agencies have shown the overall network health can be improved by keeping good roads in good condition and finding ways to plan repairs for pavements in need of rehabilitation and reconstruction.
- Environmental benefits. Pavement preservation treatments also reduce air pollution, noise and the like because of typically short construction periods. Less equipment used for shorter periods of time reduces fossil fuel demand and vehicle emissions.
- Pavement preservation treatments are “Green”. Many of the treatments produce fewer emissions that potential effect global warming and reduce the energy needed to produce the materials use in preservation.

To realize the above benefits, Caltrans and others need better information to convince the transportation commission and the legislature (or the other decisions makers) to provide more dedicated funding for pavement preservation while at the same time finding additional funds to repair pavements beyond the preservation stage. Work being done at the California Pavement Preservation Center (in cooperation with MACTEC and UC Davis) is designed to provide better information on the economic benefits of pavement preservation (Lee et al, 2007; Zhou and Barrantes, 2008). Work is also underway at the Center to document the energy and environmental benefits of pavement preservation (Stroup-Gardiner, 2008).

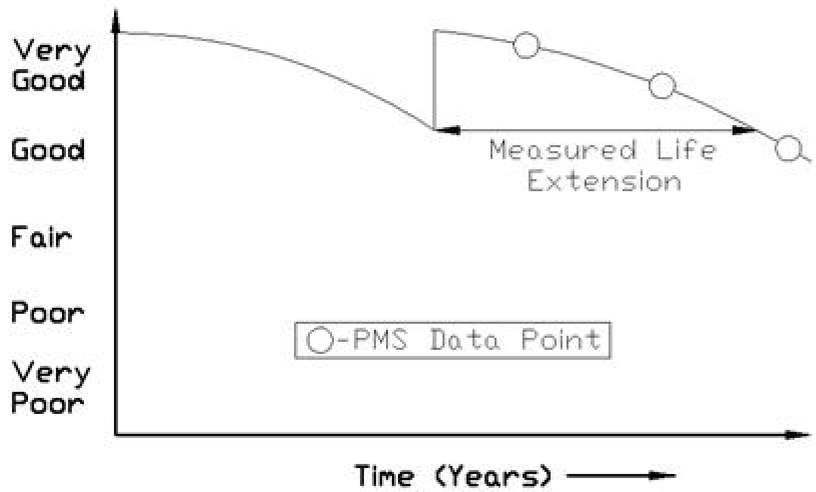

Figure 2. Schematic of life extension

4 CHALLENGES TO USING PAVEMENT PRESERVATION

There are also a number of issues and barriers that Caltrans, or any local agency, must deal with before pavement preservation is widely accepted. These issues and barriers are different depending on the group affected and are discussed in the following sections of this paper.

4.1 AGENCIES

Several issues and barriers can be identified from the agency point of view. Some of these are discussed below:

- Dealing with the paradigm shift from fixing worst-pavements first to fixing good-pavements first. One of the biggest obstacles to overcome is to convince agency personnel to move from the conventional worst-first practice of fixing pavement problems to fixing good pavements first while letting the bad ones continue to deteriorate. People simply have a hard time making this adjustment without documented evidence of the cost savings associated with pavement preservation.
- Need for top management commitment. Pavement preservation programs will not succeed without top management commitment. This includes getting a commitment for dedicated funding and for resources needed to collect information on the effectiveness of preventive maintenance treatments. Caltrans has done much in this area without the best of data due to an inadequate pavement management system. This is now being dealt with as Caltrans moves forward with the development of a new and improved pavement management system.
- Recognizing the importance of pavement preservation. Pavement preservation projects should also warrant ribbon-cutting ceremonies just like other major rehabilitation or reconstruction projects.
- Identify a champion for the program. Pavement preservation programs need a champion for them to be effective. As with any new effort or program within an

agency, someone must be constantly promoting the importance and benefits of the effort. Without a champion, the new effort will simply not succeed. Caltrans has champions for pavement preservation (Iwasaki, Miles, Takigawa, and Shatnawi) and they are promoting the benefits of the program to the legislature (Caltrans, 2005; 2007b; 2008).

- Need to show early benefits. It is important to show the early benefits of the pavement preservation program. Pavement management systems should be able to show the effect of the preventive maintenance treatments on treatment lives, life extensions, and/or reduced life cycle costs which are essential. In the absence of good data from Pavement Management Systems, alternative methods for estimating treatment lives and life extension may have to be employed. Caltrans is currently working on upgrading its pavement management system.
- Selecting the right treatment for the right pavement at the right time. Preventive maintenance treatments can be ineffective if the correct treatments are not used. One failure is equivalent to hundreds of successes in a new program such as one like pavement preservation. It is important that the right treatment be used on the pavement and that it is applied in a timely manner. Caltrans has developed strategy selection guides, but the timing of the treatment is critical to its eventual performance. Caltrans often places the treatments on pavements that are far too distressed.

4.2 INDUSTRY

Different issues and barriers have been identified for the industry groups, but they all come down to one issue - disturbing the status quo. Some of these issues include, but are not limited to, the following:

- Competition between the suppliers of maintenance and rehabilitation treatments. As we shift from the traditional rehabilitation programs of pavement overlays applied every 10-20 years to pavement preservation programs using new or different treatments, one can expect resistance from the traditional suppliers of rehabilitation materials. For example, hot mix suppliers might resist new cold mix treatments because the use of these treatments will take away from their market share.
- Competition between various suppliers of maintenance treatments. Where existing markets have been established for certain types of treatments and a new treatment type is being introduced, industry often positions itself to prevent these new products from being introduced. This could be for technical reasons or for personal reasons that make sure the new competitor does not reduce the percentage of the market share. This type of activity does not help the pavement preservation industry.
- Political lobbying to prevent new maintenance treatments from being used. In some cases, the industry will simply rely on the use of political lobbying to prevent new technologies from entering the market. Again, the reasons could be technical, but can more than likely be related to the effect on that market size of introducing the new technology into use by the agency.
- Establishing the benefits of new technologies or treatments. To introduce new technologies, often the supplier of the product does not have adequate evidence of the benefits of the product. It is essential that the supplier provide to the agency detailed documentation of the benefits and performance of the product. This is now being done as a part of the preservation process in the state of California.

4.3 TRAVELING PUBLIC

The traveling public, the ultimate customer, is also impacted by the introduction of preservation programs, and faces a different set of issues and barriers. These include the following:

- Dealing with the shift from repairing pavements from worst-first to good-first. The public simply does not understand why agencies are now working on good roads and letting the bad roads continue to deteriorate. The pavement preservation industry and pavement professionals need to demonstrate the cost effectiveness of this practice. Most of the public understands that it is important to maintain their car or house to prevent major repairs down the road; pavement preservation engineers need to be able to explain why it is important to use preventive maintenance treatments now rather than do major repairs later. We must market the benefits of pavement preservation to the public.
- Impact on delays and vehicle costs of the various maintenance and rehabilitation strategies. One of the suggested benefits of pavement preservation is the reduction in vehicle delays due to the use of faster repair techniques and reduction in user costs by keeping the pavement networks in better condition. Though this is widely acclaimed as a benefit, it still lacks documentation through national studies. This can be done through economic analysis.

5 PRESERVATION TREATMENT LIVES AND COSTS

To identify the economic benefits of using pavement preservation treatments, it is essential that accurate information on treatment lives and costs be developed. This information should be contained in any pavement management systems so that treatment lives, life extension due to the treatment, and treatment costs can be readily identified. As a part of this study, treatment lives were determined using data from pavement management systems for both Caltrans and local agencies. Estimates of the effect of pavement condition on treatment lives using the combined experience of the Pavement Preservation Task Group (PPTG) were also considered. These lives are summarized in Appendix A.

5.1 FACTORS AFFECTING PRESERVATION TREATMENT LIVES

Treatment lives are a function of several factors including the following:

- Existing pavement condition - amount of cracking prior to the treatment.
- Traffic, particularly truck traffic.
- Climate in which it is placed - temperature, number of freeze thaw cycles, and precipitation.
- Construction quality - quality of the materials and the contractor.

It was expected that treatment lives and life extension would be an output from the Caltrans and local agency pavement management systems (Lee et al, 2007; Zhou and Barrentees, 2008). However, it was very difficult to accurately quantify treatment lives (and associated life extension) from these management systems because of the lack of data or scatter in the data in these systems. Nevertheless, considerable efforts and progress were made by the Center and others to determine treatment lives.

An alternative approach to estimate treatment lives was to rely on the experience of the PPTG. This is the partnering platform for pavement preservation in the state of California and consists of members from Caltrans, local agencies, industry, and academia. The results from this effort (shown in Appendix A) are currently being used by the CP2 Center to develop improved data sets for lives of the treatments and for the life extension associated with using each treatment. The Center has completed a preliminary study to estimate life extension from this data (Sousa and Way, 2007). More on this effort is discussed later in this paper. The reports can be found on the Center website (www.cp2info.org).

5.2 PAVEMENT LIFE EXTENSION ASSOCIATED WITH TREATMENTS

Life extension was illustrated in Figure 2 and is the time a treatment extends the pavement life prior to rehabilitation. If the treatment is placed on good pavements, the life extension may approach the life of the treatment. If the treatment is placed on poor pavements, the life extension will be less. Many of the treatments used in California last only a few years suggesting that the treatments may be applied too late or not being applied on the right pavements. Table 2 summarizes typical treatment life extensions as a function of pavement condition for a variety of treatments (Scholz et al., 2002). A more detailed estimate of treatments lives, for all the treatments used in California, is given in Appendix A. As can be seen, the condition of the existing pavement has a great effect on the life extension or the time to delay pavement rehabilitation. It is anticipated that treatment life will also be affected by traffic conditions, and climate or environment.

Table 2. Typical treatment life extensions (years) for various preventive maintenance treatments (Scholz et al, 2002)

Treatment	**Good condition (% cracking = <5)**	**Fair condition (% cracking= 5-20%**	**Poor condition (% cracking = >20)**
	Typical Treatment Life, years		
Fog seal	3-5	1-3	1-2
Chip Seal	7-10	3-5	1-3
Slurry seal	7-10	3-5	1-3
Microsurfacing	8-12	5-7	2-4
Thin HMA	8-12	5-7	2-4

6 ECONOMIC ANALYSIS

Caltrans has embarked on various efforts to determine the economic benefits of pavement preservation. These efforts include projects at the CP2 Center with the support of MACTEC, the UC Davis PRP and the PPTG. In addition, a study was completed for the Center which used the information from the PPTG to estimate treatment lives (Sousa and Way, 2007) (see Appendix C).

The objective of these efforts was to evaluate the cost effectiveness of a proactive pavement preservation program as compared with the rehabilitation strategies currently employed by state and local agencies. The FHWA RealCost program (or equivalent) was used to determine the life cycle cost savings associated with the use of a proactive pavement preservation program. Cost data used in the analysis came from the State of the Pavement report for the Caltrans analysis and from the Metropolitan Transportation Commission for the local agencies studies.

The LCCA is an improved approach to economic analysis. The approach considers lives and costs of the treatments and/or other costs such as user costs in the analysis.

6.1 Cost Analysis Approaches and Assumptions

Agencies have historically used some form of LCCA to assist in the evaluation of alternative pavement design strategies. For example, the 1986 AASHTO Guide for the Design of Pavement Structures encouraged the use of LCCA and described a process to evaluate the cost effectiveness of alternative design strategies. The FHWA position on the use of LCCA is defined in its policy statement published in the September 18, 1996 register (Walls and Smith, 1998). More generally, FHWA policy indicates that LCCA is a decision support tool. As a result, FHWA encourages the use of LCCA in analyzing all investment decisions.

The life cycle cost approach used by Caltrans is the FHWA RealCost model (Caltrans, 2007). The program provides both a deterministic and probabilistic approach to determining the most cost effective strategies. To compare different investment strategies, one needs to identify the following:

- Established alternative maintenance and rehabilitation strategies.
- Determine expected life of the maintenance and rehabilitation strategies.
- Estimate the agency costs, including salvage value if necessary.
- Estimate user costs.
- Develop expenditure streams for each strategy.
- Compute net present values.
- Analyze results.

6.2 The RealCost approach was used in the studies completed by MACTEC and by UC Davis. An alternative approach was used by Sousa and Way (2007) to calculate cost effectiveness. Analysis Scenarios

6.2.1 Benefits

The work done by UC Davis using Caltrans data addressed the following questions:

- Is it more beneficial to apply pavement preservation treatments compared to applying no maintenance?
- Should pavement preservation treatments be applied at an earlier or later stage of cracking?
- How do the life cycle costs of different pavement treatment combinations compare?

The UC Davis's study made use of the data extracted from the Caltrans pavement management database. However, it should be mentioned that most of the scenarios contained in the database did not include proactive pavement preservation scenarios. Most of the treatments were placed on pavements when the cracking was between 10-25%.

The studies conducted by the CP2 Center investigated scenarios common to local agencies in California as illustrated in Figure 3a; scenarios representing pavements that received planned preventive maintenance as shown in Figure 3b; and scenarios representing pavements that received only major rehabilitation treatments (with some minor maintenance) as depicted in Figure 3c. A discount rate of 4% and analysis periods of 35 years were used in the LCCA. Salvage values (SV) of the treatments were considered and prorated during the analysis. Even though the traffic loading and repetitions for local agencies can be different than for state agencies, the results of this analysis are expected to yield useful information. The procedure used is given in the following (Caltrans, 2007c):
http://www.dot.ca.gov/hq/esc/Translab/OPD/LCCA_Manual_Master-4-1-07.pdf

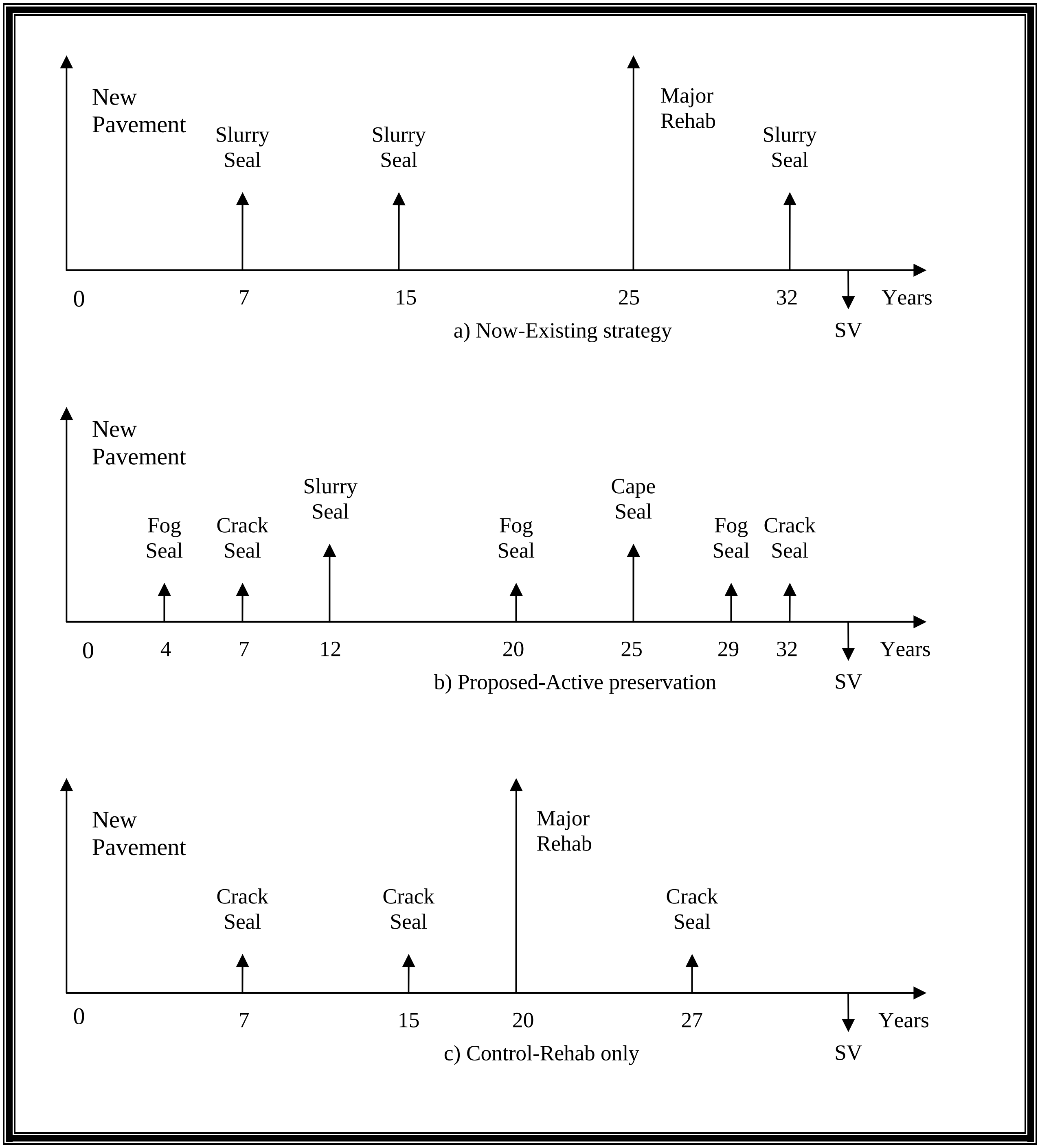

Figure 3. Scenarios used in the study using local agency data (after Zhou and Barrantees, 2008)

6.2.2 PREDICTION MODEL

The study done by Sousa and Way (2007) used the PPTG data to estimate life extension and cost effectiveness for the treatments list in Appendix A. Basically, this work used the PPTG data on treatment lives shown in Appendix A and an analytical approach to perform the following:

- Predict the life of the treatment. An approach was developed to predict the life of a treatment based on the knowledge of the existing pavement condition, traffic levels, and the climate. A parameter Treatment Performance Capacity (TPC) was used to assist with the effort. This parameter is a measure of the effectiveness of a treatment to resist cracking.
- Determine the most cost effective treatments. Cost effectiveness of treatments was defined the TPC/cost per unit area of the treatment. The higher numbers are more cost effective.

- Predict the life extension for the existing pavement. Life extension associated with the treatment is estimated using a mechanistic design approach. Both structural and environmental effects are considered in this approach, typical values for life extension are given in the following tables (Tables 3, 4 and 5). It should be noted that Caltrans changed the RAC designation to RHMA after the publication of the Sousa and Way (2007) report.

  The TPC is calculated using the following equation: TCP = Binder Content * Strain $\text{Energy}_{\text{failure ratio}}$ * $\text{Thickness}_{\text{Treatment}}$

  Where:

  Binder Content = total binder content, including tack coat, in gallons per square yard

  $\text{Strain Energy}_{\text{failure}}$ = unitless

  $\text{Thickness}_{\text{Treatment}}$ = inches

The values calculated from this equation will increase with increasing binder content, increasing area under the binder’s stress-strain curve, and increasing treatment thickness. Although the results of this study are preliminary, they hold promise as a method of predicting the performance of maintenance treatments. It should be noted that the TPC only considers the potential life extension of the treatment does not consider the life cycle cost of the treatment.

Tables 3, 4, and 5 present estimates of pavement life extensions in terms of the intial pavement condion which includes cracking as well as a number of other pavement distresses in the condition calculation.

Table 3. Calculated Estimates of Life Extension for Maintenance Treatments in Coastal and Valley Regions (after Sousa & Way, 2007)

Treatment	Pavement Life Extension for Coastal Region (PG 64-10) and Valley Region (PG 64-16)								
	Traffic Index (TI)								
	TI < 6			6 < TI < 12			TI > 12		
	Pavement Condition								
	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)
HMA Crack Sealing	2.4	1.0	N	2.3	0.8	N	1.7	0.7	N
HMA Crack Filling	1.0	0.3	N	1.0	0.2	N	0.8	0.2	N
Fog Seals	0.1	N	N	0.0	N	N	0.0	N	N
Rejuvenator Seals	0.3	N	N	0.2	N	N	0.2	N	N
Scrub Seals	1.6	0.7	N	0.8	0.5	N	0.7	0.4	N
Slurry Seals	2.3	0.7	N	2.3	0.7	N	2.3	0.6	N
REAS Slurry Seal	2.3	0.7	N	2.3	0.7	N	2.3	0.7	N
Micro-Surfacing	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
PME Chip Seals	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
PMA Chip Seals	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
AR Chip Seals	3.8	2.8	0.7	3.3	2.2	0.7	3.2	1.9	0.7
Cape Seals AR (slurry) 1/2 in.	3.9	3.2	1.1	3.8	2.9	1.1	3.5	2.5	1.1
Cape Seals AR (micro) 3/4 in.	4.1	4.2	1.4	4.1	3.2	1.4	3.8	2.7	1.4
Conventional HMA, 1 in.	2.8	1.4	N	2.4	1.4	N	2.2	1.3	N
OGAC, 1 in.	2.8	1.4	N	2.4	1.4	N	2.2	1.3	N
PBA HMA, 1 in.	2.8	1.4	N	2.8	1.4	N	2.8	1.4	N
RAC-G, 1 in.	2.8	1.6	N	2.8	1.6	N	2.8	1.6	N
RAC-O, 1 in.	2.8	1.8	0.2	2.8	1.8	0.2	2.8	1.8	0.6
RAC-O (HB), 1 in.	3.3	2.6	0.6	3.3	2.6	0.6	3.3	2.6	0.6
BWC-Open, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-Gap, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-RAC-G, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-RAC-O, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N

AR = asphalt rubber
PME = polymer modified emulsion
PHA = polymer modified asphalt
OGAC = open graded asphalt concrete
RAC-G = rubberized asphalt concrete-gap graded
RAC-O = rubberized asphalt concrete-open graded
BWC = bonded wearing course

Table 4. Calculated Estimates of Life Extension for Maintenance Treatments in Mountain Regions (after Sousa & Way, 2007)

Treatment	Pavement Life Extension for Mountain Region (PG 64-28)								
	Traffic Index (TI)								
	TI < 6			6 < TI < 12			TI > 12		
	Pavement Condition								
	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)
HMA Crack Sealing	1.8	0.6	N	1.6	0.5	N	1.0	0.3	N
HMA Crack Filling	0.6	0.1	N	0.5	0.1	N	0.4	N	N
Fog Seals	0.2	N	N	0.1	N	N	0.1	N	N
Rejuvenator Seals	0.3	0.1	N	0.2	N	N	0.2	N	N
Scrub Seals	1.0	0.4	N	0.7	0.2	N	1.5	N	N
Slurry Seals	2.3	0.6	N	2.2	0.6	N	2.2	0.5	N
REAS Slurry Seal	2.3	0.7	N	2.2	0.7	N	2.1	0.8	N
Micro-Surfacing	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
PME Chip Seals	1.8	0.5	N	1.8	0.5	N	1.7	0.3	N
PMA Chip Seals	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
AR Chip Seals	3.4	2.8	1.0	3.6	2.3	1.0	3.2	1.9	1.0
Cape Seals AR (slurry) 1/2 in.	4.2	3.0	1.3	3.6	2.5	1.3	3.2	2.0	1.3
Cape Seals AR (micro) 3/4 in.	4.3	3.4	1.6	3.7	2.8	1.7	3.3	2.2	1.7
Conventional HMA, 1 in.	2.8	1.4	N	2.8	1.4	N	2.3	1.3	N
OGAC, 1 in.	2.3	1.4	N	2.3	1.4	N	1.6	0.8	N
PBA HMA, 1 in.	2.8	1.4	N	2.8	1.4	N	2.6	1.3	N
RAC-G, 1 in.	2.8	1.6	0.2	2.8	1.6	N	2.6	1.4	0.2
RAC-O, 1 in.	2.8	1.9	0.3	2.8	1.9	0.3	2.6	1.8	0.3
RAC-O (HB), 1 in.	3.3	2.6	N	3.3	2.6	0.8	3.2	2.4	0.8
BWC-Open, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-Gap, 3/4 in.	2.3	1.3	N	2.1	1.3	N	2.0	1.4	N
BWC-RAC-G, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-RAC-O, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N

AR = asphalt rubber
PME = polymer modified emulsion
PHA = polymer modified asphalt
OGAC = open graded asphalt concrete
RAC-G = rubberized asphalt concrete-gap graded
RAC-O = rubberized asphalt concrete-open graded
BWC = bonded wearing course

Table 5. Calculated Estimates of Life Extension for Maintenance Treatments in Desert Regions (after Souza & Way, 2007)

Treatment	Pavement Life Extension for Desert Region (PG 70-10)								
	Traffic Index (TI)								
	TI < 6			6 < TI < 12			TI > 12		
	Pavement Condition								
	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)	Good (0%)	Fair (5%)	Poor (18%)
HMA Crack Sealing	2.8	1.0	N	2.6	1.0	N	2.1	0.9	N
HMA Crack Filling	1.2	0.3	N	1.1	0.3	N	1.0	0.2	N
Fog Seals	0.1	N	N	0.1	N	N	0.1	N	N
Rejuvenator Seals	0.2	N	N	0.1	N	N	0.1	N	N
Scrub Seals	1.3	0.6	N	1.0	0.3	N	0.4	0.2	N
Slurry Seals	2.3	0.6	N	2.2	0.6	N	2.2	0.5	N
REAS Slurry Seal	2.3	0.7	N	2.2	0.7	N	2.1	0.7	N
Micro-Surfacing	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
PME Chip Seals	1.8	0.5	N	1.8	0.5	N	1.7	0.3	N
PMA Chip Seals	1.8	0.5	N	1.8	0.5	N	1.8	0.5	N
AR Chip Seals	3.8	2.8	1.0	3.6	2.3	1.0	3.2	1.9	1.0
Cape Seals AR (slurry) 1/2 in.	4.4	3.2	1.3	3.9	2.9	1.3	3.6	2.5	1.3
Cape Seals AR (micro) 3/4 in.	4.9	4.1	1.7	4.1	3.2	1.7	3.7	2.7	1.7
Conventional HMA, 1 in.	2.8	1.4	N	2.4	1.4	N	1.8	0.9	N
OGAC, 1 in.	2.3	1.4	N	2.3	1.4	N	1.6	0.8	N
PBA HMA, 1 in.	2.8	1.6	N	2.8	1.4	N	2.6	1.3	N
RAC-G, 1 in.	2.8	2.0	0.2	2.8	1.6	0.2	2.6	1.4	0.2
RAC-O, 1 in.	2.8	1.6	0.3	2.8	1.9	0.3	2.6	1.8	0.3
RAC-O (HB), 1 in.	3.3	2.6	0.8	3.3	2.6	0.8	3.2	2.4	0.8
BWC-Open, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-Gap, 3/4 in.	2.3	1.4	N	2.1	1.3	N	2.1	1.3	N
BWC-RAC-G, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N
BWC-RAC-O, 3/4 in.	2.3	1.4	N	2.3	1.4	N	2.3	1.4	N

AR = asphalt rubber
PME = polymer modified emulsion
PHA = polymer modified asphalt
OGAC = open graded asphalt concrete
RAC-G = rubberized asphalt concrete-gap graded
RAC-O = rubberized asphalt concrete-open graded
BWC = bonded wearing course

6.3 RESULTS

The results of the studies indicated the following:

- For local agencies data, the life cycle cost savings with the proactive pavement preservation program compared to the traditional rehabilitation program could save up to 20 % over the analysis period.
- For the Caltrans data, the life cycle cost savings when using pavement preservation varied from 20 to nearly 50%. Additionally, applying preservation treatments at later stage of cracking results in life-cycle costs up to 14% higher than if treatments are placed at an earlier stage of cracking.
- Life extension is a function of the pavement condition, traffic, and climate.

These studies for local agencies consider including the user of use costs, but the effect was not that significant. Studies by others (Scholz et. al. 2002 and Smith et. al, 2005) for higher volume roads would suggest that the savings can be higher if users' costs are considered.

6.4 RETURN ON INVESTMENT USING PAVEMENT PRESERVATION

Considering the current pavement preservation budget for Caltrans is $300 million per year, an annual savings of 20 to 50% could result from pavement preservation programs. These savings or a return on an investment of $60 to $150 million per year could be used on other projects to improve the overall health of the roadway network. As illustrated in Figure 1, building in pavement preservation early in the life of a new rehabilitation or reconstruction job is a wise investment of funds.

7 CONCLUSIONS AND RECOMMENDATIONS

This paper has presented information on the benefits of pavement preservation. It also identifies the important issues and barriers that Caltrans must deal with when developing and implementing the pavement preservation programs. Finally, it presents the results of the analyses on the cost-effectiveness of pavement preservation compared with the traditional rehabilitation approach.

7.1 CONCLUSIONS

Specific conclusions are presented as follows:

- It is beneficial to place treatments on good pavements. The LCCA savings can range from 20 -50 % when pavement preservation treatments are applied sooner rather than later. The anticipated savings of any preservation treatment needs to consider a complete life cycle cost analysis that includes both user delay and vehicle operating costs.
- It is more effective to place treatments on pavements with 5-10 % cracking, or on pavements in good condition (i.e., limited evidence of pavement distresses)

7.2 RECOMMENDATIONS

Additional work is needed to refine the model for estimating life extension. Further work is needed to verify the treatment lives and costs. Finally with the rapid increases in asphalt costs, the cost effectiveness of treatments may change as the prices for treatments change.

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APPENDIX A

EXPECTED TREATMENT LIVES

Developed by the California Pavement Preservation Task Group (PPTG)

Expected Treatment Lives (Years) for California Conditions

The data presented in this appendix, as developed by the PPTG, were used by Sousa and Way (2007) in their treatment performance capacity (TPC) calculation.

Background

To establish the cost effectiveness of pavement preservation treatments, information on treatment lives and life extension associated with applying a given treatment is needed. The information compiled in this document is based on the collective experience of the PPTG. The data still needs to be verified using actual performance data from existing performance data bases or pavement management systems. The life of the treatment is highly dependent not only on the timing of the treatment, but also on the expected traffic and climate. Treatments placed on good pavements will last longer than treatments placed on bad pavements. Many times, a treatment is scheduled to be placed on a good pavement, but by the time it is actually placed the condition of the pavement has deteriorated and this will affect the expected life of the treatment. The lives of the treatment are also dependent on the level of traffic as well as the climate (coastal, valley, mountains, and desert) in which the treatment is placed. New tables representing the different climate zones are currently under development.

It should be noted that not all the treatments used in California are yet included in this table. Data from the interlayer group still need to be added to this table. They are special cases since these treatments are generally covered by other maintenance treatments. As new data is provided for other treatments, they will be added to this list.

Treatment Lives

The following table summarizes the information provided by the various PPTG subtask groups. It represents ranges in lives for the various treatments and is subject to change. Additional work is needed to define the influence of climate on the life of a given treatment placed over a specific pavement with a known traffic level. By sorting out climate it is expected that the ranges in lives can be narrowed. However, for the time being it is the best data we have to perform cost effectiveness studies. It is possible for the lives of the treatments to be greater or less than the numbers provided in this table.

Again, the lives of the treatments shown are affected not only by the condition of the pavement it is placed on and the expected traffic, but also by the climate and the quality of the materials used and construction practices. We are continually working on securing better information on treatment lives and the life extension provide by the treatment (e.g. delay in time to rehabilitation or reconstruction).

Table A-1. Treatment Lives*

Treatment	Traffic index (10 years)								
	< 6			6-12			> 12		
	Pavement Condition								
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
HMA Crack sealing	5-9	3-7	**	5-8	3-6	**	3-7	2-5	**
HMA Crack filling	2-8	2-6	1-4	2-7	2-5	1-4	2-6	2-4	1-4
Fog seals	1-3	N	N	1-2	N	N	1-2	N	N
Rejuvenator seals	3-6	3-4	2-3	2-4	2-3	2-3	2-4	2-3	1-3
Scrub seals with chip	8-10	6-9	3-6	6-10	4-6	3-5	5-8	3-6	2-4
Slurry Seals	8-10	4-6	2-4	7-10	4-6	1-4	7-10	3-5	1-3
REAS slurry seal	8-10	5-7	***	7-10	5-7	***	7-9	5-7	***
Micro-Surfacing	8-12	5-8	2-4	7-12	5-7	2-4	7-10	3-6	1-4
PME chip seals	8-12	5-8	2-4	7-12	5-7	2-4	7-10	3-6	1-4
PMA chip seals	8-12	6-9	4-6	7-12	5-7	4-6	7-10	4-6	3-5
AR chip seals	8-12	6-9	4-6	7-12	5-7	4-6	7-10	4-6	3-5
Chip seal with fabric interlayer									
Cape seals (with slurry)	9-14	7-10	5-7	8-12	6-8	5-7	8-10	5-7	4-6
Cape Seals (with micro)	10-14	8-10	5-8	8-12	6-8	5-8	8-10	5-7	4-6
Conventional HMA (30mm)	8-12	5-10	4-6	8-10	6-9	3-6	6-8	4-6	1-3
OGAC (30 mm)	8-10	5-10	4-6	8-10	6-9	3-5	6-8	4-6	2-5
PMA HMA (30mm)	8-14	6-12	4-7	8-12	6-10	4-5	8-10	5-7	3-5
RAC-G (30 mm)	8-14	6-10	4-6	8-12	5-9	4-5	8-10	5-7	3-5
RAC-O (30 mm)	8-14	5-12	4-7	8-12	5-10	4-5	8-10	5-9	3-5
RAC-O (HB)	8-15	6-12	4-8	10-12	6-12	4-6	8-12	5-10	4-5
BWC-Gap	8-15	5-10	4-6	8-10	5-9	4-5	8-10	5-9	4-5
BWC-Open	8-15	5-10	4-6	8-10	5-9	4-5	8-10	5-9	3-4
BWC-RAC-G	8-15	5-10	4-6	8-10	5-9	4-5	8-10	5-9	3-4
BWC-RAC-O	8-15	5-10	4-6	8-10	5-9	4-5	8-12	5-9	3-5
CIR with a surface layer	na	12-15	10-12	na	10-12	8-10	na	8-10	7-9
HIR with a surface layer	na	7-10	5-8	na	6-9	4-7	na	5-8	4-6
PCC Joint re-sealing	8-10	7-9	6-8	8-10	7-9	6-8	8-10	7-9	6-8
PCC Crack sealing	5-7	4-6	3-5	5-7	4-6	3-5	5-7	4-6	3-5

Diamond Grinding	15-17	12-15	10-12	15-17	12-15	10-12	15-17	12-15	10-12
Partial depth Spall Repair	10-12	9-11	8-10	10-12	9-11	8-10	10-12	9-11	8-10
Full depth spall repair	12-15	11-14	10-12	12-15	11-14	10-12	12-15	11-14	10-12
Dowel Bar Retrofit****	15-20	12-15	10-12	15-20	12-15	10-12	15-20	12-15	10-12
Random slab replacement	15-20	12-15	10-12	12-18	11-15	8-12	10-15	10-12	8-10

* Treatment life is defined as the number of years a given treatment will serve its function (before another treatment is required). Treatment life is a function of the existing pavement condition and other factors such as traffic, climate, quality of materials and construction). Pavement condition was defined by the PPTG as a PCI of 80 or better for good; 60 for fair; 40 for poor. Following are tentative definitions for cracking in the various categories in pavement condition:

- Good- Minor distress (< 5 % cracking A+B). Expected life of 10 years.
- Fair- minor to moderate distress (5-20% cracking A+B). Expected life of 4-6 years.
- Poor condition- (>20 % cracking A+B)). Moderate to severe distress and with structural problems. Expected life of 2-4 years

**Crack filling is recommended for this situation
*** Treatment not recommended
**** National average

APPENDIX B

TYPICAL TREATMENT COSTS FOR CALIFORNIA-2007

Typical Treatment Costs for California-2007

Background

Cost data for the various pavement preservation treatments is needed to evaluate the cost effectiveness of a proactive pavement preservation program with existing practices. This document consists of information provided by the various PPTG subgroups dealing with the treatments. It includes typical costs for normal jobs, for night time work, and for jobs with short work periods. Further, the costs are further subdivided into costs for large, medium and small jobs for each of the treatments. The actual definition of the size of the job needs to be provided by the various sub-groups. The costs in this table represent only the material and application costs. Costs of traffic control, striping, raised markers and the like are not included.

Table B-1. Estimated Costs for Pavement Preservation Treatments Used in California

Treatment	Size of Job	Cost ($/square yard)		Premium for Night Work ($/square yard)		Premium for Short Work Periods / Zones ($/square yards)	
		Low	High	Low	High	Low	High
FLEXIBLE TREATMENTS							
HMA Crack Sealing (10-15% cracking)	Small	0.60	1.05	0.15	0.30	0.30	0.60
HMA Crack Sealing (10-15% cracking)	Medium	0.40	0.65	0.10	0.15	0.20	0.35
HMA Crack Sealing (10-15% cracking)	Large	0.30	0.45	0.05	0.10	0.15	0.30
HMA Crack Filling (10-15% cracking)	Small	0.55	1.00	0.15	0.30	0.30	0.60
HMA Crack Filling (10-15% cracking)	Medium	0.35	0.60	0.10	0.15	0.20	0.35
HMA Crack Filling (10-15% cracking)	Large	0.25	0.40	0.05	0.10	0.15	0.30
Fog Seals	n/a	0.15	0.30	0.05	0.05	0.10	0.10
Rejuvenator Seals	n/a	0.20	0.50	0.10	0.10	0.20	0.20
Scrub Seals with Chips	n/a	2.15	2.15	n/a	n/a	n/a	n/a
Slurry Seals	Small	1.90	2.60	n/a	n/a	n/a	n/a
Slurry Seals	Medium	1.75	2.40	n/a	n/a	n/a	n/a
Slurry Seals	Large	1.60	2.20	n/a	n/a	0.30	0.30
Rubberized Slurry Seal (REAS)	Small	2.20	2.80	n/a	n/a	0.30	0.30
Rubberized Slurry Seal (REAS)	Medium	n/a	n/a	n/a	n/a	n/a	n/a
Microsurfacing	Small	2.25	3.00	0.20	0.20	n/a	n/a
Microsurfacing	Medium	2.10	2.90	0.15	0.15	n/a	n/a
Microsurfacing	Large	2.00	2.80	0.10	0.10	n/a	n/a
PME Chip Seals	Small	3.00	3.50	n/a	n/a	0.50	1.00
PME Chip Seals	Medium	2.25	5.75	n/a	n/a	n/a	n/a
PME Chip Seals	Large	1.80	2.00	n/a	n/a	n/a	n/a
PMA Chip Seals	Small	3.00	3.50	n/a	n/a	0.50	1.00
PMA Chip Seals	Medium	2.25	2.75	n/a	n/a	n/a	n/a
AR Chip Seals	Small	4.25	5.00	n/a	n/a	0.50	1.00
AR Chip Seals	Medium	4.00	4.75	n/a	n/a	n/a	n/a
AR Chip Seals	Large	3.75	4.55	n/a	n/a	n/a	n/a
Chip Seal with Fabric Interlayer	Small	n/a	n/a	n/a	n/a	n/a	n/a
Chip Seal with Fabric Interlayer	Medium	n/a	n/a	n/a	n/a	n/a	n/a

Treatment	Size of Job	Cost ($/square yard)		Premium for Night Work ($/square yard)		Premium for Short Work Periods / Zones ($/square yards)	
		Low	**High**	**Low**	**High**	**Low**	**High**
Cape Seals (with slurry)	Small	n/a	n/a	n/a	n/a	n/a	n/a
Cape Seals (with slurry)	Medium	n/a	n/a	n/a	n/a	n/a	n/a
Cape Seals (with slurry)	Large	n/a	n/a	n/a	n/a	n/a	n/a
Cape Seals (with micro)	Small	n/a	n/a	n/a	n/a	n/a	n/a
Cape Seals (with micro)	Medium	n/a	n/a	n/a	n/a	n/a	n/a
Cape Seals (with micro)	Large	n/a	n/a	n/a	n/a	n/a	n/a
Conventional HMA (30 mm)	Medium	8.00	12.00	**15%**	**15%**	**15%**	**25%**
Conventional HMA (30 mm)	Large	n/a	n/a	n/a	n/a	n/a	n/a
PMA HMA (30 mm)	Medium	10.00	14.00	n/a	n/a	**15%**	**25%**
PMA HMA (30 mm)	Large	n/a	n/a	n/a	n/a	n/a	n/a
RAC-G (30 mm)	Medium	10.00	14.00	n/a	n/a	**15%**	**25%**
RAC-G (30 mm)	Large	n/a	n/a	n/a	n/a	n/a	n/a
RAC-O (30 mm)	Medium	10.00	14.00	n/a	n/a	**15%**	**25%**
RAC-O (30 mm)	Large	n/a	n/a	n/a	n/a	n/a	n/a
BWC-polymers (Gap and Open)	Medium	10.00	14.00	n/a	n/a	**15%**	**25%**
BWC-polymers (Gap and Open)	Large	n/a	n/a	n/a	n/a	n/a	n/a
BWC-Rubber (Gap and Open)	Medium	10.00	14.00	n/a	n/a	**15%**	**25%**
BWC-Rubber (Gap and Open)	Large	n/a	n/a	n/a	n/a	n/a	n/a
CIR-prices do not include surface course	Small	5.00	7.50	n/a	n/a	**25%**	**40%**
CIR-prices do not include surface course	Large	4.00	6.50	n/a	n/a	n/a	n/a
HIR-prices do not include surface course	Small	6.50	8.50	3.50	3.50	**35%**	**60%**
HIR-prices do not include surface course	Large	5.50	7.50	n/a	n/a	n/a	n/a
RIGID TREATMENTS							
PCC Joint Re-Sealing	All	1.00	1.00	0.15	0.15	n/a	n/a
PCC Crack Sealing	All	0.75	0.75	0.15	0.15	n/a	n/a
PCC Silicone Crack Sealing	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Diamond Grinding	Medium	5.25	5.25	0.25	0.25	n/a	n/a
Diamond Grinding	Large	4.75	4.75	0.25	0.25	n/a	n/a
Partial Depth Spall Repair	Medium	25.00	25.00	5.00	5.00	n/a	n/a
Partial Depth Spall Repair	Large	20.00	20.00	5.00	5.00	n/a	n/a
Full Depth Spall Repair	Medium	n/a	n/a	n/a	n/a	n/a	n/a
Full Depth Spall Repair	Large	n/a	n/a	n/a	n/a	n/a	n/a
Random Slab Replacement	Medium	650.00	650.00	50.00	50.00	n/a	n/a
Random Slab Replacement	Large	550.00	550.00	50.00	50.00	n/a	n/a
Dowel Bar Retrofit	Medium	40.00	40.00	5.00	5.00	n/a	n/a
Dowel Bar Retrofit	Large	35.00	35.00	5.00	5.00	n/a	n/a

* Other forms of maintenance are recommended for cracking greater than 20%
** Not Advisable