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EFFECTIVENESS OF CHIP SEALING AND MICRO SURFACING ON PAVEMENT SERVICEABILITY AND LIFE

FINAL REPORT

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16. Abstract:

This report presents the details of an investigation to evaluate the effectiveness of Ohio Department of Transportation's prevailing chip seal and micro surfacing practices. The investigation focused primarily on two issues namely, optimal timing of treatment placement and cost-effectiveness. Data was derived from ODOT's Pavement Management Information System and included location, limits, data of installation, and annual performance data for 225 chip seal and 214 micro surfacing projects. At the end, this study resulted in a critical review and comprehensive understanding of the chip seal and micro surfacing program in Ohio and provided the basic data needed to determine when and where such preventive maintenance treatments are appropriate form the standpoint of both economics and performance. Based on the results obtained, the following conclusions are made:

1. Chip seals are cost effective treatments. They provide maximum benefits when applied on pavements whose Pavement Condition Rating is in the range **66 to 80**. Under such conditions, chip seals can extend the service life of pavements up to seven years.
2. Micro surfacing treatments on general system (2-lane state routes) are reasonably effective. The best range of prior PCR for their installation is **61 to 70**. Life of micro surfacing treatments on general system is nine years.
3. Micro surfacing treatments on priority system (4-lane or more) are marginally effective. The best range of prior PCR for their installation is **61 to 70**. Micro surfacing on priority system can extend the service life of treated pavements by eight years.

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DISCLAIMER

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EFECTIVENSS OF CHIP SEALING AND MICRO SURFACING ON PAVEMENT SERVICEABILITY AND LIFE

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Problem Statement

Chip Seal and Micro Surfacing are important components of ODOT's pavement preventive maintenance program. Thorough understanding of how well these treatments are performing is critical to the nature and extent of their continued use in the future. Currently, there is a lack of objective information on fundamental issues such as the expected improvement in pavement condition resulting from the use of chip seal and micro surfacing, the extent to which the treatments slow the deterioration of the pavement, and the optimum timing of the treatment. As a result, present guidelines are based on anecdotal observations and experience. This study was initiated to systematically evaluate and quantify the performance and cost-effectiveness of ODOT's current chip sealing and micro surfacing practices using the data from completed and in-service projects.

Objectives

The study addressed three basic issues:

1. Treatment effectiveness: how well do chip seals and micro surfacing improve the condition of treated pavements?
2. Extension of pavement service life: to what extent does each of the treatments delay the pavement deterioration process?

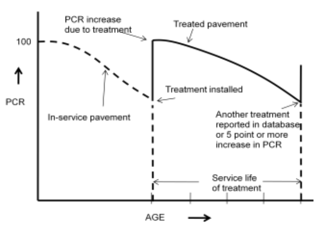
3. Influence of treatment time: what is optimal time or pavement condition when the treatment can be most effectively applied?

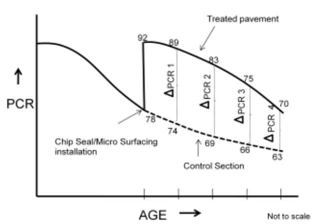
Methodology

A total of 225 chip seal and 214 micro surfacing treatments were applied in Ohio between the years 1999 and 2006. ODOT's pavement management information system consisted of relevant information including project location, dates of treatment, Pavement Condition Rating (before the treatment and for every year after the treatment), pavement type and functional classification. An experiment was designed to utilize this data to evaluate the effectiveness of the treatments. In addition, control sections with similar attributes were identified and used as 'do-nothing' sections. Effectiveness was evaluated with the aid of following five performance indicators:

1. Service life of treatments based on actual number of years in service
2. Average performance gain
3. Service life of treatments using performance models
4. Cost-effectiveness
5. Life cycle costs.

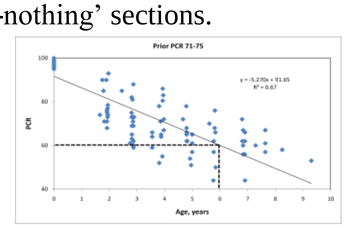
Service life was calculated as the time from the period of treatment installation till the time another activity was reported in the database.





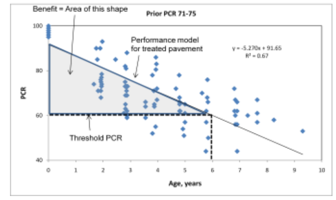
Performance gain was calculated for each project as the average difference in the PCR for each year between the treated and 'do-nothing' sections.

Treated pavements were divided into various groups based on the PCR prior to the treatment. Performance prediction

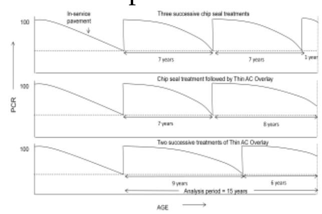


models were developed for each of these groups. Life of treated pavements was obtained as the number of years to reach a threshold PCR.

Benefit cost ratio of the chip seal and micro surfacing treatments was obtained as the ratio of area of performance curve and the cost of treatment.



From a previously completed study, benefit cost ratios were available for Thin Asphalt Overlays, another preventive maintenance treatment practiced in Ohio. Life cycle cost analysis of chip seal and micro surfacing treatments was performed by comparing the benefit cost ratios with that of thin AC overlays.



Conclusions:

1. Chip seals are cost effective treatments. They provide maximum benefits when applied on pavements whose PCR is in the range 66 to 80. Under such conditions, chip seals can extend the service life of pavements up to seven years.
2. Micro surfacing treatments on general system (2-lane state routes) are reasonably effective. The best range of prior PCR for their installation is 61 to 70. Life of micro surfacing treatments on general system is nine years.
3. Micro surfacing treatments on priority system (4-lane or more) are marginally effective. The best range of prior PCR for their installation is 61 to 70. Micro surfacing on priority system can extend the service life of treated pavements by eight years.

Implementation Potential:

The results of the study can be translated into appropriate revisions of ODOT's Preventive Maintenance Guidelines. With this, the district and county officials will be better able to identify which pavements are suited for chip seal and micro surfacing treatments.

EFFECTIVENESS OF CHIP SEALING AND MICRO SURFACING ON PAVEMENT SERVICEABILITY AND LIFE

1.0 GENERAL

Chip Seal and Micro Surfacing are two of the many preventive maintenance treatments used in Ohio for the preservation of asphalt surfaced pavements. The primary intent of using these treatments is to arrest pavement deterioration and defer costly rehabilitation actions. In Ohio practice [1], chip seal is a sprayed application of a polymer-modified asphalt binder covered immediately by washed limestone or dolomite aggregate, and rolled with a pneumatic-tired roller to seat the aggregate in the binder. Chip seals are used to provide a new wearing surface on low volume roadways that is intended to eliminate raveling, retard oxidation, reduce the intrusion of water, improve skid resistance and seal cracks. A double application chip seal is a possible (but rarely used) option for reactive maintenance, not as a preventive treatment. Double application chip seals are not only used for reactive maintenance but also as minor rehabilitation for low volume general system pavements. Figures 1 and 2 illustrate chip seal treatment in progress and finished surface respectively.

Figure 1. Chip Seal Treatment in Progress

Figure 2. Close-up View of Finished Chip Seal Project

Micro surfacing is a cold-applied paving mixture composed of polymer-modified asphalt emulsion, crushed aggregate, mineral filler, water and a hardening-controlling additive. A traveling pug mill is used to proportion, mix and apply a thin layer of the mixture to the pavement. No rolling is required and the finished surface can generally be opened to traffic soon after placement. Like a chip seal, micro surfacing can be used as a blanket cover on pavements suffering from loss of skid resistance, oxidation, raveling and surface permeability. In addition, micro surfacing can be used to fill ruts and improve rideability by removing minor surface irregularities. Micro surfacing is suitable for all traffic levels. In Ohio, micro surfacing treatment has been primarily applied on high volume roads. A double application is required for traffic volumes in excess of 10,000 vehicles per day [1]. Figures 3 and 4 depict micro surfacing treatment in progress and completed surface respectively.

Figure 3. Micro Surfacing Treatment in Progress

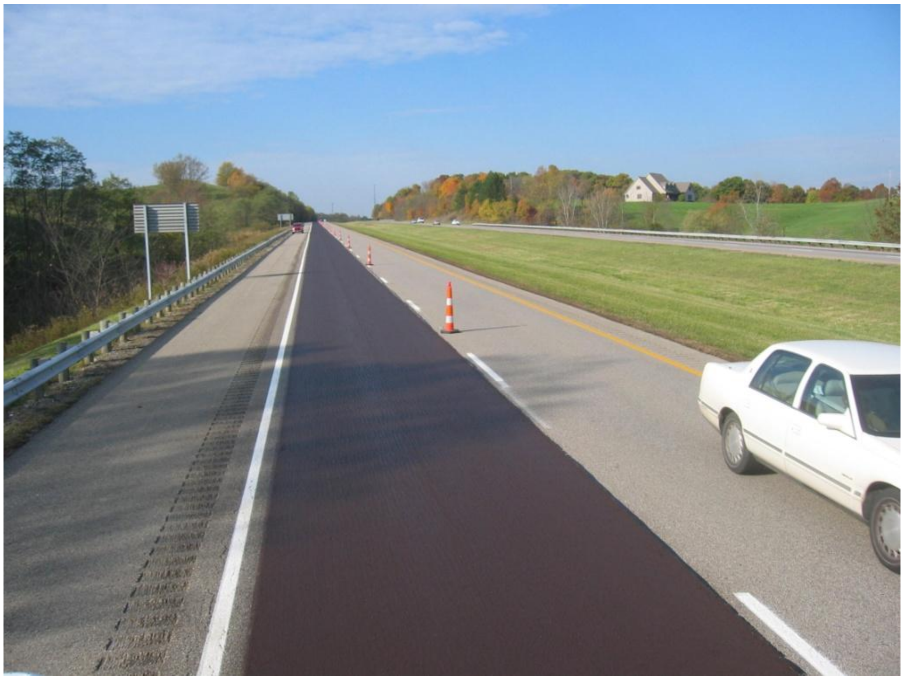


Figure 4. Finished Micro Surfacing Project

2.0 OHIO DEPARTMENT OF TRANSPORTATION SPECIFICATIONS AND QUALITY REQUIREMENTS

2.1 Chip Seal

In 1997, the ODOT specification for surface treatment item was Seal Coat (Item 409), and consisted of a traditional cut-back asphalt binder and graded aggregate. In 2000, ODOT adopted a supplementary specification which substituted a polymer-modified asphalt emulsion for the traditional cut-back binder in surface treatments. In late 2001, the current chip seal item was adopted as a supplementary specification (Item 821) and continued as a standard (Item 422) in the 2002 Construction and Materials Specification (CMS) [2]. Among other refinements, the new provisions provided for:

- Use of a polymer-modified asphalt emulsion binder, which sets up more quickly, retains chips better, and is generally more durable.
- Use of a more restricted (uniform) aggregate gradation to promote chip retention.
- Use of a job-mix formula to promote quality control of the aggregate gradation.
- Use of a test strip to demonstrate that the contractor's materials and construction techniques are capable of producing the desired result.

A unique evaluation criterion, based on visual observation of the finished surface, is in force for the quality control and acceptance of chip seal jobs in Ohio [3]. Three types of defects are evaluated namely, surface patterns, bleeding/flushing, and loss of cover aggregates. The finished surface is reviewed to ensure: (i) a uniform pattern without alternate lean and heavy lines, (ii) appropriate amount of binder not leading to bleeding/flushing, and (iii) no loss of aggregate from the surface.

2.2 Micro Surfacing

While micro surfacing is a more recent development than chip sealing, it too has been in use for many years. Micro surfacing was originally developed in Germany in the early 1970's by engineers who were seeking a way to modify a conventional slurry-seal to permit it to be used as a narrow, wheelpath inlay to correct rutting without destroying the expensive striping on the autobahns. The German engineers succeeded by developing a special (proprietary) blend of aggregates, polymers and emulsifiers.

This product was introduced in the U.S. in 1980 as "Ralumac", a trade-marked product distributed by Koch Materials. Based on the ability of the material to provide stable layers of variable thickness, the uses expanded over time from wheelpath inlays [4] to include wedge courses, scratch courses, and full-width surfacing. Eventually, the treatment became the generic product micro surfacing.

ODOT began using micro surfacing on an experimental basis in the early 1990's; it was first included as a standard in the 1997 specifications (Item 406) and continued as Item 421 in the 2002 CMS [2]. Due in large part to its history as a proprietary product, the ODOT quality requirements for micro surfacing have not generally evolved in a manner similar to chip seals, but basically have remained unchanged from the earliest installations.

2.3 Unresolved Issues Affecting the Successful Use of Chip Seal and Micro Surfacing Treatments

2.3.1 Cost-Effectiveness

Of late, many highway agencies, including the Ohio Department of Transportation (ODOT), are increasing their investment in chip seals and micro surfacing as a means of preserving the system and postponing more costly rehabilitation efforts. Underlying this shift in focus is the widely-accepted assumption that these efforts are consistently cost-effective. Nationally, it is estimated that a total of some 950 million square yards of chip seals and about one million tons of micro surfacing are placed each year [4, 5].

In fact, despite the widespread use of chip seals and micro surfacing nationally, very little performance monitoring has been performed to quantify their cost-effectiveness on pavements of different levels of distress. For example, a literature review undertaken by the Wisconsin DOT noted that only a few studies were found which were specifically designed to track the cost-effectiveness of preventive maintenance treatments [6]. Further complicating this situation is the relatively long time often required for the benefits of preventive maintenance to be realized in terms of improved pavement condition [7]. Consequently, there is a lack of objective information on such fundamental issues such as the expected improvement in pavement condition resulting from the use of chip seals and micro surfacing, the extent to which the treatments slow the deterioration of the pavement, and the optimum timing of the treatments. This lack of information obviously inhibits making the most informed and effective decisions regarding alternative maintenance strategies, funding levels, and other important issues of maintenance administration.

2.3.2 Treatment Timing

As implied in the preventive maintenance mantra "apply the right treatment to the right pavement at the right time", many investigators have indicated that the real challenge in the determination of cost-effectiveness is determining the optimal time to apply the treatment.

Time and money are the basic yardsticks for measuring cost-effectiveness. If a treatment is placed too late–after structural distress has appeared– the treatment will be ineffective because a structural distress will render the treatment ineffective due to premature failure created by the same underlying distress. Conversely, placing a treatment too early adds little benefit, and thus is a waste of money. The optimal treatment time defines the window of time when preventive maintenance treatments perform as intended, thus providing the most efficient use of funding to extend pavement life (i.e., providing the greatest improvement at the lowest cost).

A recently concluded NCHRP study [8] summarized the problematic nature of the state-of-the-practice with regard to optimal timing as follows:

- There is almost no guidance available on the topic of optimal treatment time, even within agencies identified as national leaders in preventive maintenance.
- There is no indication that agencies are optimizing the timing of their treatment placement, nor are there any signs that a form of optimization is actually being applied.

2.3.3 Integration of Preventive Maintenance and Pavement Management

A recurring point made in preventive maintenance guidelines is the essential need to integrate an agency's preventive maintenance program with its pavement management system (PMS). This permits the inclusion of strategies, facilitating planning and budgeting functions, to promote more optimal treatments on a network scale.

A major remaining challenge to the integration of preventive maintenance treatments into a PMS is the need to develop performance models for various preventive maintenance treatments. Simply, to match feasible treatments with pavement conditions, the decision-maker needs to be able to predict the short- and long-term changes in pavement condition expected to result from the treatment.

Unfortunately, due to a lack of data regarding the cost-effectiveness of maintenance treatments in general, and the optimal treatment time in particular, (a) very few pavement deterioration models include maintenance as an explanatory variable and (b) none have been refined to the point of optimization. As a consequence, many agencies use estimates of the service life of maintenance treatments based on local experience to formulate rules-of-thumb which estimate the effect on the life of the pavement. For example, ODOT's Pavement Preventive Maintenance (PPM) Training Manual [1] indicates that while no data currently exists concerning Pavement Condition Rating (PCR) trends of chip sealed or micro surfaced pavements, the expected service lives are 5-7 and 5-8 years respectively, and in each case, the rate of PCR drop should be similar to that observed since the last overlay.

3.0 CURRENT RESEARCH TRENDS

3.1 Specifications and Quality Requirements

As with any highway project, the successful application of a preventive maintenance treatment requires consideration of both project *planning* and project *execution*. In the case of chip sealing and micro surfacing, success in the planning phase basically requires (a) suitably matching feasible treatments with pavement conditions based on their cost-effectiveness and (b) determining the appropriate treatment timing.

3.1.1 <u>Chip Seals</u>

A number of national studies of chip seal performance [9, 10], including installations made as part of the Long-Term Pavement Performance (LTPP) SPS-3 experiment [11, 12], indicate that these treatments generally perform well. However, despite their widespread use and reported successes in preventive maintenance, the performance of chip seals does not always meet expectations. Slow curing times, unpredictable quality, premature failures, and vehicle damage from unbound chips continue to be reported. As recently noted by the Foundation for Pavement Preservation, chip sealing continues to be an art, and when not properly applied, can result in early failures and costly reactive maintenance [13]. For example, in a recent Utah survey [14], responses from 18 states that use chip seals indicated that an estimated 27% of installations fail prior to overlay. In part, these failure rates reflect differing definitions of failure between agencies and differences in service conditions (i.e., chip seals are obviously used for *corrective* as well as preventive maintenance).

A number of initiatives have recently been undertaken by highway agencies to improve chip seal performance, including:

- *Use of a design procedure to assess the proper amount of aggregate as well as the quantity of binder*. Some agencies (including ODOT) specify an application rate for the chip seal binder, but not the aggregate. Based on extensive field research, the Minnesota DOT (MnDOT) has found that a chip seal design procedure that yields a specific target rate for applying the aggregate results in more durable treatment, with reduced potential for excess chips [15]. The MnDOT design procedure is a variation of the McLeod method used in the SHRP research. Minnesota reports that the aggregate application rate determined from the design process is almost always the correct rate to apply in the field. Because the binder rate depends on the texture and porosity of the existing pavement, it often needs to be adjusted (usually upwards). Based on the MnDOT's convincing research, South Dakota [16] and Iowa [17] have recently opted to use the design procedure.

- *New test methods for predicting field performance of chip seal aggregates.* ASTM has recently adopted a performance-related test procedure which reportedly better characterizes the breaking, curing and chip retention of chip seal emulsions using project materials [18].
- *Use of a more uniform aggregate gradation*. This permits the use of a thicker membrane, which promotes long- term adhesion of the aggregate, higher surface friction, and better waterproofing characteristics [15].
- *Use of faster setting emulsions*. This permits earlier opening to traffic [19].

3.1.2 Micro surfacing

Unlike chip sealing, few recent studies have been undertaken which are specifically directed at improving specifications and quality requirements for micro surfacing.

The most significant current work on this topic is a pooled fund study designed to develop improved mix design procedures for slurry seals and micro surfacing. The overall goal of the study is to improve the performance of slurry seal and micro surfacing systems through the development of a rational mix design procedure, guidelines, and specifications. Fourteen states are currently participating in the study, with Caltrans serving as the lead agency [20].

The pooled fund study was undertaken in recognition of the fact that--despite the widespread use of slurry seals and micro surfacing-- current tests and design methods for these treatments are primarily empirical and not related to field performance [21]. The current design procedure for micro surfacing (A143) by the International Slurry Seal Association and the corresponding ASTM Standard (D6372) were originated in the 1980's before the widespread use of micro surfacing and polymer-modified emulsions. The problems associated with the current existing methods for micro surfacing were documented in Texas Transportation Institute (TTI) studies [22]. In a nutshell, to achieve success with micro surfacing, the current practice relies heavily on the experience of the construction crew; to more consistently provide good results, what is needed are additional performance-related design inputs. Recognizing this need, the FHWA enlisted Caltrans to form the pooled fund study.

In addition to developing improved micro surfacing mix design procedures, the Caltrans study is intended to:

- provide guidance on the appropriate use of the treatment (e.g., pavement conditions),
- identify characteristics that ensure long-term performance,
- provide guidance on project selection, and
- provide recommended project specifications.

3.2 Analysis Methodology for Preventive Maintenance Treatments

3.2.1 Optimal Treatment Timing

Currently, the guidance for timely application of preventive maintenance is often very general. For example, based on practices recommended by the SHRP research, the average asphalt-surfaced highway should receive an initial preventive maintenance treatment after 7 years, a second treatment after 14 years, and an overlay after 19 years. A study of the economics of preventive maintenance indicated that current practice is to apply preventive maintenance later in a pavement's life cycle. Such a practice necessitates an earlier overlay [23].

Several recently completed studies [8, 24] address the treatment timing issue. For the most part, the cited studies have primarily involved modeling, rather than the collection and analysis of field data. For example, because of the limited amount of data available to support an analysis of preventive maintenance performance at various application timings, the focus of the NCHRP study [8] was changed from developing a guide for optimal timing to developing a spreadsheet-based analytical tool. This tool (*"OPTime*") should be useful in assessing "what if" treatment timing scenarios.

3.2.2 Quantifying Effectiveness

A recent publication by Purdue researchers [25] quantified the effectiveness of micro surfacing treatments. Based on a review of 29 completed projects, they reported that micro surfacing can offer average reduction of 0.442 m/km International Roughness Index, 4 mm rut depth and 6.2 points increase in pavement condition rating. The report also stated that the average service life offered by micro surfacing treatment is five years.

3.2.3 Cost-Effectiveness Models

A number of economic models are available for analyzing the cost-effectiveness of preventive maintenance treatments, each of which has advantages and disadvantages. These various approaches are distinctly different:

- some are very simple, others are relatively complex;
- some focus on minimizing costs, others on maximizing benefits, and some address both (i.e., benefit/cost ratios);
- some provide a direct measure of monetary benefits/costs, others rely on a surrogate (indirect) economic measure;

- some focus on the economic impact on the highway agency, others on the consequences to the motorist, and
- some are based on relatively short-term data (treatment service life), others require long-term data (extensions of pavement service life).

The cost-effectiveness evaluation technique recommended for use by the Foundation for Pavement Preservation [26] and others [27] is the Equivalent Annual Cost method. The computation required for this technique, which was used by Louisiana in a study of chip sealing and micro surfacing [28, 29], is simply the ratio of treatment construction cost to the expected service life of the treatment.

While the EAC method is undoubtedly useful as a way of comparing the relative costs of alternate treatments of *known* cost-effectiveness, it is ill-suited to determining *whether or not* those treatments are in fact cost-effective in the first place. Simply, this approach provides no insight on the central question of cost-effectiveness: “What are the economic consequences of applying this preventive maintenance treatment–i.e., the benefit in terms of extended service life or other quantitative effect on pavement performance– *as compared to* the do-nothing alternative?”

Resolving this economic issue requires use of a model which (a) takes the time-value of money into account and (b) focuses on pavement service life, not treatment life. One such model was used in cost-effectiveness analyses undertaken in the previously-cited Purdue study [24]. There, for a variety of preventive maintenance strategies, an Incremental Benefit Cost Ratio for each strategy relative to the zero-maintenance strategy was computed.

Once the necessary comparative field performance data has been obtained, computation of the cost term is very straightforward, requiring application of well-established Life-Cycle Cost Analysis (LCCA) procedures. The results of this computation are a direct measure of the savings resulting from the deferral of time to overlay, reduced overlay thickness required, and/or reduced need for corrective maintenance resulting from the preventive treatment.

Computation of the benefits term is less direct. Indeed, because of the difficulty traditionally encountered in quantifying differential performance benefits between alternate project strategies, highway engineers often make simplifying assumptions that avoid the benefits issue in economic analyses. For example, LCCA procedures assume that the benefits of keeping the roadway above some pre-established terminal serviceability level are the same for all design alternates [30]. Thus, the procedures do not consider the condition of the pavement in the analysis and assume that the lowest cost treatment is the best one.

The approach to the computation of benefits adopted by the Purdue researchers was to use area under the performance curve as a surrogate measure of monetary benefits. This concept has been in use since the 1980's, particularly in studies designed to assess the notoriously difficult-to-quantify user benefits associated with highway projects [9]. The concept has great intuitive appeal: a consistently well-maintained pavement (with a gently sloping performance curve, yielding a large area under the curve) provides greater benefits to motorists than a poorly maintained pavement (with a steep performance curve having a small underlying area).

The NCHRP Optimum Timing study also used performance curve area as a surrogate measure of the benefits of preventive maintenance treatments. While the study did not address cost-effectiveness directly, the criteria used to select optimum timing were defined as the time at which the benefit-cost ratio was a maximum. The numerous refinements in the techniques for analyzing performance curves developed during the NCHRP work can be accessed through the use of the study's *OPTime* computer program.

4.0 PRESENT STUDY – SCOPE AND OBJECTIVES

Since the inception of standards 421 (Micro Surfacing) and 422 (Chip Seal), there has been a steady interest in Ohio in using these treatments. Figure 5 illustrates the extent of chip and micro surfacing applications.

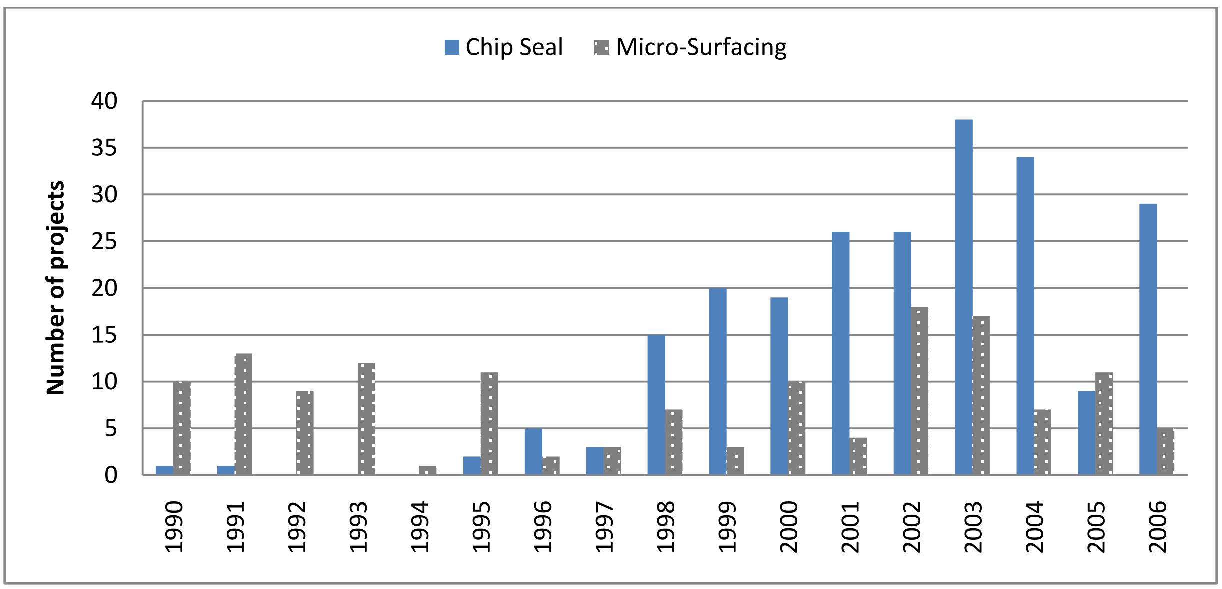


Figure 5. Chip Seal and Micro Surfacing Projects in Ohio

Assessment of performance and cost-effectiveness of these treatments is currently based on anecdotal observations and experience, rather than on objective data from a systematic investigation. Recognizing the importance of these information needs, the present study was undertaken to systematically evaluate the performance and cost-effectiveness of its current chip seal and micro surfacing program. The primary objective of this study is to comprehensively evaluate and quantify the cost-effectiveness of ODOT's current chip seal and micro surfacing pavement preventive maintenance treatment practices based on a review of historic performance data. The research was directed to address the following three basic issues:

- Treatment effectiveness: how well do chip seals and micro surfacing correct the existing distress which they are intended to remedy?
- Extension of pavement service life: to what extent does each of the treatments delay the pavement deterioration process?
- Influence of treatment time: what is the optimal time or pavement condition when the treatment can be most effectively applied?

This study resulted in a critical review and comprehensive understanding of the chip seal and micro surfacing program in Ohio and provided the basic data needed to determine when and where such preventive maintenance treatments are appropriate from the standpoint of both economics and performance. This report describes the details of the study.

5.0 DESIGN OF EXPERIMENT

The evaluation of the performance of a maintenance treatment requires the application of the particular treatment to an in-service pavement and monitoring its condition over a period of time. The effectiveness of the treatment can be determined using two approaches:

1. By comparing the relative performance of the treatment with an option of not doing anything to the pavement, termed as 'do-nothing' treatment;

2. By comparing the performance of the treatment with another treatment whose performance has previously been established.

The first approach will lead to an evaluation of performance effectiveness while the second approach provides data to determine the cost-effectiveness of the treatment under investigation. A do-nothing treatment will not have cost associated with the treatment and hence impedes cost comparisons. As a result, the pavement engineers often use one of the available treatments as a benchmark. It should be recognized that the performance and cost-effectiveness details of the benchmark treatment should be available to the agency.

In either case, it is necessary to apply the treatment to a large number of pavements so as to encompass a variety of variables such as pavement type, composition, traffic and environmental characteristics. Such a field experiment will provide the necessary data required to statistically evaluate the effectiveness of treatments under investigation.

Although a field experiment can provide the much needed data for performance and cost-effectiveness evaluation, it is obvious that setting up an experiment will require an enormous amount of time and effort to - identify candidate projects, select pavement sections, apply treatments, and monitor their condition over the full service life of treatments. According to ODOT's preventive maintenance guidelines, average life of chip seal and micro surfacing treatments vary from 5 to 8 years. To (a) confirm these service life projections and (b) develop treatment performance curves, data should be collected for up to eight years after the treatment. Hence, as an alternate, it was decided to explore the possibility of using historic data to study the behavior of constructed pavements and evaluate the performance of chip seal and micro surfacing treatments in Ohio.

6.0 REVIEW OF ODOT'S PAVEMENT MANAGEMENT DATABASE

ODOT's Pavement Management Information System (PMIS) is a repository of pavement management information. The database is comprehensive and includes all the information required to track the performance of a project. This is a relational database and has the data organized in various tables. With simple queries, it is possible to generate a list of chip seal and micro surfacing projects completed in Ohio including other relevant information such as location, construction history, geometric data, performance data, and cost-related data. Table 1 shows certain relevant details of chip seal and micro surfacing projects completed in Ohio as extracted from the database.

Treatment	# of sections	Pavement type that received treatment	Functional class
Chip seal	225	AC overlay without repairs (type 50)	General
Micro surfacing	214	AC overlay without repairs (type 50)	General and priority

Table 1. Chip Seal and Micro Surfacing Projects in Ohio

A total of 225 chip seal treatments and 214 micro surfacing treatments were applied between the years 1999 and 2006. These treatments have been placed predominantly on asphalt overlays without repairs. All of the chip seal treatments were applied on pavements on the general system highway network. Micro surfacing was applied on pavements on both the general and the priority systems. The general system is comprised predominantly of 2-lane state routes, whereas the priority system is comprised of all interstates and 4-lane (or more) divided highways. The lengths of previously completed chip seal sections have varied from 0.01 mile to

13.47 miles while corresponding lengths of micro surfacing projects varied from 0.01 mile to 9.67 miles. A significant variable in the application of these treatments has been in the pavement condition prior to the time of treatment. In Ohio, the pavement condition is expressed in terms of Pavement Condition Rating (PCR). PCR is a composite index of several distresses. Various forms of distresses depending on the pavement type - flexible, composite, jointed and continuously reinforced concrete - formulate into this index. They are subjectively rated based on the severity and extent of each distress type. Predefined weights are assigned for each distress type, severity and extent and are used to calculate PCR of each pavement section. PCR ranges from 0-100, with a pavement having no distress assigned a value of 100. ODOT's pavement management database consists of PCR data for all the chip seal and micro surfacing treated sections, for all the years they have been in service including the condition rating prior to the treatment. Figures 6, 7, and 8 depict a distribution of PCR of pavements prior to the application of chip seal and micro surfacing. Based on the availability of the PMIS data, the development of a simulated field experiment to investigate the effectiveness of chip seal and micro surfacing treatments was possible.

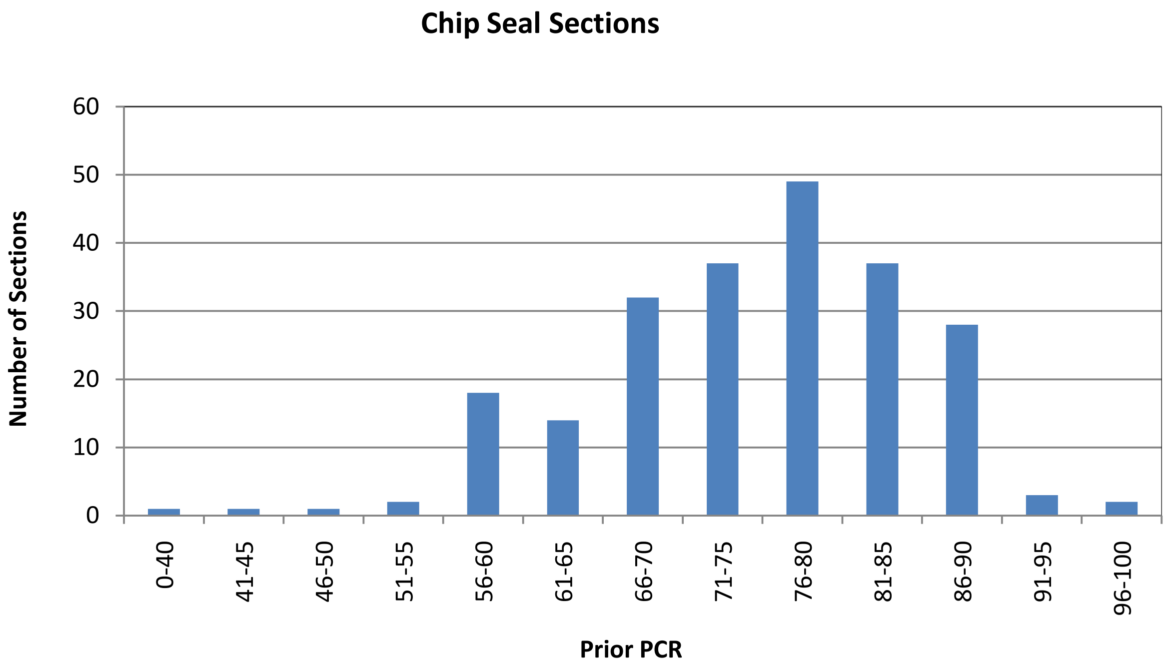


Figure 6. Condition of Pavements Before Chip Seal Treatment

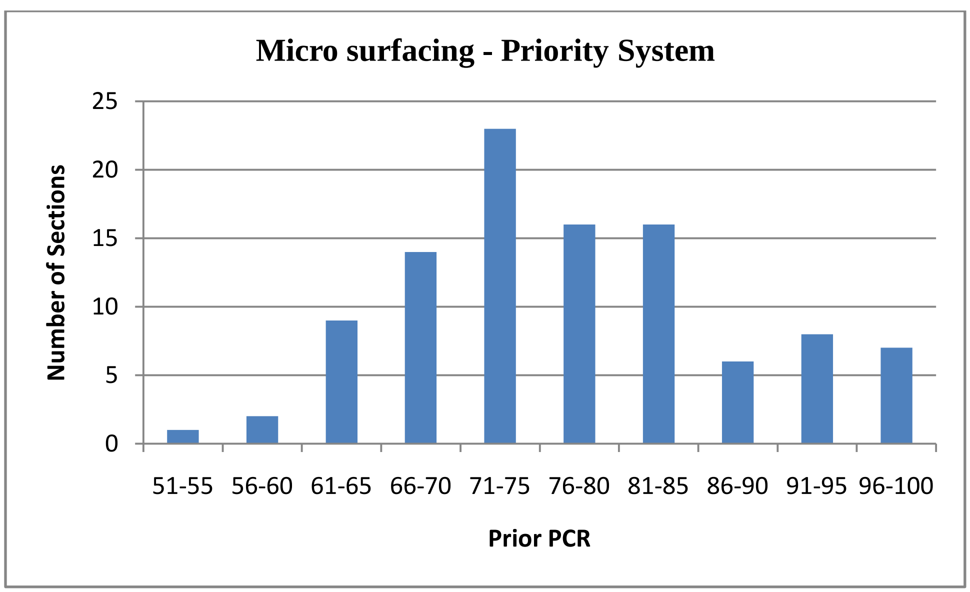


Figure 7. Condition of Pavements Before Micro Surfacing on Priority System

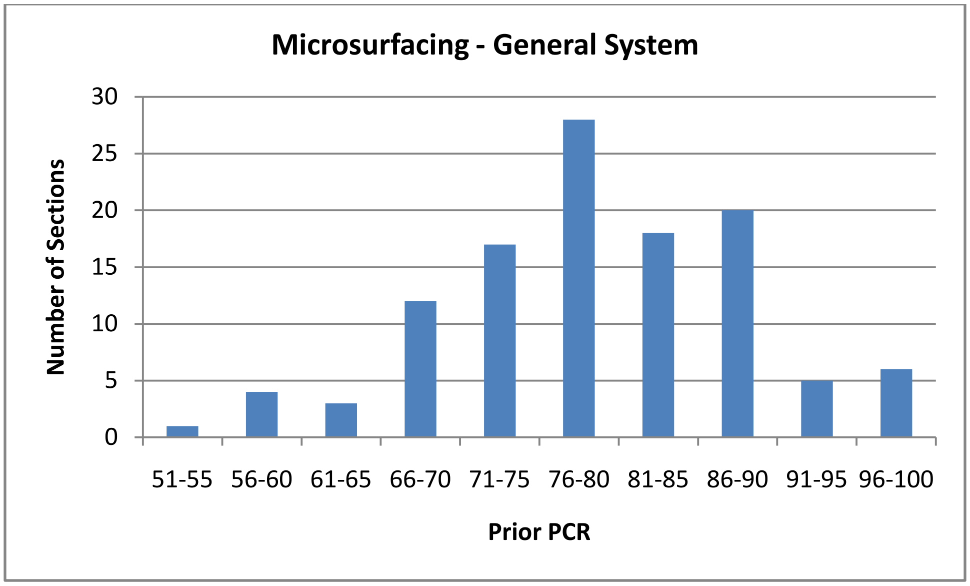


Figure 8. Condition of Pavements Before Micro Surfacing on General System

7.0 THE SIMULATION OF THE FIELD EXPERIMENT

An actual field experiment would involve the following tasks:

1. Select an array of pavement sections
2. Conduct condition survey and record preexisting conditions
3. Divide each pavement section into two parts
4. Treat the first part with chip seal/micro surfacing
5. Designate the second part as control section
6. Either leave the control section as is and do-nothing, or apply another treatment whose performance is known
7. Collect construction related data during treatment
8. Define performance indicator

9. Monitor performance of treated and control sections over a period of time
10. Develop performance curves
11. Analyze the data for cost-effectiveness of treatments

The simulation of such a field experiment requires inclusion of the above tasks and emulating all the field conditions that prevail during the field experiment. To begin with, several queries were written to extract a list of chip seal and micro surfacing treated pavement sections from the pavement management database. The list included project location, limits, pavement type, date of treatment, type of treatment, PCR data before the treatment and for every year during the service life, and functional classification of pavements. Information about the cost of treatments was obtained from construction records.

The next step was to identify control (do-nothing) sections having similar attributes as the treated pavements but did not receive any treatment. In a field experiment, the control sections are generally placed adjacent to the experimental sections and hence satisfy the required conditions of control sections. However, in a simulated experiment, it was a challenge to identify control sections from the database. A careful review of the database revealed that the pavement sections directly adjacent to the treated sections either received different treatments or had different characteristics. Hence, in order to locate control sections, the pavement management database was systematically queried to generate a list of possible control sections corresponding to each treated section. The main principle of this effort was to generate data that would allow comparing the performance of a treated section with that of a control section from a point in the service life of control section that is close to the conditions before the application of a treatment. This data formed the basis for investigating the performance effectiveness of chip seal and micro surfacing treatments. The database thus generated is listed in Tables I-A, I-B and I-C in Appendix I.

The layout of each test section simply consisted of a uniform pavement section treated with chip seal or micro surfacing. Control section with similar attributes through its length - type, severity and extent of distresses, pavement composition, maintenance and rehabilitation history, performance history, soil type, and traffic – was identified from the database to match the attributes of treated section. The control section represented "Do-Nothing" treatment.

The above effort culminated in the development of a database to compare performance of chip seal and micro surfacing with do-nothing treatment. In addition, it was also intended to compare the performance of these treatments with another maintenance treatment so as to derive information about cost-effectiveness. In consultation with ODOT engineers, the thin AC overlay treatment was chosen for this purpose. The primary reason for this decision was that this treatment was recently investigated by ODOT and hence the performance and cost-effectiveness data was available. The benefit cost computation published in the report [31] was used to compare the cost-effectiveness of chip seal and micro surfacing treatments.

8.0 PERFORMANCE INDICATORS

An important aspect of this experiment was to clearly define the performance indicators that can adequately describe the performance and cost-effectiveness of chip seal and micro surfacing treatments. In view of the data assembled, the following performance indicators were derived:

1. Service life of treatments based on actual number of years in service
2. Average performance gain
3. Service life of treatments (using performance prediction models)
4. Cost-effectiveness
5. Life cycle costs

8.1 Service life of treatments based on actual number of years in service

The data for this task was obtained directly from ODOT's PMIS. A pavement section is deemed to have completed its service life when a maintenance and/or rehabilitation activity is reported in the database following the treatment installation. The service life of chip seal and micro surfacing treatments was calculated as the time from the period of treatment installation till the time another activity was reported in the database. Construction records available in the database and project plans were used to obtain the dates of construction required for this task. Occasionally, there were some treated sections for which no further construction activity was reported. However, an increase in performance rating was noticed a few years after the treatment installation. In such events, based on consultation with ODOT engineers, an activity was assumed to have been performed when a five or more point increase in PCR was noticed in one year. Figure 9 depicts the procedure adopted to determine the service life of treatments using the historic data.

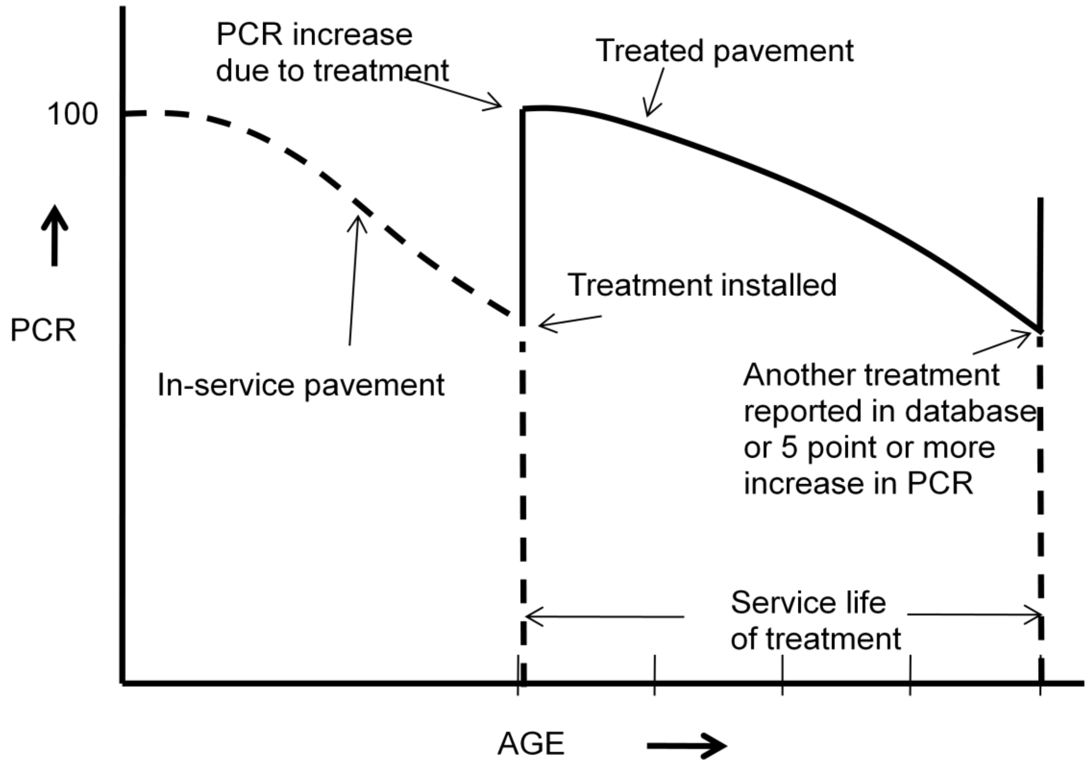


Figure 9. Calculating Service Life of Treatments Using Historic Data

8.2 Average Performance Gain

Figure 10 illustrates the method adopted for deriving average performance gain. The graph and the PCR values shown are typical of performance history of pavement sections investigated in the present study.

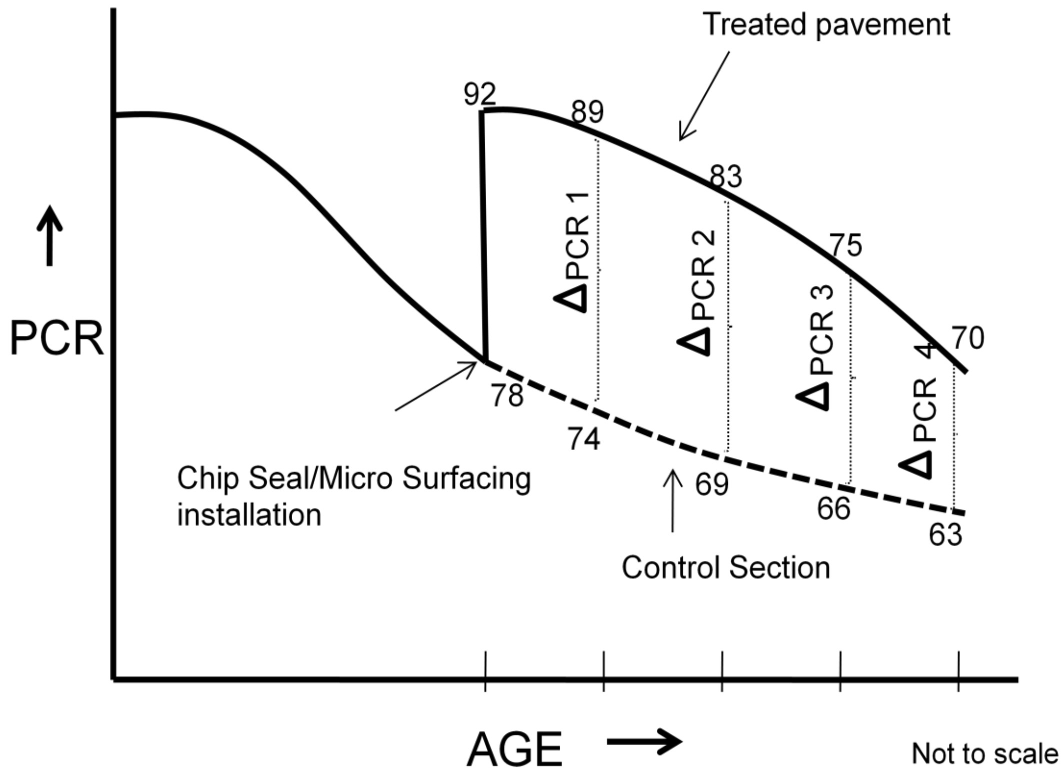


Figure 10. Calculating Performance Gain

The figure shows two performance curves – one for a control section and the other for a treated pavement. The in-service pavement was treated when its PCR was 78. As a result, its PCR increased to 92. The performance of the treated pavement is shown in the figure. The PCR value obtained before the treatment was designated as 'prior PCR'. The control section was identified from the database. The control section has very similar attributes as that of the treated section and is closest in proximity. The performance of the control section from the point when its PCR is identical to the prior PCR value of the treated section was compared with the treated section as illustrated in the figure. Performance gain for each year was calculated as the difference in PCR between the treated and control sections, Table 2.

Age, years	PCR of treated pavement	PCR of control section	PCR difference
0	92	78	14
1	89	74	15
2	83	69	14
3	75	66	9
4	70	63	7
		Average performance gain:	12

Table 2. Calculating Average Performance Gain

As can be seen, the performance gain varies with time, with maximum gain achieved soon after the treatment and the difference in PCR becoming narrower with time. Average performance gain was calculated as the average of PCR difference. Performance data was most often available for the treated sections for 3 to 5 years. As a result, a minimum of three and up to five years data was used to calculate the average performance gain.

Another point to be recognized is that, sometimes more than one pavement section was found to be candidate control section for a given treated pavement. In such cases, the average performance of all those sections was used to represent a control section.

8.3 Service Life of Treatments (using performance prediction models)

As a precursor to the analysis, PCR groups were created on a 5-point scale beginning from 51, such as 51-55, 56-60 and so on. All the treated pavement sections included in the study were placed in one of these groups based on their prior PCR values. Performance prediction models were developed for each group of treated pavements with PCR as a function of age. Various types of models namely linear and non-linear were attempted. It was determined in most instances that the linear models either provided the best fit or another shape was marginally better. For the sake of uniformity, only the linear models are presented. The number of years required for any group of pavements to reach a threshold PCR value was read from the graph and this value was reported as the life of the treated pavements. The threshold PCR values used in the analysis is 60 for general system and 65 for priority system roads. It should again be recognized here that, all chip seal installations were made on general system roads while micro surfacing installations were made on both general and priority system roads.

An example of the illustrated method is shown in Figure 11. Following this, the life of the treated pavements corresponding to each PCR group was tabulated.

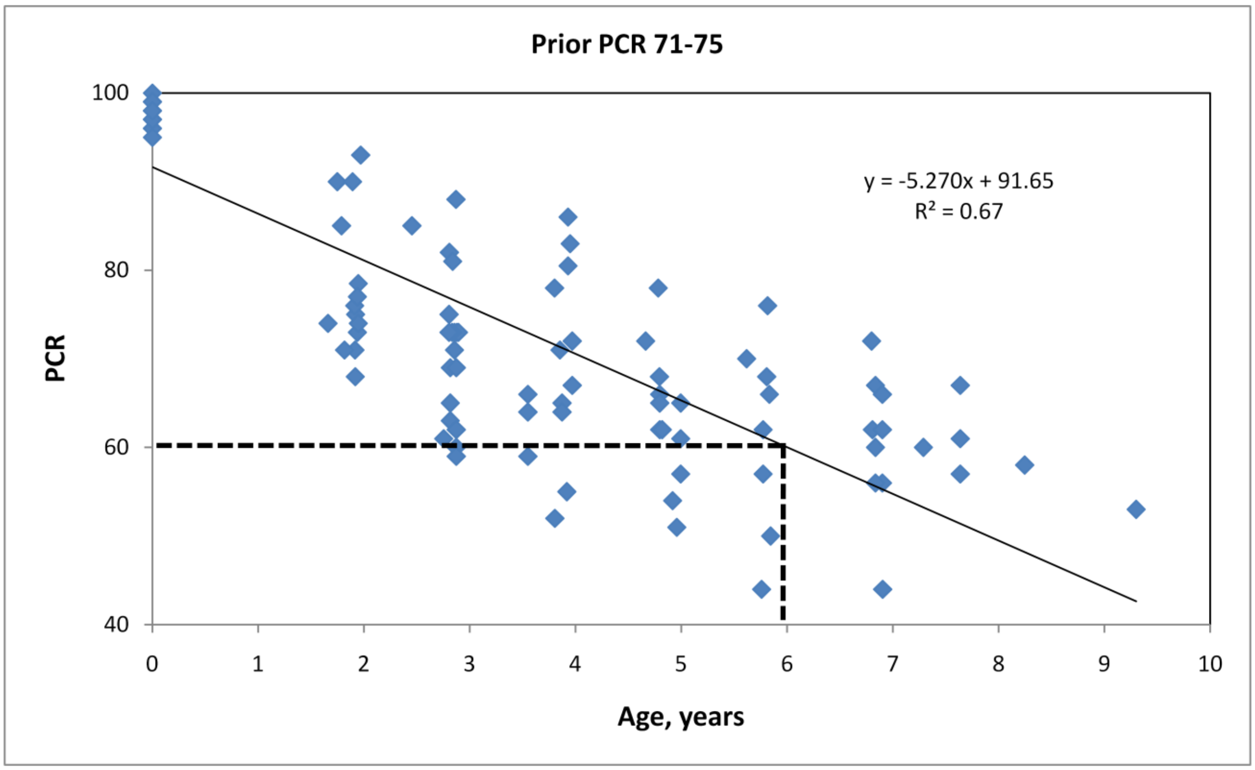


Figure 11. Calculating Life of Treatments Using Performance Prediction Models

8.4 Cost-effectiveness

Cost-effectiveness analysis is a method of comparing the relative efficiency (in monetary terms) of two or more alternatives, which allows the decision-maker to consider whether one preventive maintenance treatment is better than the other. Such comparisons are made between two competing materials to determine the relative cost-effectiveness.

In 2008, ODOT, in association with the University of Toledo, completed a study to investigate the effectiveness of thin overlays as a cost effective maintenance alternative [31]. Thin overlays of thickness two inches or less are commonly used in Ohio with the intent to improve pavement performance and extend the service life of in-service pavements. In using the historic data, the study concluded that thin overlays provide cost effective maintenance solutions. As a part of the study, the UT researchers developed performance prediction models and reported area under the performance curve as benefit of thin overlays. Figures 12 and 13 show the benefit curves developed by the UT researchers for the general and priority systems.

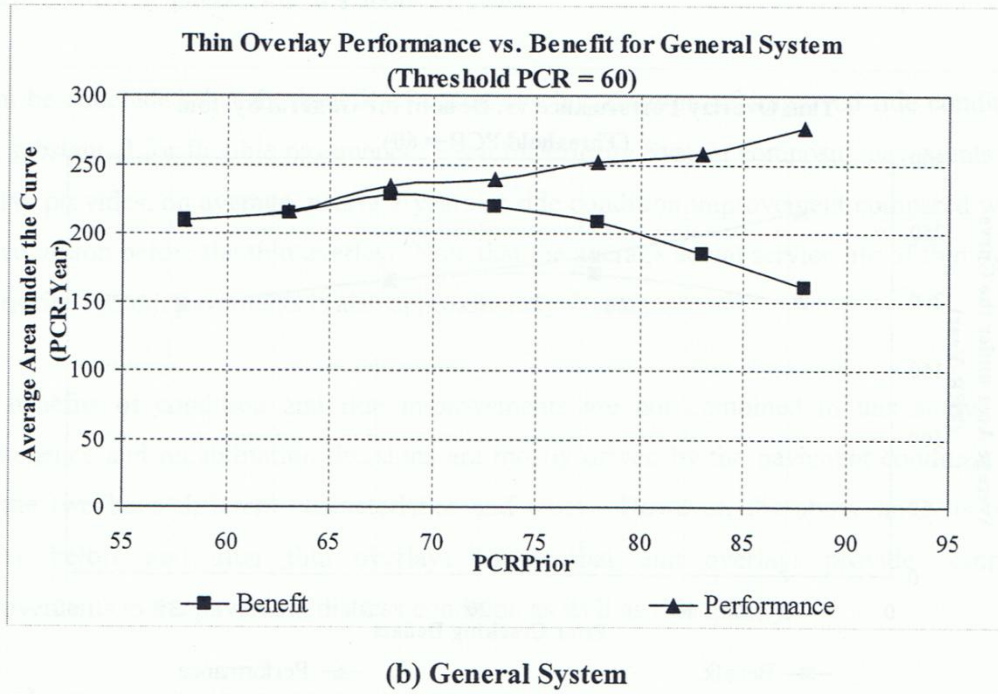


Figure 12. Benefit of Thin AC Overlay on General System Highway Network [31]

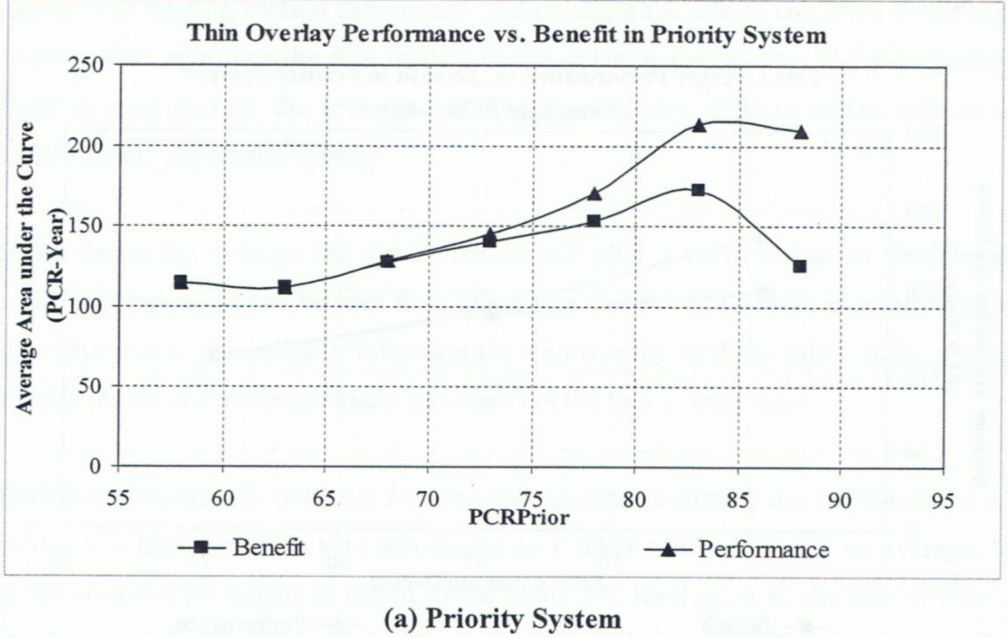


Figure 13. Benefit of Thin AC Overlay on Priority System Highway Network [31]

Cost-effectiveness of thin overlays was calculated as the ratio of benefit and cost of the treatment. Benefit values were derived for various pavement condition scenarios as noted in the figures above. Cost information was assembled from a review of construction records of previously completed projects.

In order to determine the cost-effectiveness of chip seal and micro surfacing treatments, the cost-effectiveness of these treatments were compared with that of thin AC overlays. To do this, it was necessary to generate benefit-cost ratios of chip seal and micro surfacing treatments. Performance prediction models for each of these treatments were used to obtain the benefit, as shown in Figure 14.

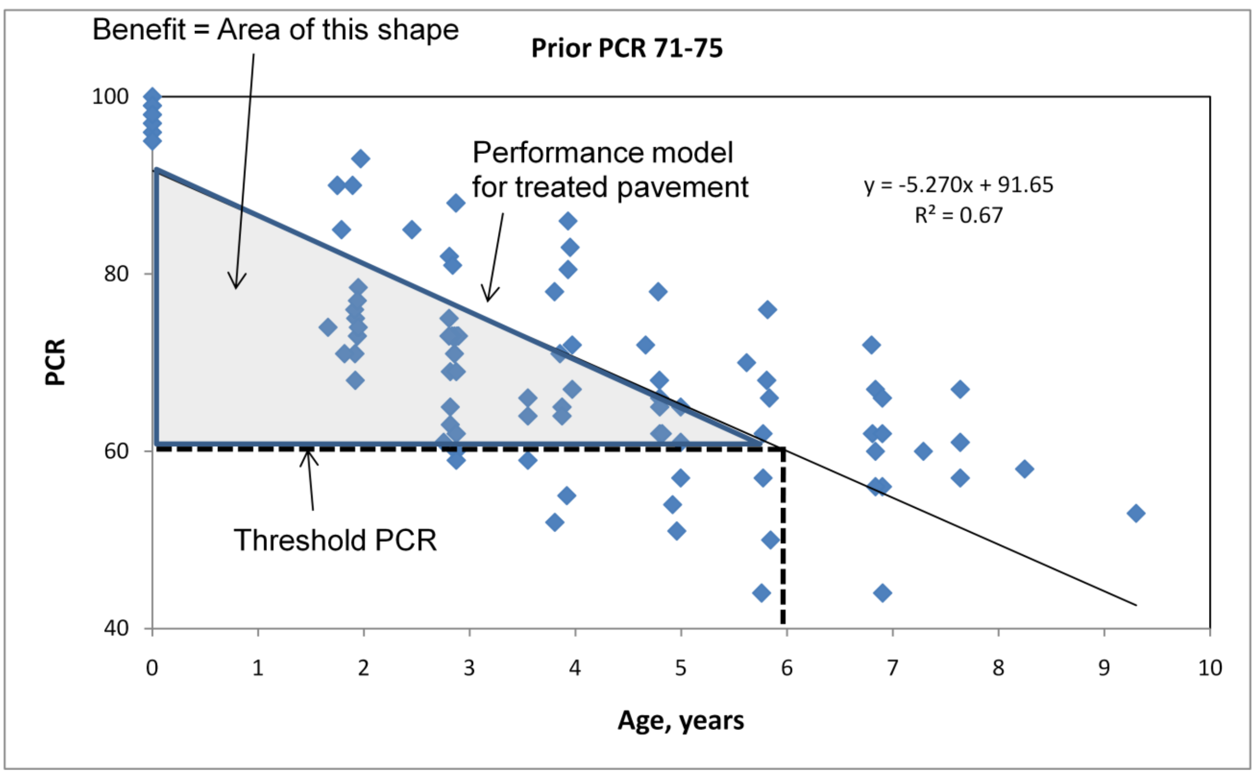


Figure 14. Computing Benefit of Treatment

As illustrated in the figure, area of the performance curve was calculated and reported as the benefit. Cost of chip seal and micro surfacing was obtained from construction records. Benefit cost was computed for various groups of pavements depending on the prior PCR values. The cost of the treatments used in the analysis was obtained in 2008 and is presented below:

- Chip seal: $10,565 per lane mile
- Micro surfacing – general system: $17,450 per lane mile
- Micro surfacing – priority system: $26,350 per lane mile
- Thin AC overlay: $66,358 per lane mile

In the next step, the ratio of the above two ratios, i.e., benefit-cost ratio of chip seal divided by the benefit-cost ratio of thin AC overlay was determined. Terming this ratio '***Relative Benefit Ratio***, it is expressed as:

$$Relative\ Benefit\ Ratio = \frac{\text{B/C Ratio of Chip Seal}}{B/C\ Ratio\ of\ Thin\ AC\ Overlay}$$

If the ratio is greater than 1.0, it can be deduced that chip seal or micro surfacing treatments provide more cost-effective performance than thin AC overlay, otherwise thin AC overlay would be a more cost effective treatment.

8.5 Life Cycle Costs

Life cycle cost analysis entails consideration of an analysis period and selection of various possible maintenance and rehabilitation scenarios during that period. A conceptual illustration of the procedure used is shown in Figure 15.

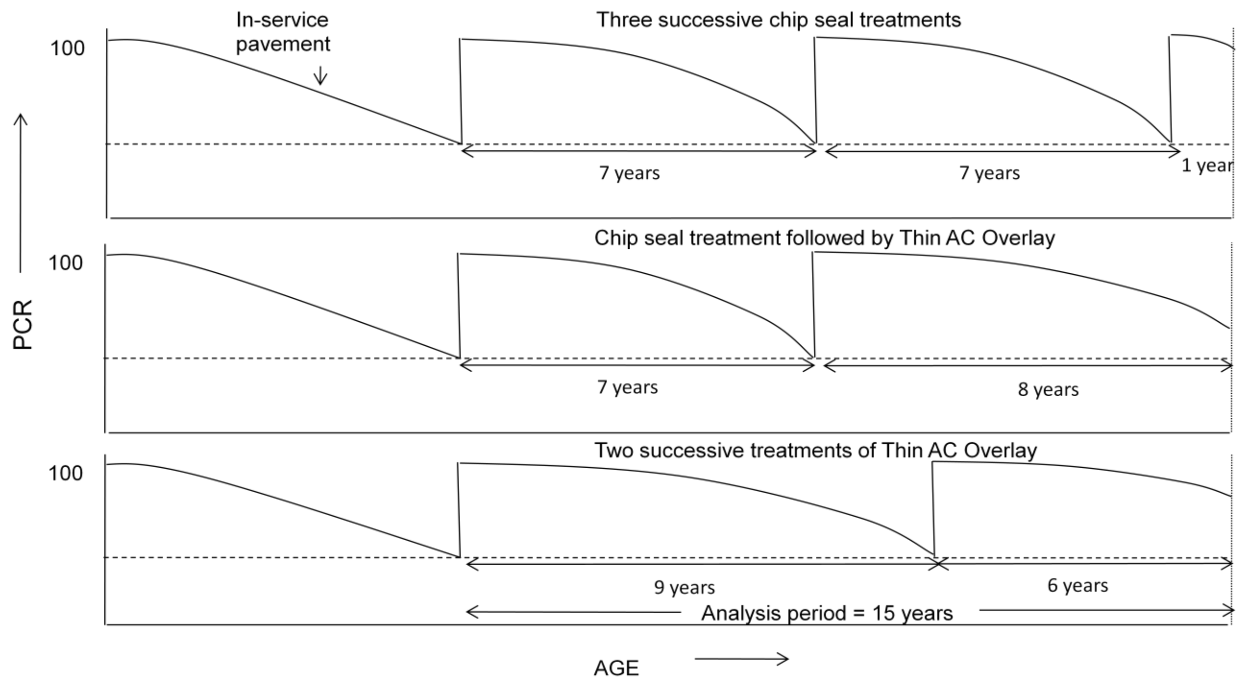


Figure 15. Life Cycle Cost Analysis of Chip Seal Treatment

The analysis presented here utilizes 15 year period. As shown, three different scenarios have been considered. The scenarios are:

1. Three successive chip seal treatments
2. Chip seal followed by thin overlay
3. Two successive treatments of thin AC overlay

For micro surfacing jobs, similar scenarios were used. However, the service life of the treatments varied.

Primary data used for this analysis was the life of treatments, cost of treatments and discount rate. Regardless of prior pavement condition, all the data was combined and one performance model was developed for each treatment type namely, chip seal, micro surfacing –

general system and micro surfacing – priority system. Because of wide variation in preexisting pavement conditions, the resulting models showed poor correlation. However, one use of these models was to estimate life of treatments on an average for use in life cycle analysis. The values used in the life cycle cost analysis are presented below:

	Life of Treatment, years	Cost of Treatment per lane mile
Chip Seal	7 years	$10,565
Micro Surfacing – general system	9 years	$17,450
Micro Surfacing – priority system	8 years	$26,350
Thin AC Overlay	9 years	$66,358

Discount Rate: 4 %

Net Present Value is used to determine the cost of the three alternatives using the formula:

$$\text{NPV}=\sum_{t=0}^{N}\frac{C_t}{(1+r)^t}$$

Where:

t – time at which cash is spent

N – total time under consideration

r –discount rate

C_t – amount spent at time t.

In the first scenario, three successive chip seal treatments were assumed at seven year intervals. At the end of 15 year analysis period, there was a salvage value of chip seal with a remaining service life of six years. Straight line depreciation method was used for the determination of salvage value. Net present value of each scenario was computed and the scenario that provided the least cost during the 15-year analysis period was considered most cost effective.

9.0 ANALYSIS OF CHIP SEAL TREATMENTS

9.1 Chip Seal - Service Life from Historic Data

As described in section 8.1, the service life of chip seal treatments was determined using the data from previously completed projects. Figure 16 and Table 3 show chip seal projects that have completed their service life and those still in service. Here the definition of 'life completed' is the pavement sections that have received another treatment after chip seal or the PCR has increased by 5 or more points. Only the projects that have completed their service life have been used in the analysis. Weighted average of service life was found to be 4 years. This indicates, ODOT's chip seal projects are being renewed on an average at intervals of four years.

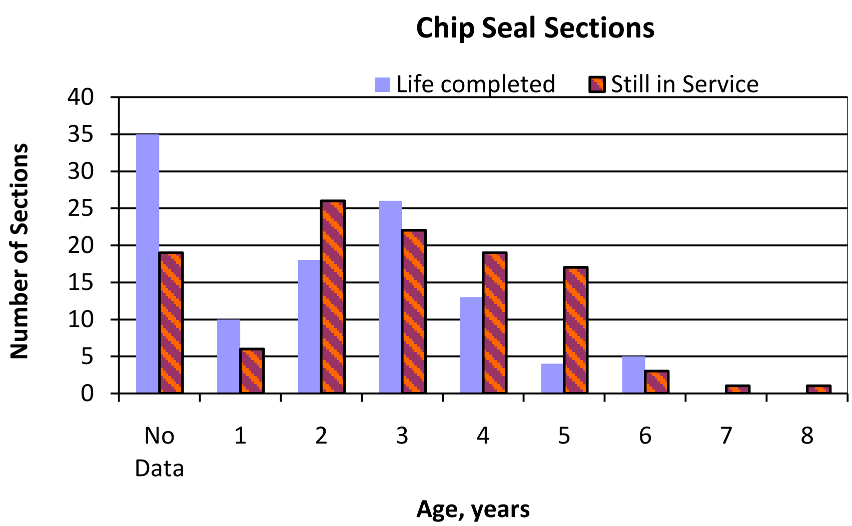


Figure 16. Service Life of Chip Seal Treatments

Chip Seal - life, years	Life completed	Still in Service
No data	35	19
1	10	6
2	18	26
3	26	22
4	13	19
5	4	17
6	5	3
7	0	1
8	0	1
Grand Total	111	114

Table 3. Service Life of Chip Seal Treatments

9.2 Chip Seal - Average Performance Gain

Figure 17 depicts average performance gain, in terms of PCR, due to chip seal treatment. The results are based on analysis of 225 projects. As seen, the performance gain varies with condition of pavements prior to chip seal treatment. Performance gain peaks when prior PCR is 66-70, closely followed by prior PCR group of 71-75. This gain is calculated over three to five year period after the treatment. Table 4 shows a distribution of the number of chip seal sections by prior PCR value, extracted from PMIS. Figure 17 shows average PCR gain sorted by prior PCR values. As can be seen, the gain diminishes as the prior pavement condition rating increases. The optimal pavement condition at which the treatment is most effective is a matter of significance to all agencies including ODOT. This can help them formulate and/or revise policy for the use of chip seal treatment.

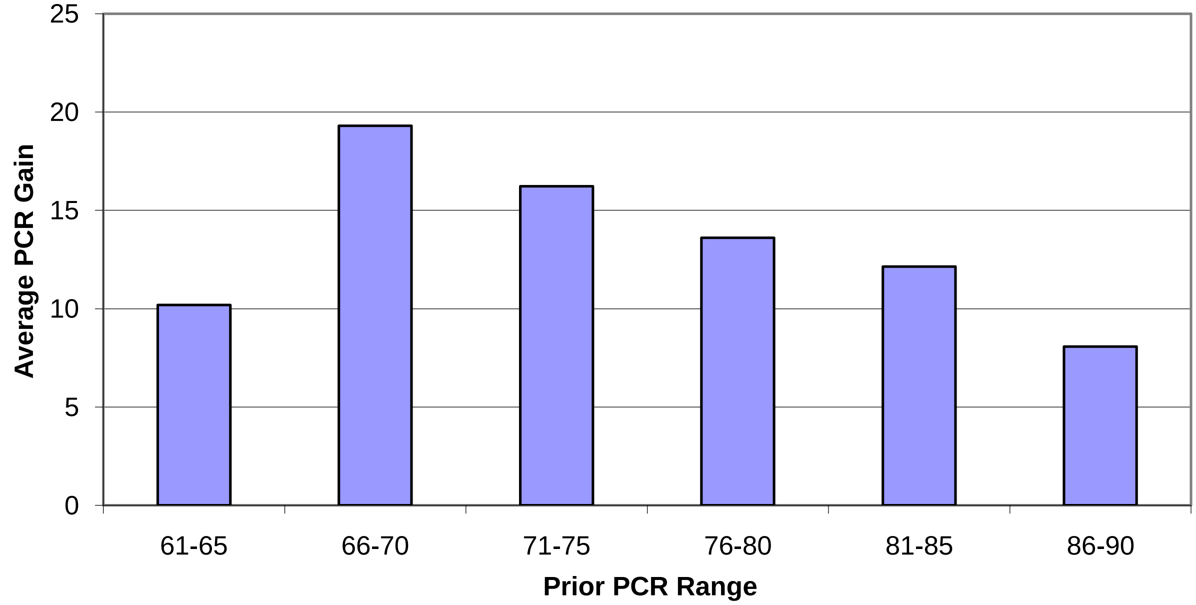


Figure 17. Average PCR Gain Due to Chip Seal

Prior PCR	Number of Sections
0-40	1
41-45	1
46-50	1
51-55	2
56-60	18
61-65	14
66-70	32
71-75	37
76-80	49
81-85	37
86-90	28
91-95	3
96-100	2
Total	225

Table 4. Number of Chip Seal Treatments vs. Prior PCR

9.3 Chip Seal - Life of treatments (using performance prediction models)

Performance prediction models developed for groups of pavements with varying prior PCR values are presented in Figures 18 to 24. The graphs also present the linear models, number of data points and regression constant. Such models were developed only when the number of available projects was ten or more. Life was measured corresponding to threshold PCR equal to 60. Table 5 shows the life values corresponding to various prior PCR values.

Prior PCR	Life corresponding to threshold PCR = 60, years
56-60	4
61-65	4.5
66-70	7
71-75	7.5
76-80	8.5
81-85	7.5

Table 5. Life of Chip Seal Treatment from Performance Models

Obviously, the pre-existing condition of pavements has an influence on the life obtained. The results also follow a logical trend with an increase in life as the prior PCR increases except when prior PCR is 81 to 85. The results will be immensely helpful in understanding the consequences of timing of treatment on the life of chip seal treatment.

As shown in Table 4, 33 chip seal installations were made when the prior PCR was greater than 86. Although this is a significant number, the data from these sections was not used to report the service life because of the need to extrapolate the performance model far beyond the study period. To illustrate this, refer to Figure 24 which shows a performance model for the chip seal treatment when the prior PCR was 86 to 90. In order to obtain the service life corresponding to threshold PCR of 60, this model was extrapolated beyond the range of values observed in the study. In doing so, this procedure used *unrepresentative* samples and resulted in an error referred to as *error of extrapolation*. The result of extrapolation in this case is unrealistic values for service life and benefit cost. A longer monitoring period would be required to utilize the data from these sections. As a result, it was decided not to consider the treated pavements with prior PCR greater than 85 for comparison and further discussion. A similar decision was made in the case of micro surfacing treatments also.

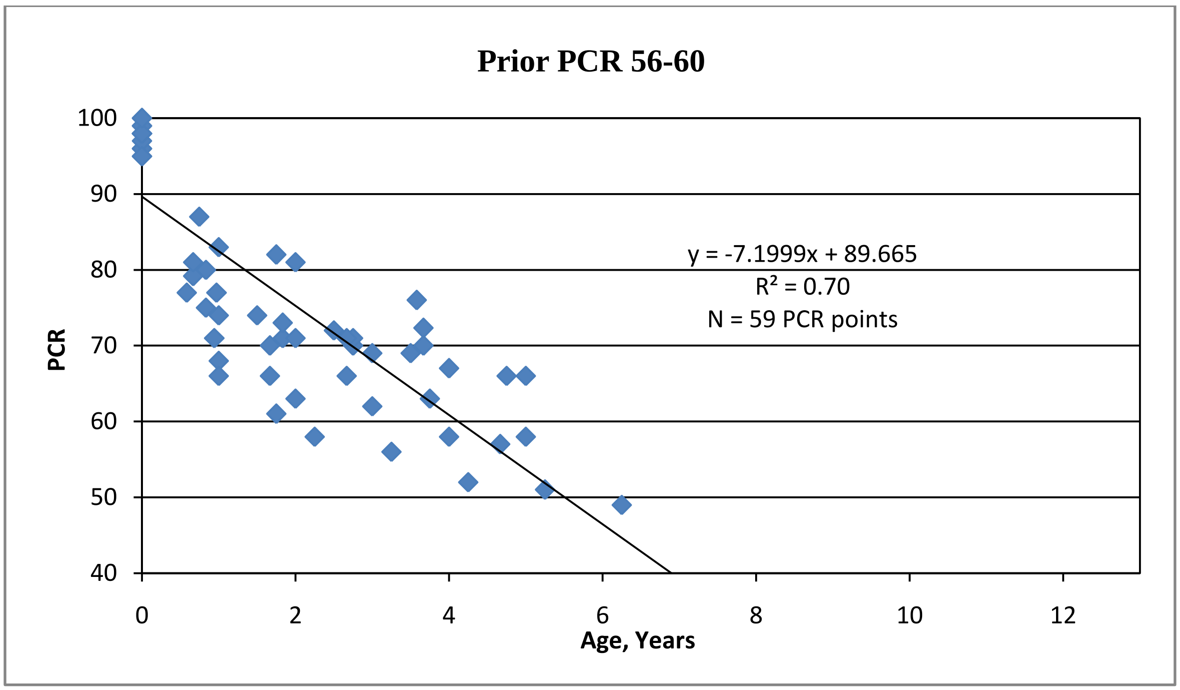


Figure 18. Performance Prediction Model for Chip Seal Treatment, Prior PCR 56-60

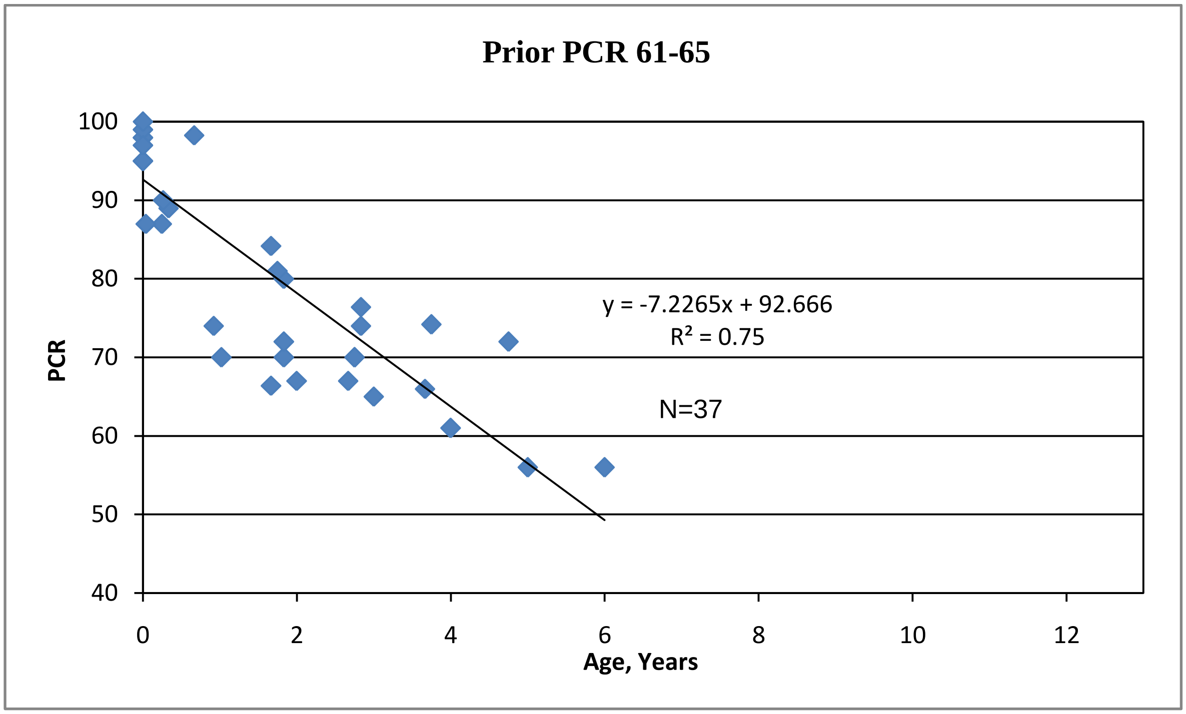


Figure 19. Performance Prediction Model for Chip Seal Treatment Prior, PCR 61-65

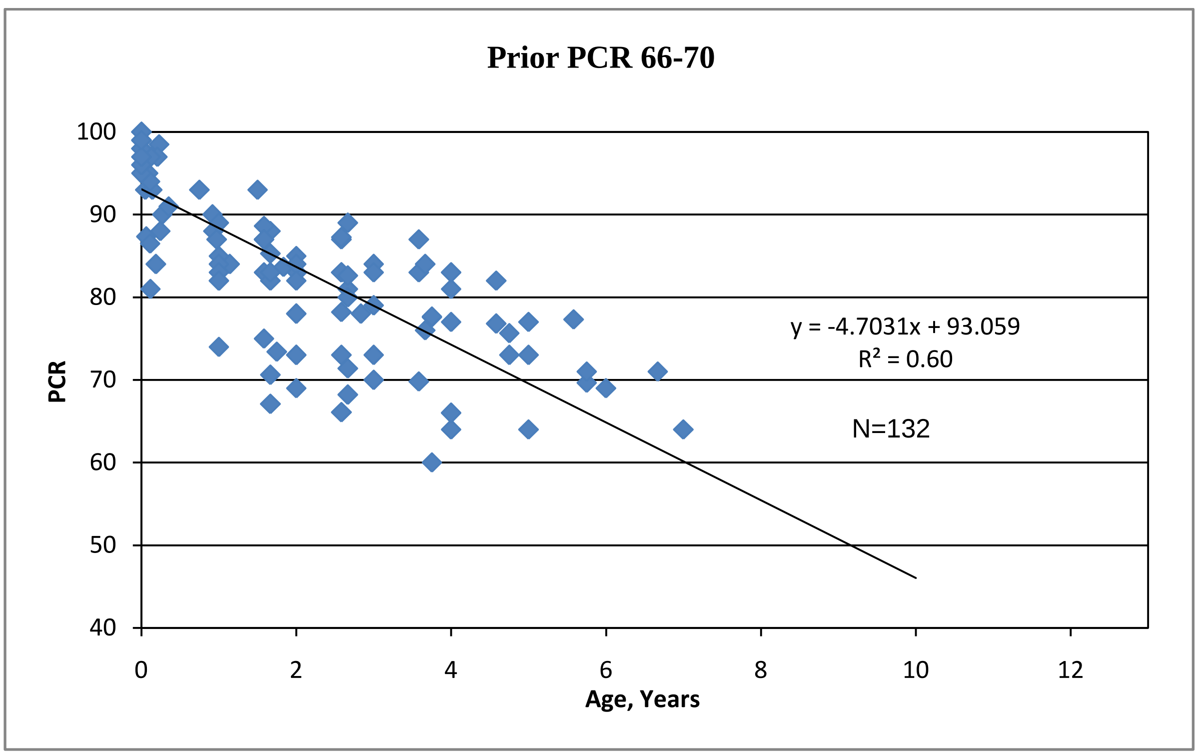


Figure 20. Performance Prediction Model for Chip Seal Treatment, Prior PCR 66-70

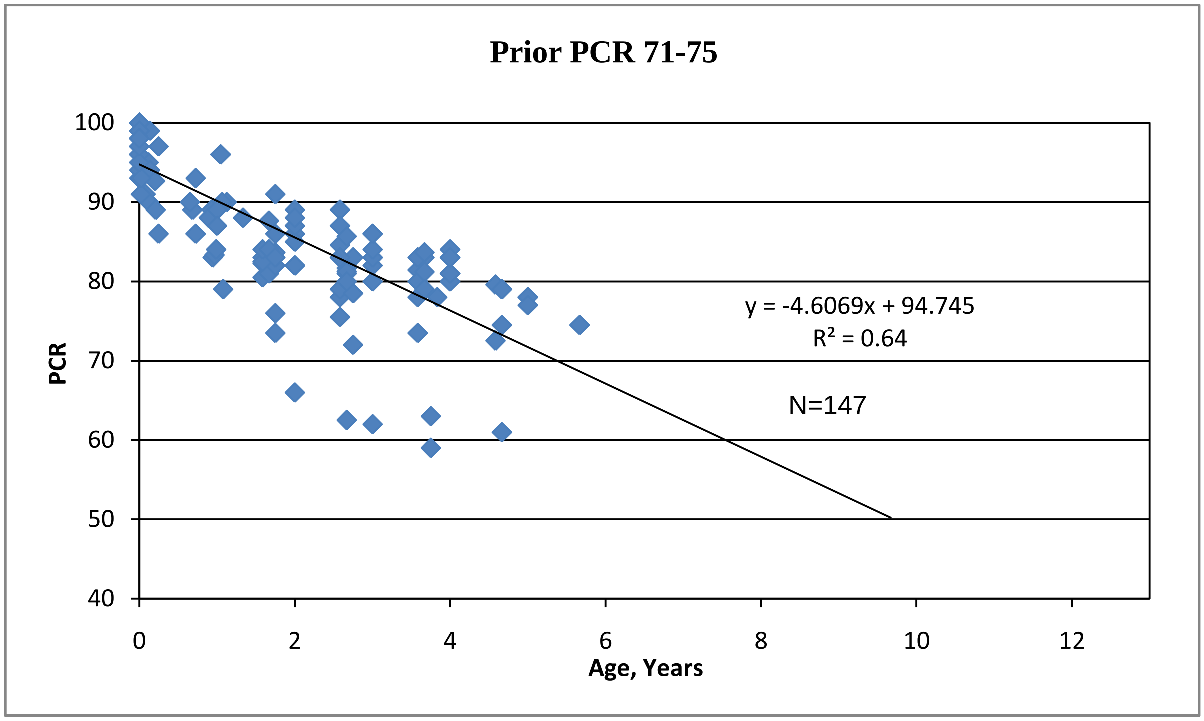


Figure 21. Performance Prediction Model for Chip Seal Treatment, Prior PCR 71-75

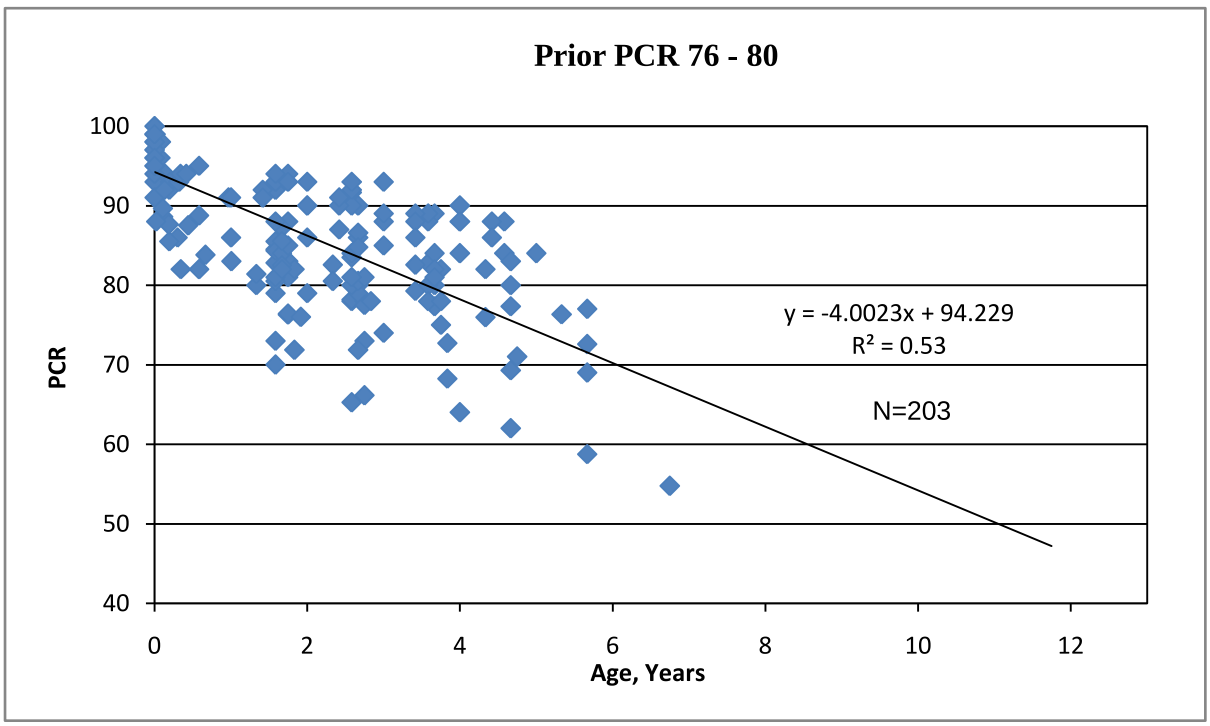


Figure 22. Performance Prediction Model for Chip Seal Treatment, Prior PCR 76-80

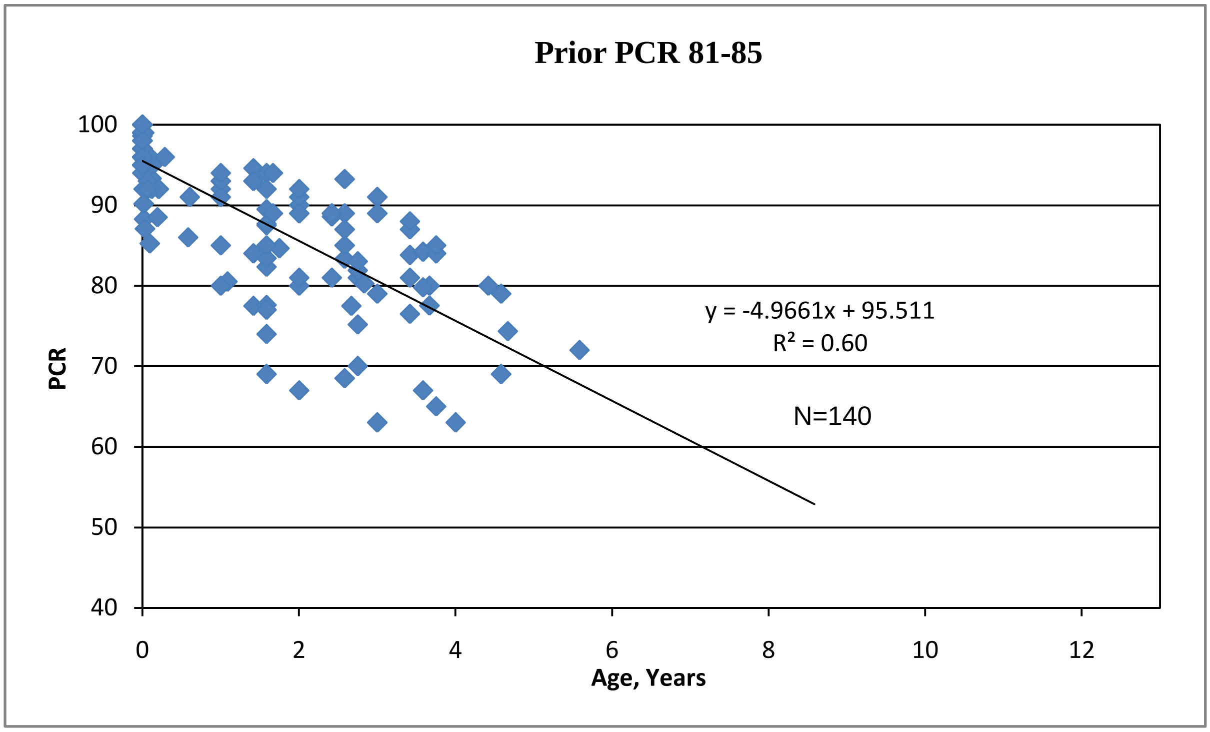


Figure 23. Performance Prediction Model for Chip Seal Treatment, Prior PCR 81-85

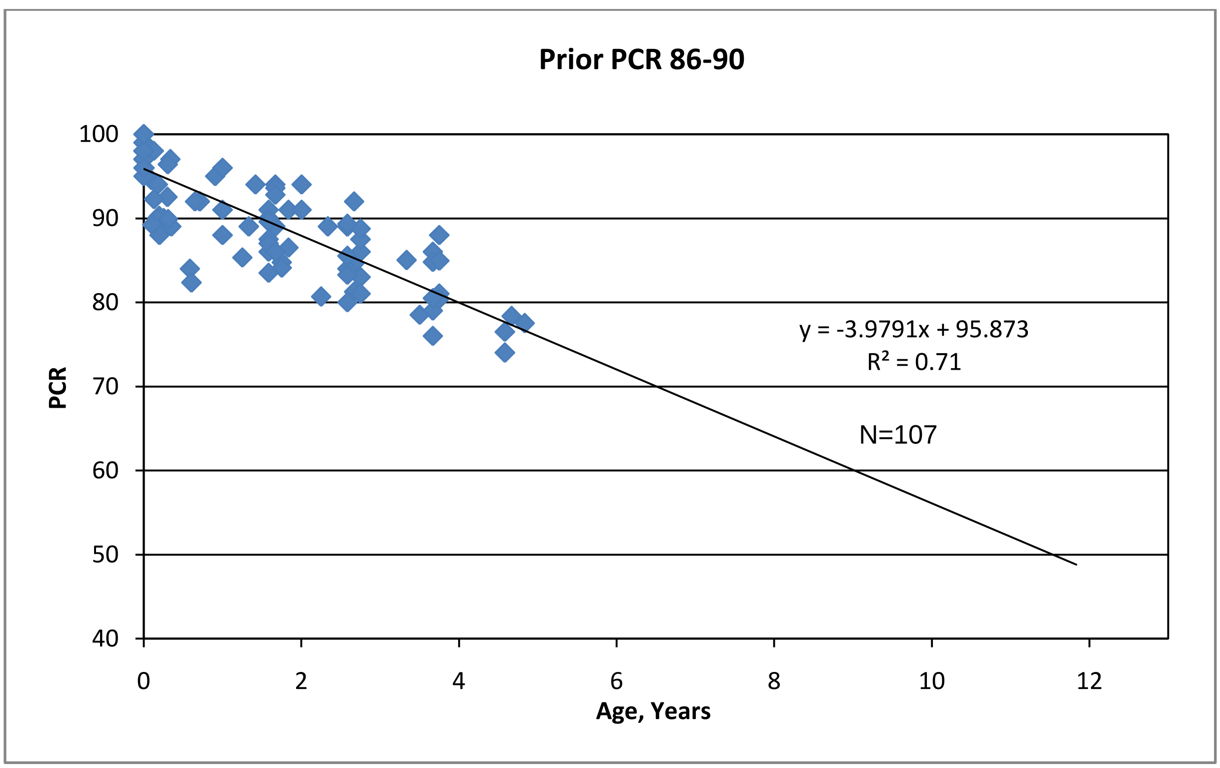


Figure 24. Performance Prediction Model for Chip Seal Treatment, Prior PCR 86-90

9.4 Chip Seal - Cost-effectiveness

Benefit values for chip seal treatments were obtained from the performance prediction models. The benefit cost ratios of chip seal treatments for various groups of pavements were compared with that of thin AC overlays. The results are presented in Table 6 and summarized in Figure 25.

Prior PCR		Chip Seal	Thin AC
56-60	Area under the curve	80	210
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0076	0.0032
	Relative Benefit Ratio	2.39	
61-65	Area under the curve	100	215
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0095	0.0032
	Relative Benefit Ratio	2.92	
66-70	Area under the curve	140	230
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0133	0.0035
	Relative Benefit Ratio	3.82	
71-75	Area under the curve	160	235
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0151	0.0035
	Relative Benefit Ratio	4.27	
76-80	Area under the curve	160	250
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0151	0.0038
	Relative Benefit Ratio	4.02	
81-85	Area under the curve	140	255
	Cost of treatment per lane mile	$10,565.00	$66,358.00
	B/C	0.0133	0.0038
	Relative Benefit Ratio	3.45	

Table 6. Relative Benefit Ratio of Chip Seal Treatments

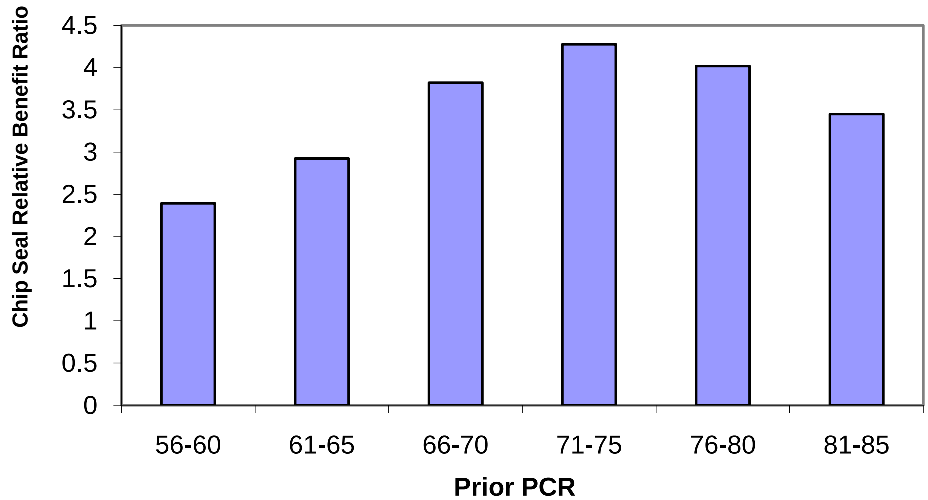


Figure 25. Summary of Relative Benefit of Chip Seal Treatment

Maximum ratio is realized when prior PCR is 71 to 75. Although the Relative Benefit Ratio is high when prior PCR is 86-90, it should be recognized that, chip seal treatment was performed by the counties on such pavements solely to improve skid resistance and the treatment was not intended to be preventive maintenance. The difference in the ratios for prior PCR values 66-70, 71-, 75 and 76-80 is narrow. A question arises here as to what magnitude of difference in such ratios can be considered as significant difference. However, there is no such data reported in the literature. As a result it can be inferred that, maximum Relative Benefit Ratio for chip seal is derived when the prior PCR of pavements on general system highway network is between 66 and 80. In other words, chip seal is most cost-effective, compared to thin AC overlay, when prior PCR is in the range of 66 and 80.

9.5 Chip Seal - Life Cycle Costs

Life cycle cost analysis was performed for three scenarios. The solutions for the three scenarios are provided below.

Scenario 1

In year 1, a chip seal treatment is provided. After seven and fourteen years chip seal treatment is renewed. At the end of 15 year analysis period, there is a salvage value of chip seal with a remaining service life of six years. Straight line depreciation method is used in the determination of salvage value.

$$\text{Net Present Value}_1 = 10{,}565 + 10{,}565/1.04^{7} + 10{,}565/1.04^{14} - (10{,}565*6/7)/1.04^{15}$$

$$= \$19{,}666$$

Scenario 2

Here chip seal is provided initially, followed by a thin AC overlay seven years later. At the end of 15 year analysis period, there is a salvage value of thin AC overlay with a remaining service life of one year. Straight line depreciation method is used in the determination of salvage value.

$$\text{Net Present Value}_2 = 10{,}565 + 66{,}358\,/1.04^{7} - (66{,}358*1/9)/1.04^{15}$$

$$= \$56{,}898$$

Scenario 3

In scenario 3, initially a thin AC overlay is provided, and another thin AC overlay is provided nine years later. At the end of 15 year analysis period, there is a salvage value of thin

AC overlay with a remaining service life of three years. Straight line depreciation method is used for the determination of salvage value.

$$\text{Net Present Value}_3 = 66{,}358 + 66{,}358/1.04^{9} - (66{,}358*3/9)/1.04^{15}$$

$$= \$100{,}698$$

The net present values of three scenarios show that successive chip seal treatment results in significantly smaller cost than the other two alternatives, during the 15 year analysis period. Thus, periodic chip seal treatment is more economical compared to the use of thin AC overlay. It should be recognized, however that, chip seals do not provide structural strength, and are suitable for application within a particular window of opportunity, i.e., chip seals are provided in response to functional failure of pavement rather than structural failure.

10.0 ANALYSIS OF MICRO SURFACING TREATMENTS ON GENERAL SYSTEM

10.1 Micro Surfacing (General System) - Service Life from Historic Data

Figure 26 and Table 7 show micro surfacing projects on general system network. The figure shows projects that have completed their service as well as those in service. Weighted average of projects that completed their service lives was found to be 5 years. This indicates, on an average, micro surfacing projects are being renewed at five year intervals.

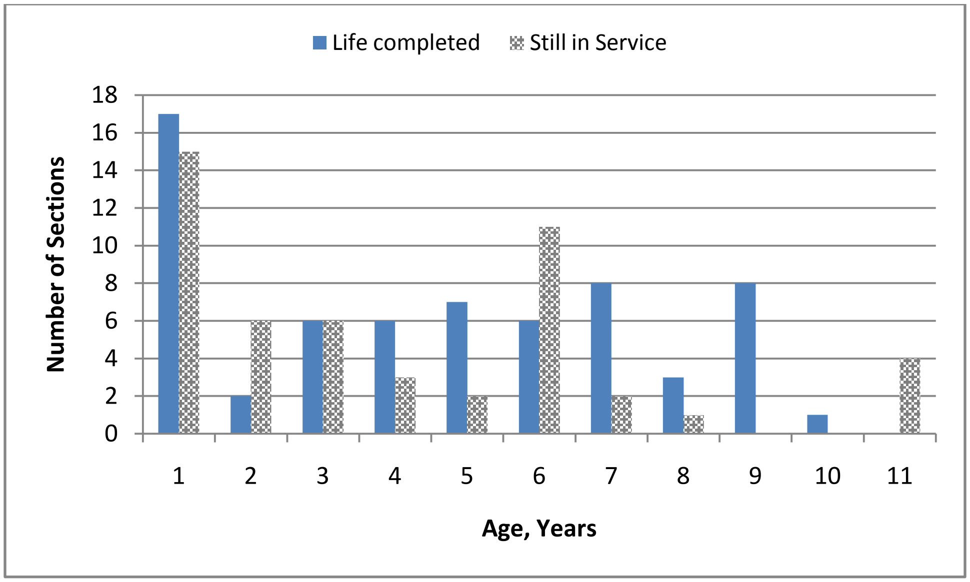


Figure 26. Service Life of Micro Surfacing Treatments on General System

Micro surfacing Life, years	Life completed	Still in Service
1	17	15
2	2	6
3	6	6
4	6	3
5	7	2
6	6	11
7	8	2
8	3	1
9	8	0
10	1	0
12	0	4
Grand Total	64	50

Table 7. Service Life of Micro Surfacing Treatments on General System

10.2 Micro Surfacing (General System) - Average Performance Gain

Figure 27 presents average performance gain due to micro surfacing treatments on general system. A total of 114 projects were available for this analysis. The gain is calculated using performance data for three to five years. As seen, the performance gain is maximum when prior PCR is 61 to 65. Owing to minor difference in the performance gain between other groups, it can be inferred that maximum performance gain is achieved when prior PCR is between 56 and 70.

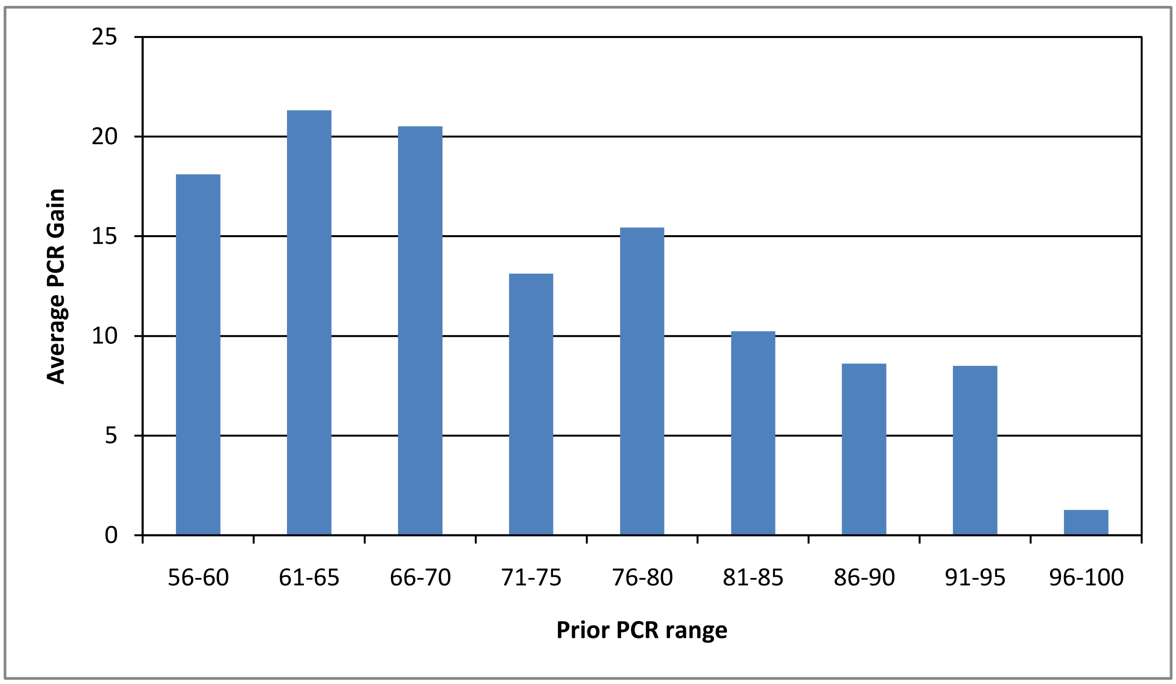


Figure 27. Average PCR Gain for Micro Surfacing Treatment on General System

10.3 Micro Surfacing (General System)-Life (using performance prediction models)

Performance prediction models developed for groups of pavements with varying prior PCR values are presented in Figures 28 to 33. To compute service life extension of micro surfacing installations on general system, in conformity with ODOT's policy a threshold PCR of 60 was used. Table 8 shows the service life values corresponding to various prior PCR values.

Prior PCR	Service life corresponding to threshold PCR = 60 years
56-60	3.5
61-65	Limited data
66-70	7.5
71-75	8.5
76-80	12
81-85	8

Table 8. Life of Micro Surfacing (General System) from Performance Models

The graphs also present the linear model and regression constant. Maximum service life extension relates to prior PCR range of 76 to 80. The results show that the use of micro surfacing as a preventive maintenance treatment is meaningful when the prior PCR is greater than 66.

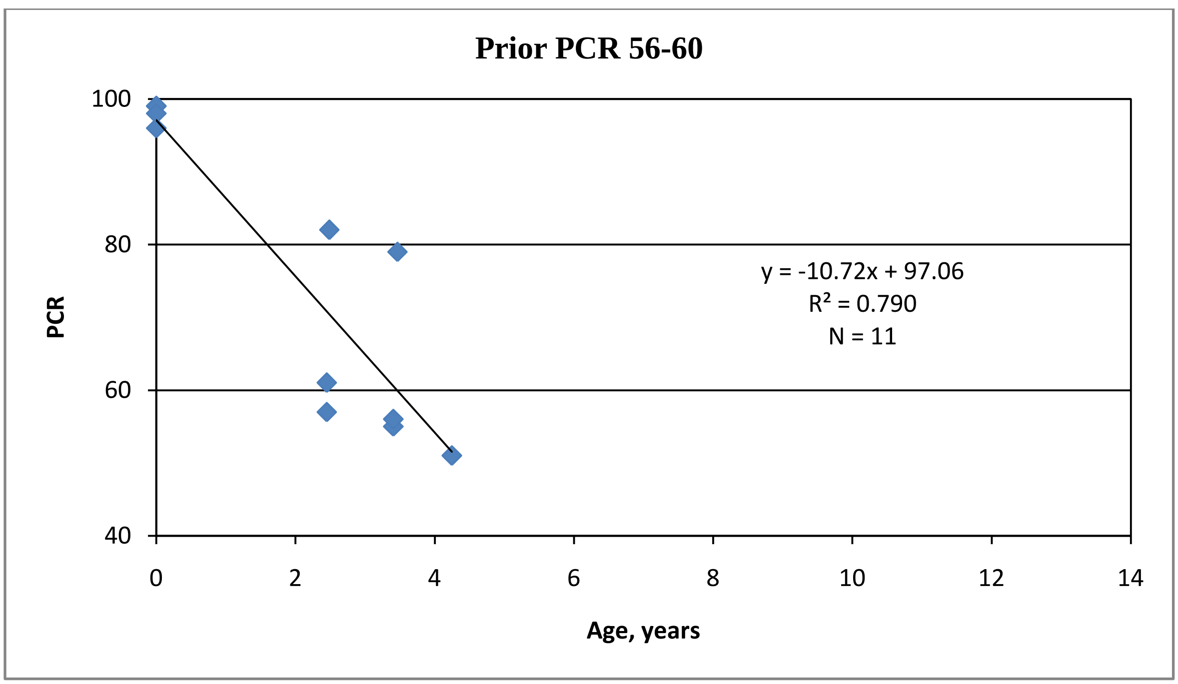


Figure 28. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 56-60

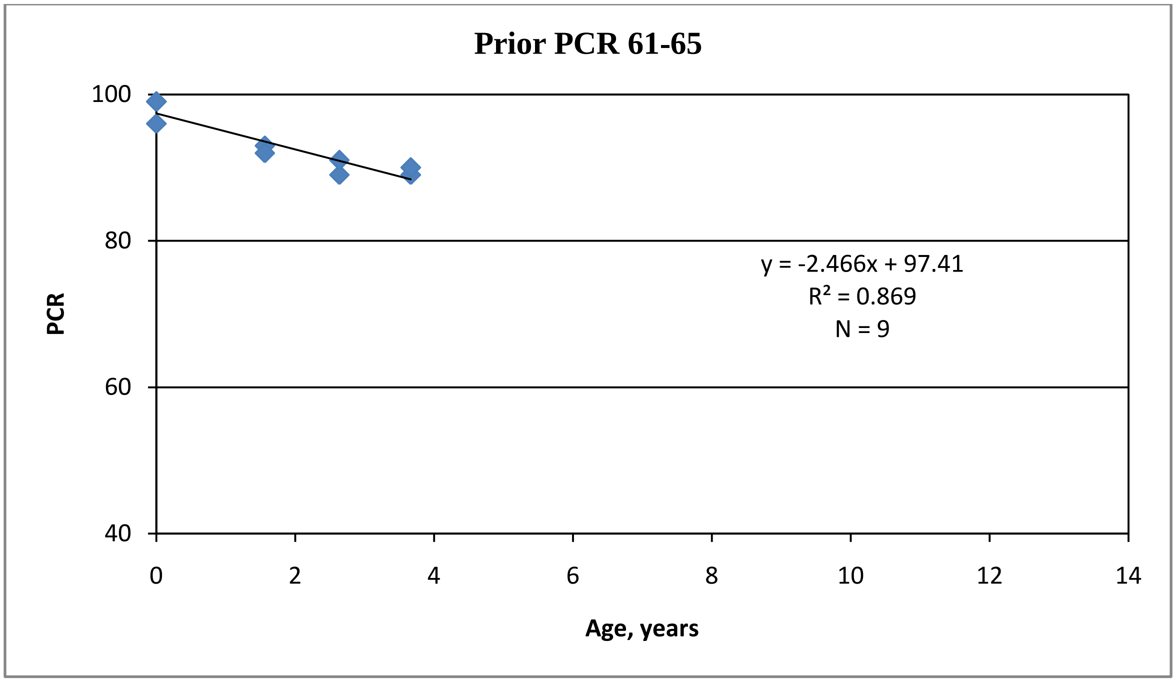


Figure 29. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 61-65

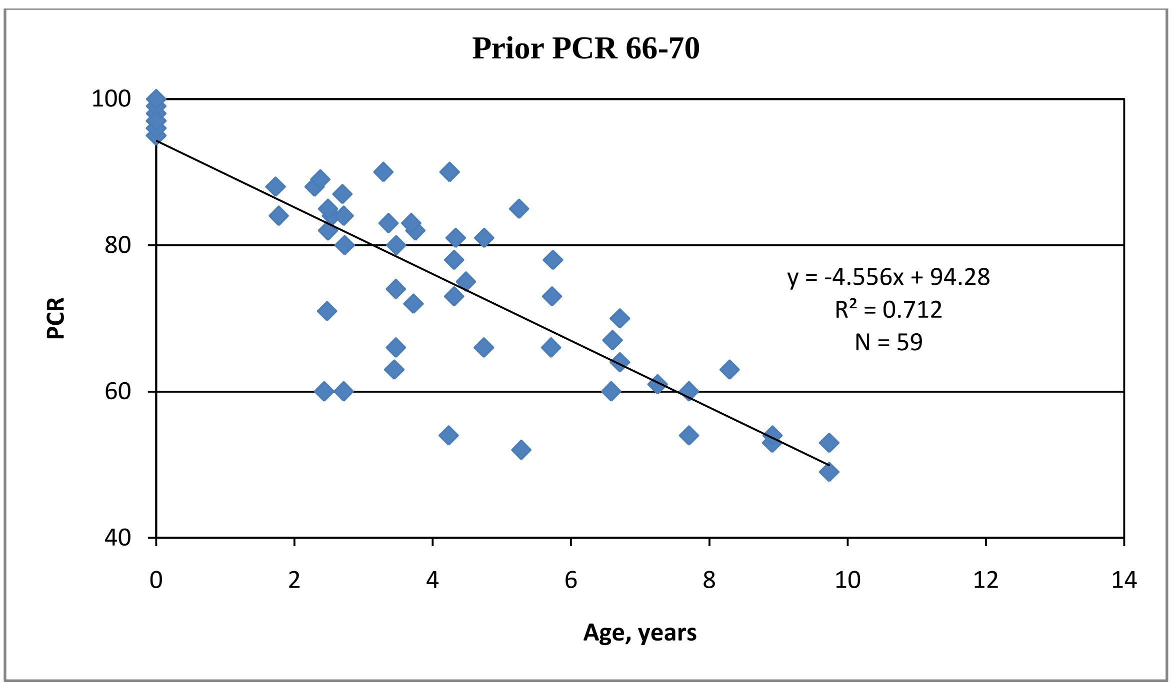


Figure 30. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 66-70

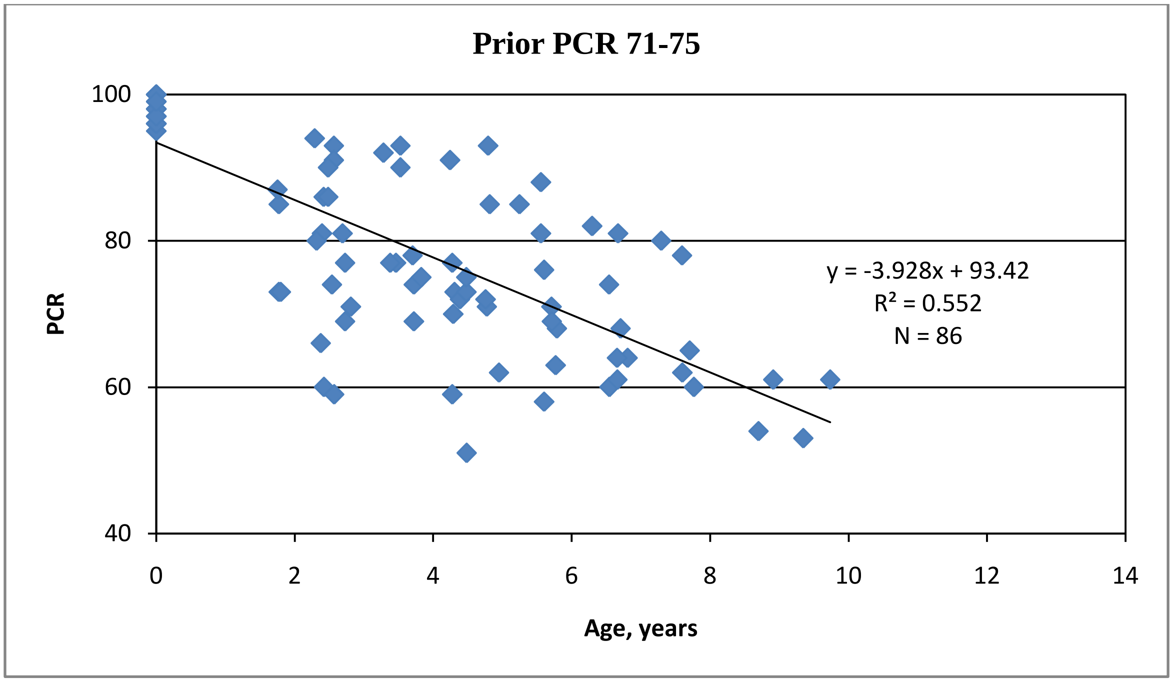


Figure 31. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 71-75

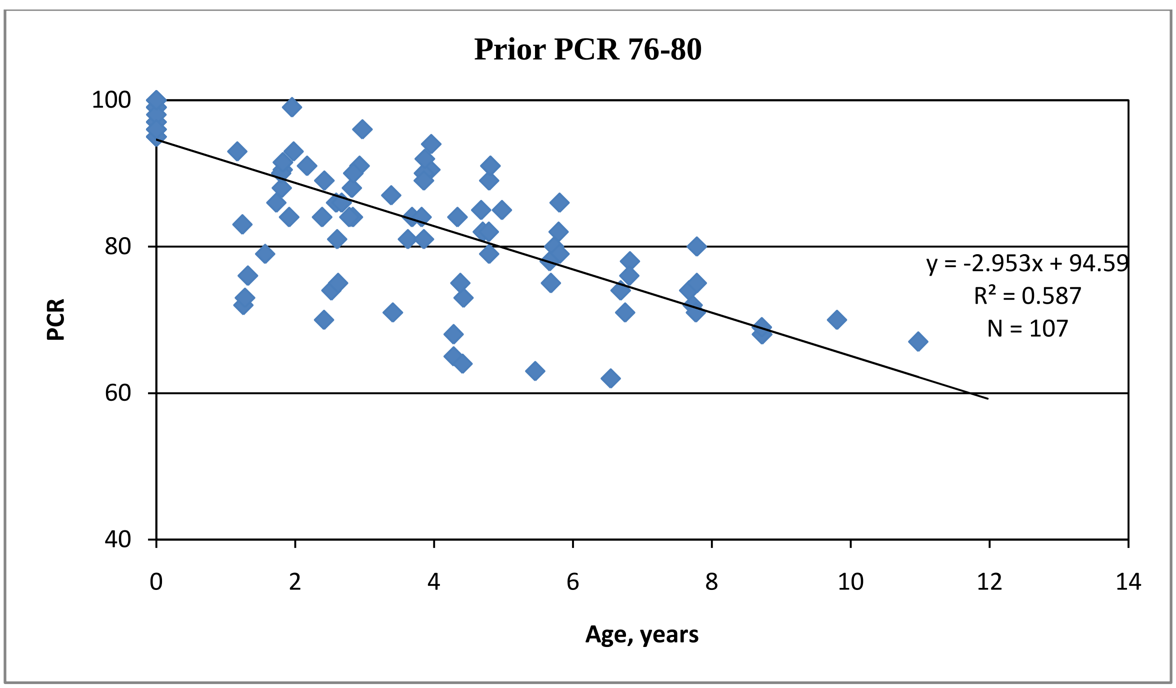


Figure 32. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 76-80

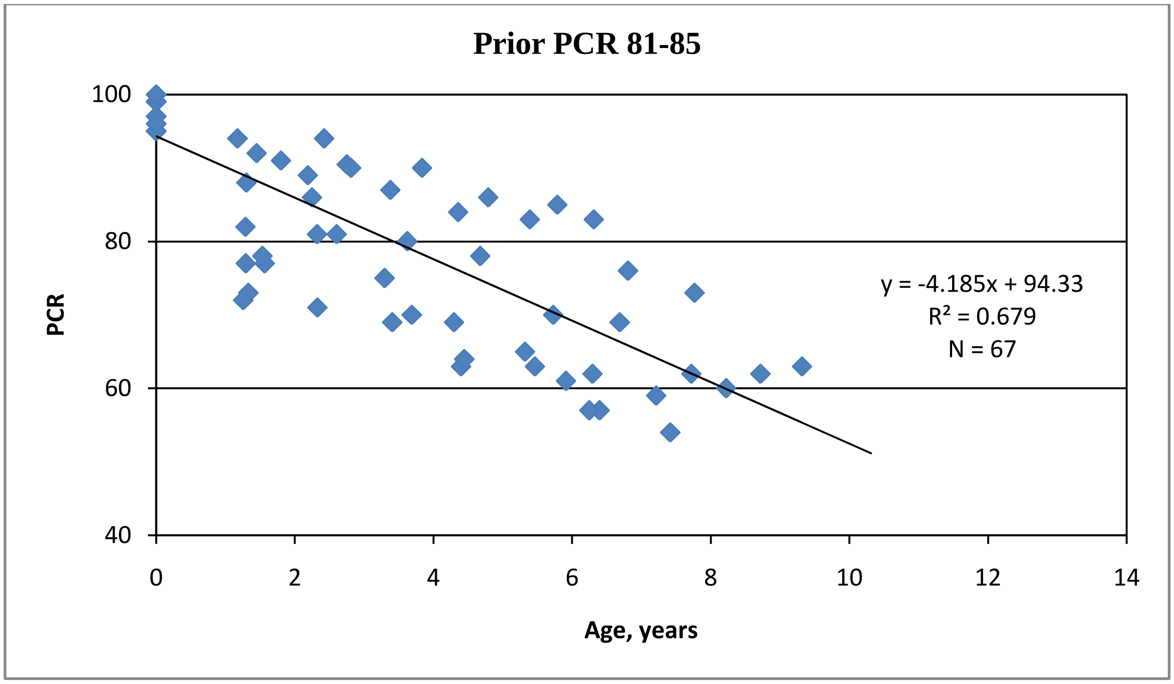


Figure 33. Performance Prediction Model for Micro Surfacing Treatment, General System, Prior PCR 81-85

10.4 Micro Surfacing (General System) - Cost-effectiveness

Cost-effectiveness was calculated as a ratio of benefit and cost. Benefit values were derived from the performance models as area under the performance curve. Similar values were obtained for the thin AC overlay treatment [31] for general system. The Relative Benefit Ratio of micro surfacing on general system is presented in Table 9. Figure 34 is a summary of Relative Benefit Ratios versus prior PCR values. Benefit attains maximum when prior PCR is 76-80. It should be recognized here that the maximum service life extension presented in Table 8 also relates to the same PCR range.

Prior PCR		Micro surfacing	Thin AC
56-60	**Area under the curve**	74	210
	Cost of treatment per lane mile	$17,450	$66,358.00
	B/C	0.0042	0.0032
	Relative Benefit Ratio	1.34	
66-70	**Area under the curve**	136	235
	Cost of treatment per lane mile	$17,450	$66,358.00
	B/C	0.0078	0.0035
	Relative Benefit Ratio	2.2	
71-75	**Area under the curve**	148.5	240
	Cost of treatment per lane mile	$17,450	$66,358.00
	B/C	0.0085	0.0036
	Relative Benefit Ratio	2.35	
76-80	**Area under the curve**	210	250
	Cost of treatment per lane mile	$17,450	$66,358.00
	B/C	0.012	0.0038
	Relative Benefit Ratio	3.19	
81-85	**Area under the curve**	136	255
	Cost of treatment per lane mile	$17,450	$66,358.00
	B/C	0.0078	0.0038
	Relative Benefit Ratio	2.02	

Table 9. Relative Benefit Ratio of Micro Surfacing Treatments on General System

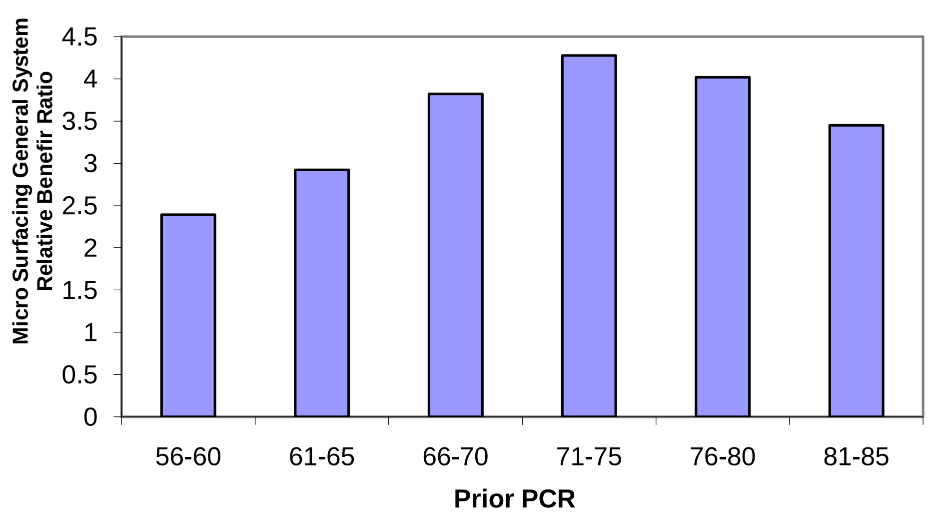


Figure 34. Summary of Relative Benefit of Micro Surfacing on General System

10.5 Micro Surfacing (General System) - Life Cycle Costs

Life cycle cost analysis was performed for three scenarios as below:

1. Two successive treatments of micro surfacing
2. Micro surfacing followed by thin AC overlay
3. Two successive treatments of thin AC overlay

Scenario 1

In year 1, a micro surfacing treatment is provided followed by another micro surfacing treatment nine years later. At the end of 15 year analysis period, there is a salvage value of micro surfacing with a remaining service life of three years. Straight line depreciation method is used in the determination of salvage value. Net present value is calculated as:

$$\text{Net Present Value}_1 = \$17{,}450 + \$17{,}450/1.04^9 - (\$17{,}450*3/9)/1.04^{15}$$

$$= \$26{,}480$$

Scenario 2

Here micro surfacing is provided initially, followed by a thin AC overlay nine years later. At the end of 15 year analysis period, there is a salvage value of thin AC overlay with a remaining service life of three years. Straight line depreciation method is used in the determination of salvage value.

$$\text{Net Present Value}_2 = \$17{,}450 + 66{,}358/1.04^9 - (66{,}358*3/9)/1.04^{15}$$

$$= \$51{,}790$$

Scenario 3

In scenario 3, a thin AC overlay is provided initially followed by another thin AC overlay nine years later. At the end of 15 year analysis period, there is a salvage value of thin AC overlay with a remaining service life of three years. Straight line depreciation method is used for the determination of salvage value.

$$\text{Net Present Value}_3 = 66{,}358 + 66{,}358 / 1.04^9 - (66{,}358 * 3/9)/1.04^{15}$$

$$= \$100{,}698$$

The net present values of three scenarios show that successive micro surfacing treatment results in significantly smaller life cycle cost than the other two alternatives during the 15 year analysis period. Thus, according to this analysis, periodic micro surfacing treatments are more economical than providing thin AC overlay. However, this statement may hold well as long as the pavements are structurally sound and only require preventive maintenance.

11.0 ANALYSIS OF MICRO SURFACING TREATMENTS ON PRIORITY SYSTEM

11.1 Micro Surfacing (Priority System) - Service Life from Historic Data

Figure 35 and Table 10 show micro surfacing projects on priority system network. The figure shows projects that have completed their service as well as those in service. Weighted average of projects that completed their service lives was found to be 5 years. This indicates, on an average, micro surfacing projects are being renewed at five year intervals.

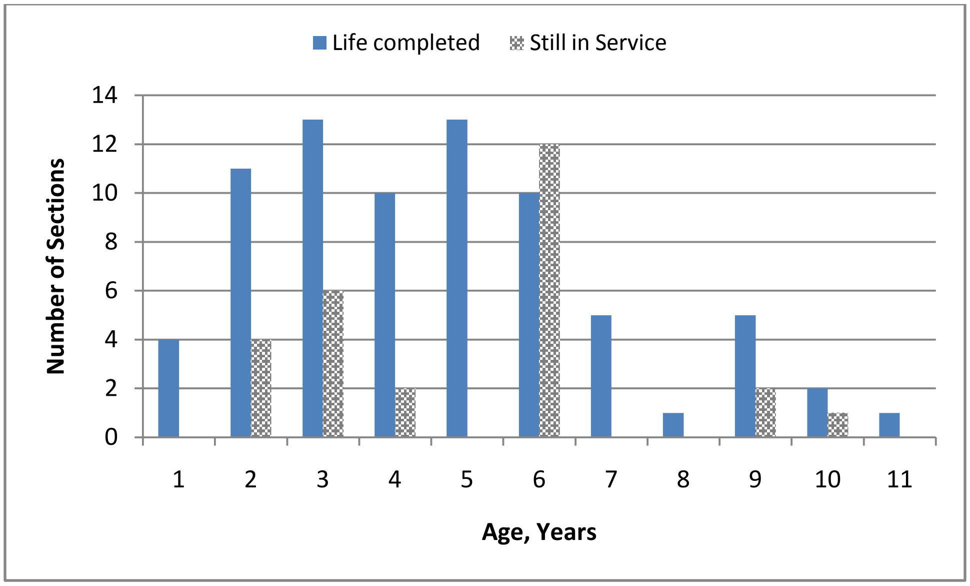


Figure 35. Service Life of Micro Surfacing Treatments on Priority System

Micro surfacing Life, years	Life completed	Still in Service
1	4	0
2	11	4
3	13	6
4	10	2
5	13	0
6	10	12
7	5	0
8	1	0
9	5	2
10	2	1
12	1	0
Grand Total	75	27

Table 10. Service Life of Micro Surfacing Treatments on Priority System

11.2 Micro Surfacing (Priority System) - Average Performance Gain

Figure 36 presents average performance gain due to micro surfacing treatments on priority system. A total of 102 projects were available for this analysis. The gain is calculated using performance data for three to five years. As seen, the performance gain is maximum when prior PCR is 61 to 65. Interestingly, this range compares favorably with the treatments performed on general system (Figure 27).

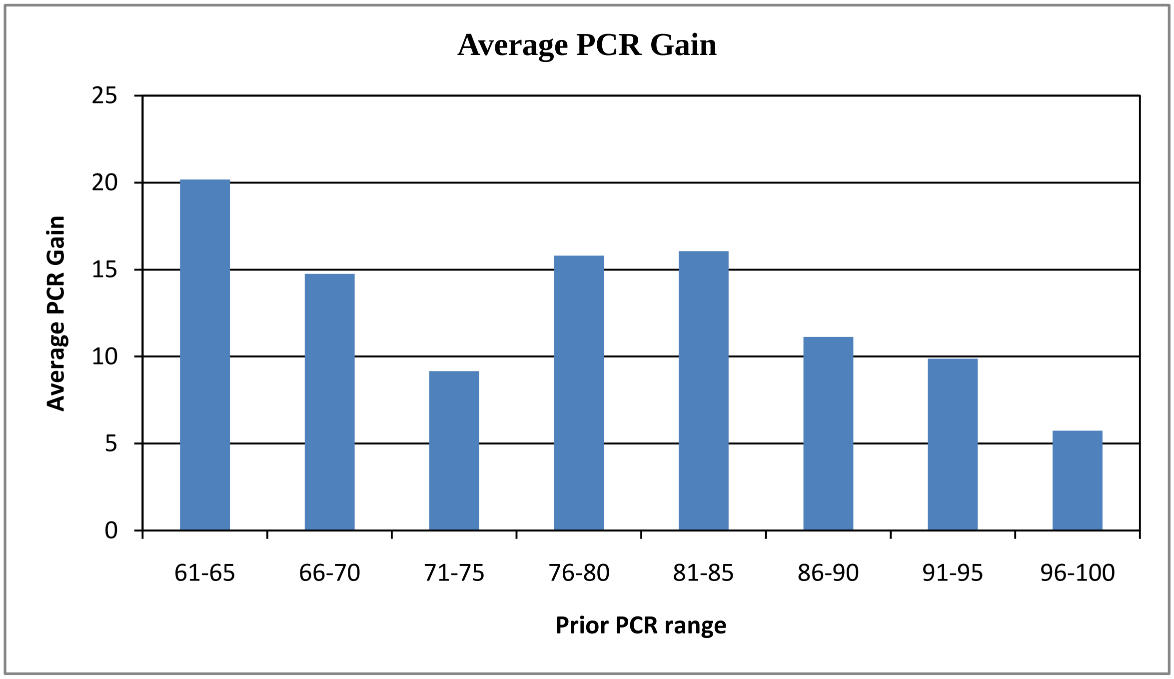


Figure 36. Average PCR Gain Due to Micro Surfacing on Priority System

11.3 Micro Surfacing (Priority System) - Life of Treatments (using performance prediction models)

Performance prediction models developed for groups of pavements with varying prior PCR values are presented in Figures 37 to 41. For computation of service life extension of micro surfacing installations on priority system, in conformity with ODOT's policy a threshold PCR of 65 was used. Table 11 shows the life values corresponding to various prior PCR values.

Prior PCR	Service life corresponding to threshold PCR = 65, years
61-65	4.5
66-70	5
71-75	4.5
76-80	8.5
81-85	11

Table 11. Life of Micro Surfacing (Priority System) from Performance Models

The graphs also present the linear models and regression constant. The results (Table 11) again reveal a logical trend showing increase in service life extension with increasing prior PCR values. Needless to say that, other factors such as cost of the treatment and associated benefits will need to be considered before interpreting the significance of these findings.

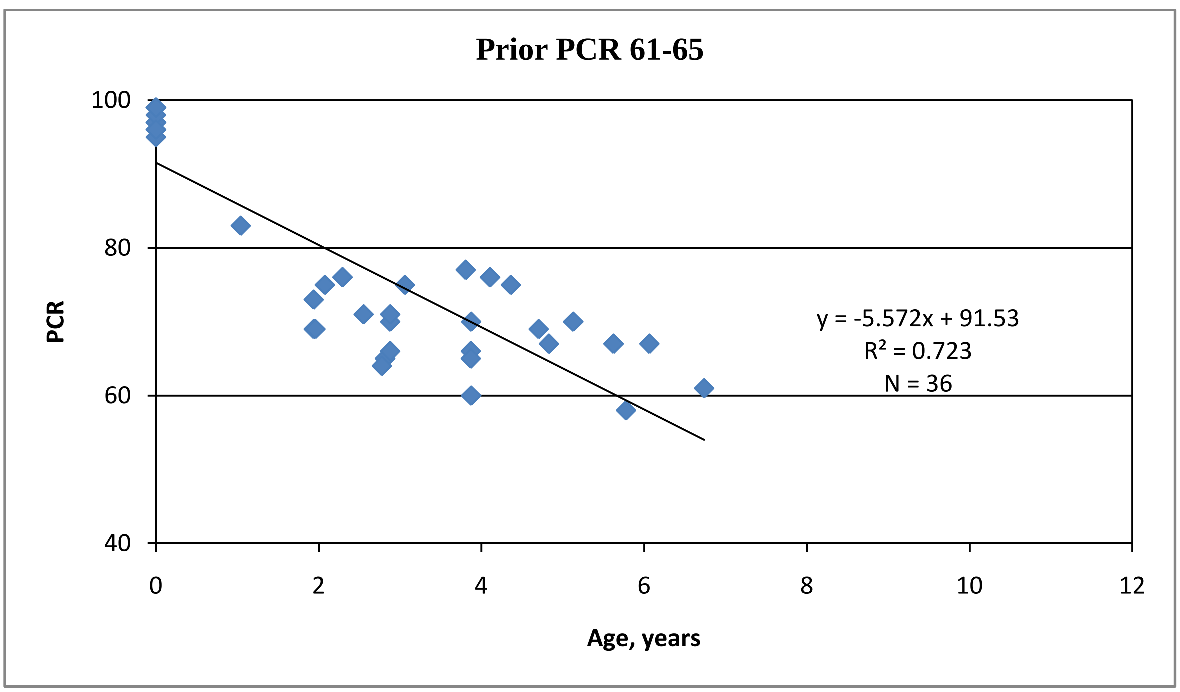


Figure 37. Performance Prediction Model for Micro Surfacing Treatment, Priority System, Prior PCR 61-65

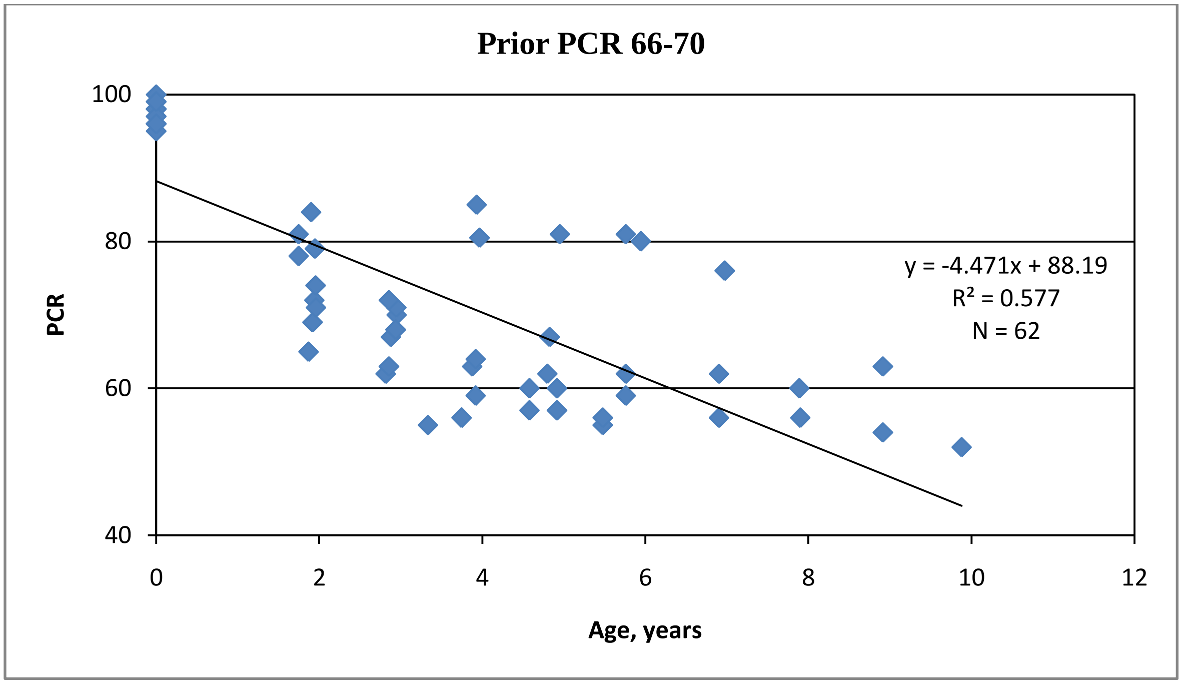


Figure 38. Performance Prediction Model for Micro Surfacing Treatment, Priority System, Prior PCR 66-70

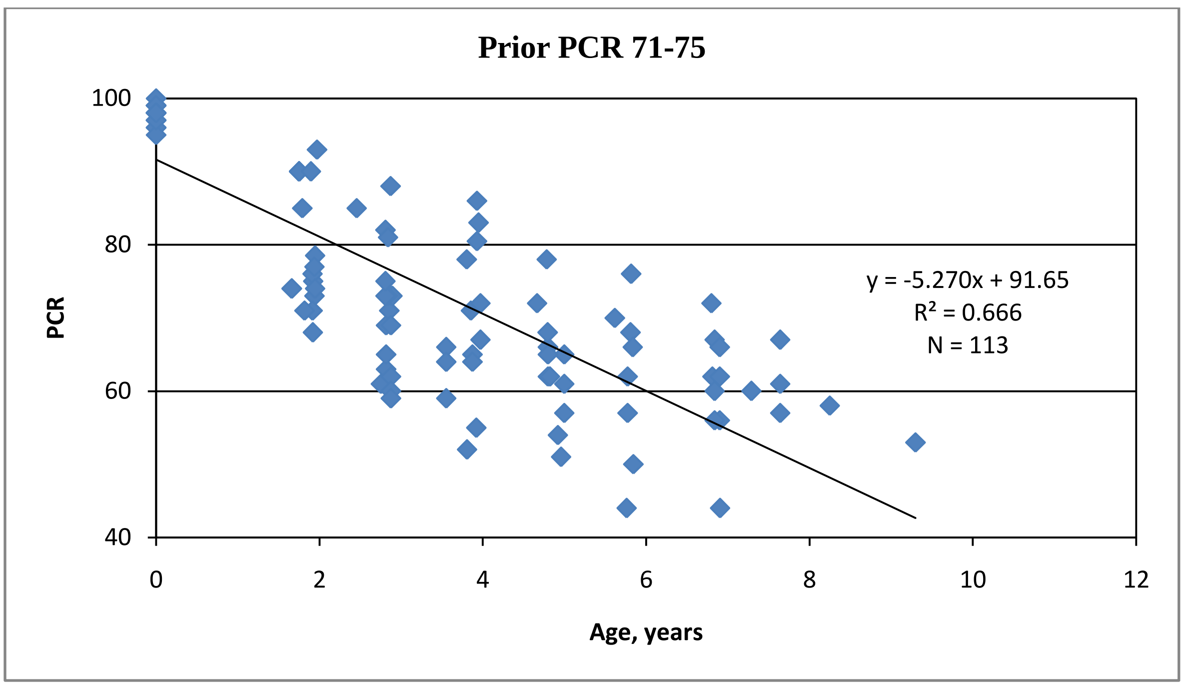


Figure 39. Performance Prediction Model for Micro Surfacing Treatment, Priority System, Prior PCR 71-75

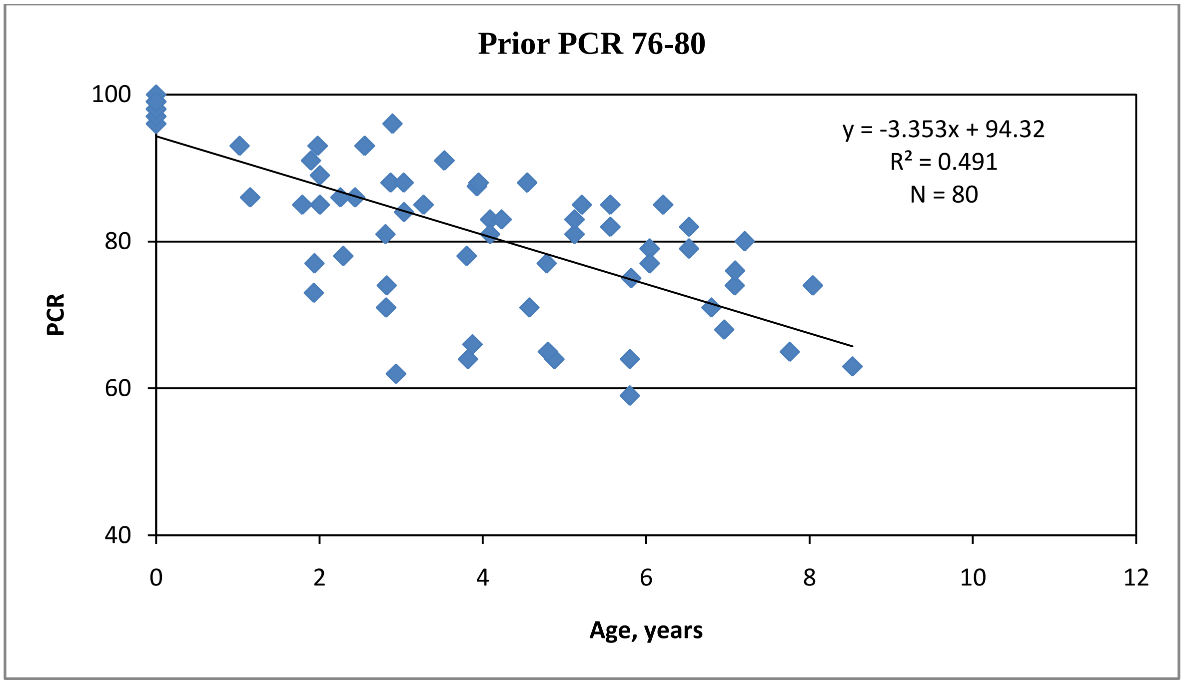


Figure 40. Performance Prediction Model for Micro Surfacing Treatment, Priority System, Prior PCR 76-80

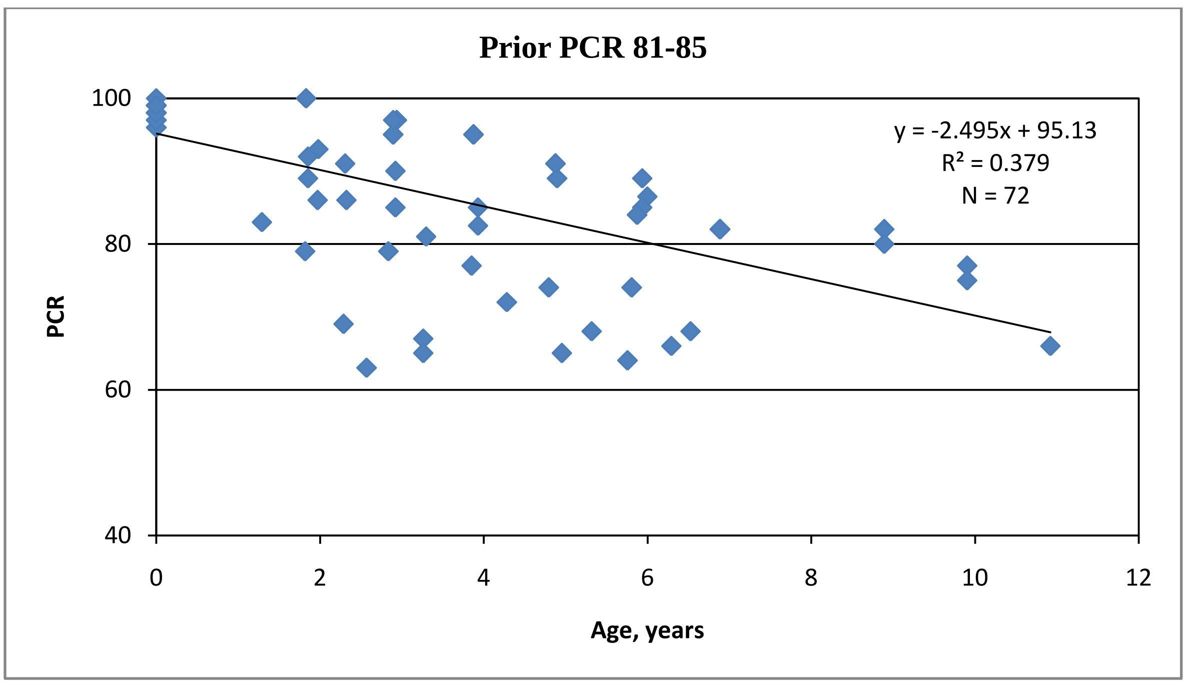


Figure 41. Performance Prediction Model for Micro Surfacing Treatment, Priority System, Prior PCR 81-85

11.4 Micro Surfacing (Priority System) - Cost-effectiveness

Cost-effectiveness was calculated as the ratio of benefit and cost. Benefit values were derived from the performance models as area under the performance curve. Similar values were obtained for the thin AC overlay treatment [31] on priority system. The Relative Benefit Ratio of micro surfacing on priority system is presented in Table 12.

Prior PCR		Micro surfacing	Thin AC
61-65	Area under the curve	67.5	115
	Cost of treatment per lane mile	$26,350	$66,358.00
	B/C	0.0026	0.0017
	Relative Benefit Ratio	1.48	
66-70	Area under the curve	57.5	130
	Cost of treatment per lane mile	$26,350	$66,358.00
	B/C	0.0022	0.002
	Relative Benefit Ratio	1.11	
71-75	Area under the curve	67.5	145
	Cost of treatment per lane mile	$26,350	$66,358.00
	B/C	0.0026	0.0022
	Relative Benefit Ratio	1.17	
76-80	Area under the curve	130.5	170
	Cost of treatment per lane mile	$26,350	$66,358.00
	B/C	0.005	0.0026
	Relative Benefit Ratio	1.93	
81-85	Area under the curve	165	215
	Cost of treatment per lane mile	$26,350	$66,358.00
	B/C	0.0063	0.0032
	Relative Benefit Ratio	1.93	

Table 12. Relative Benefit of Micro Surfacing Treatments on Priority System

Figure 42 is a summary of Relative Benefit Ratio versus prior PCR values. The ratio is maximum when prior PCR is 76-85. Micro surfacing treatments on priority system highways also showed the same range of prior PCR. From Table 11, the maximum life extension corresponding to prior PCR range 76 to 80 is 8.5 years.

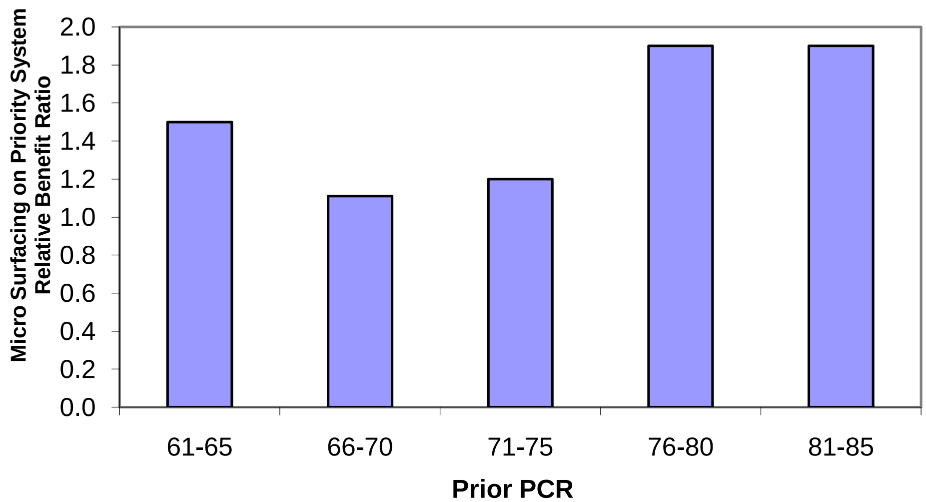


Figure 42. Summary of Relative Benefit of Micro Surfacing on Priority System

11.5 Micro Surfacing (Priority System) - Life Cycle Costs

Life cycle cost analysis was performed for three scenarios as below:

1. Two successive treatments of micro surfacing
2. Micro surfacing followed by thin AC overlay
3. Two successive treatments of thin AC overlay

Scenario 1

In year 1, a micro surfacing treatment is provided followed by another micro surfacing treatment eight years later. At the end of 15 year analysis period, there is a salvage value of micro surfacing with a remaining service life of one year. Straight line depreciation method is used in the determination of salvage value. Net present value is calculated as:

Net Present Value$_1$ $= 26,350 + 26,350/1.04^8 - (26,350*1/8)/1.04^{15}$

$= \$43,775$

Scenario 2

Here micro surfacing is provided initially, followed by a thin AC overlay nine years later. At the end of 15 year analysis period, there is a salvage value of the thin AC overlay with a remaining service life of two years. Straight line depreciation method is used in the determination of salvage value.

Net Present Value$_2$ $= 26,350 + 66,358 /1.04^8 – (66,358*2/9)/1.04^{15}$

$= \$66,649$

Scenario 3

In scenario 3, a thin AC overlay is provided initially followed by another thin AC overlay nine years later. At the end of 15 year analysis period, there is a salvage value of the thin AC overlay with a remaining service life of three years. Straight line depreciation method is used for the determination of salvage value.

Net Present Value$_1$ $= 66,358 + 66,358 /1.04^9 – (66,358*3/9)/1.04^{15}$

$= \$100,698$

The net present values of three scenarios show that successive micro surfacing treatment results in significantly smaller life cycle cost than the other two alternatives during the 15 year analysis period. Thus, according to this analysis, periodic micro surfacing treatments are more economical than providing thin AC overlay. However, this statement may hold well as long as the pavements are structurally sound and only require preventive maintenance.

12.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report presents the details of an investigation to evaluate the effectiveness of chip seal and micro surfacing as preventive maintenance treatments. The study utilizes data from previously completed projects in Ohio and reflects current practices. The study focused primarily on the following two issues:

1. Optimal timing of treatment placement,
2. Cost-effectiveness of treatments.

The study began with a review of ODOT's pavement management database. The database consisted of related information about chip seal and micro surfacing treatments, including project location, project limits, date of installation, and annual performance data. In all, data was available for 225 chip seal and 214 micro surfacing projects. Performance monitoring data was available for these projects most often for three to five years.

Nearly 50% of the chip seal treatments were made in District 1. Districts 2 and 3 combined accounted for 25% chip seal projects. The three districts lie in similar climatic zone. All installations were made on general system. As a result, effects of factors such as environment and traffic on performance of chip sealed pavements were not considered. The 214 micro surfacing projects, on the other hand, were equally distributed among general and priority systems. Hence, these projects were grouped based on functional class of pavements namely general and priority systems.

The following five performance indicators were used to describe the effectiveness of chip seal and micro surfacing treatments:

1. Service life of treatments based on actual number of years in service

2. Average performance gain

3. Life of treatments (using performance prediction models)

4. Cost-effectiveness

5. Life cycle costs

A summary of the results of data analysis is presented in Tables 13, 14 and 15.

Prior PCR	Performance Indicator				
	Service life from historic data	Average Performance Gain (PCR Points)	Life from Prediction Models, years	B/C Ratio	Life Cycle Costs
56-60	4 years		4.0	2.4	CS+CS+CS $19,666
61-65		10	4.5	2.9	
66-70		19	7.0	3.8	
71-75		17	7.5	4.3	CS+TAC $56,898
76-80		14	8.5	3.0	
81-85		13	7.5	3.4	
86-90		8	9.0	4.1	TAC+TAC $100,698

Table 13. Summary of Results for Chip Seal Treatment

Note: CS = Chip Seal, TAC = Thin AC Overlay

Prior PCR	Performance Indicator				
	Service life from historic data	Average Performance Gain (PCR Points)	Life from Prediction Models, years	B/C Ratio	Life Cycle Costs
56-60	5 years	18	3.5	1.3	MS+MS $26,480
61-65		22			
66-70		21	7.5	2.2	
71-75		13	8.5	2.4	MS+TAC $51,790
76-80		16	12.0	3.2	
81-85		10	8.9	2.0	TAC+TAC $100,698

Table 14. Summary of Results for Micro Surfacing Treatment on General System

Note: MS = Micro surfacing

Prior PCR	Performance Indicator				
	Service life from historic data	Average Performance Gain (PCR Points)	Life from Prediction Models, years	B/C Ratio	Life Cycle Costs
56-60	5 years				MS+MS $43,775 MS+TAC $66,649 TAC+TAC $100,698
61-65		20	4.5	1.5	
66-70		15	5.0	1.1	
71-75		9	4.5	1.2	
76-80		16	8.5	1.9	
81-85		16	11.0	1.9	

Table 15. Summary of Results for Micro Surfacing Treatment on Priority System

The highlighted values in the tables indicate effective range of prior PCR values at which the performance indicators show maximum efficiency. Obviously, the pre-existing condition of pavements selected for treatment has played a significant role in the observed historical performance of Ohio's chip seal and micro surfacing projects.

Ideally, all performance indicators should point to the same prior PCR range. However, the results show difference. Here, it is important to discuss the significance of each indicator.

Life from historic data for example, is a derivative of the actual practice. In other words, it does not include analysis of variation in pavement condition that existed among projects prior to the installation of each treatment. Pavement condition in such cases do not relate to standard frame of reference, threshold PCR for example. However, it reflects the current practices and provides data about the nature and extent of modifications needed to the existing program

Average performance gain utilizes annual PCR data for individual projects. Although it can provide a rational procedure to judge the effectiveness of treatments, it does not include cost element. The results can however be used to understand the optimal timing of the treatment at which effectiveness is maximum.

Life prediction from models is obtained through the development of performance prediction models. Life is measured for a given threshold and the procedure provides a rational basis to compare various scenarios. This procedure evaluates the effectiveness with respect to 'do-nothing' treatment and as such inhibits cost calculations. The advantage of the method is in generating service life extension for various preexisting condition of pavements.

Cost-effectiveness is, to some extent, an extension of the life extension method. Here the performance characteristics of chip seal and micro surfacing treatments are compared with another treatment whose effectiveness is known beforehand. Only this method allows the computation of cost-effectiveness of maintenance treatments.

Life cycle cost analysis combines the attributes of methods 3 and 4. However, the drawback of this method is that the use of multiple treatments during the analysis period is rarely verified and validated in the field. The method also assumes certain condition of pavements at the end of each treatment cycle, a fact that is highly uncertain in reality.

The foregoing discussion is to suggest that direct comparison of the results should not be made among the five performance indicators derived in this study.

In summary, this study resulted in a critical review and comprehensive understanding of the chip seal and micro surfacing program in Ohio, and provided the basic data needed to determine when and where such preventive maintenance treatments are appropriate from the standpoint of both economics and performance. The results of this study, in association with similar studies to evaluate preventive maintenance activities, will enable ODOT staff to better determine what role chip seal and micro surfacing treatments should play in the overall preventive maintenance program (e.g., which pavements, what funding level).

Using the results from this study, in consultation with the project evaluation team, the following conclusions are made:

1. Chip seals are cost effective treatments. They provide maximum benefits when applied on pavements whose PCR is in the range **66 to 80**. Under such conditions, chip seals can extend the service life of pavements up to seven years.
2. Micro surfacing treatments on general system are reasonably effective. The best range of prior PCR for their installation is **61 to 70**. Life of micro surfacing treatments on general system is nine years.
3. Micro surfacing treatments on priority system are marginally effective. The best range of prior PCR for their installation is **61 to 70**. Micro surfacing on priority system can extend the service life of treated pavements by eight years.

It is recommended that ODOT continue with its chip sealing program on general system. Care should be exercised to select appropriate candidate pavements for the treatment to ensure maximum performance and benefit. This study did not address materials and mix design issues. It is recommended to research more in these areas that will result in improved product and placement and thereby performance. ODOT may also conduct in-house research to verify and validate the performance of successive chip seal treatments.

Micro surfacing is also a viable preventive maintenance option. It can provide the same general benefits that chip seals offer, but at a relatively higher cost. The added benefits of using micro surfacing, rut filling for example, may offset the additional cost. Because of the marginal benefits observed in the study, it is recommended that ODOT further review the micro surfacing program to enable the department determine what role such treatments should play in the overall maintenance program.

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APPENDIX

Table I-A. Ohio's Chip Seal Projects

DISTRICT	County	Route	Blog	Elog	Prior PCR
1	ALL	066R	0	1.21	81
1	ALL	066R	2.44	10.58	78
1	ALL	081R	0	3.05	
1	ALL	081R	0	3	86
1	ALL	081R	19.68	29.42	81
1	ALL	117R	0	2.02	79
1	ALL	190R	0.54	1.41	67
1	ALL	196R	0	3.05	88
1	ALL	198R	0	1.5	72
1	ALL	501R	0	4.34	72
1	ALL	696R	1.89	7.64	76
1	DEF	002R	3.68	11.2	77
1	DEF	002R	11.22	13.23	81
1	DEF	002R	13.23	16.59	77
1	DEF	002R	13.23	16.59	82
1	DEF	018R	0	2.07	68
1	DEF	018R	28.87	33.3	71
1	DEF	018R	28.97	30.11	64
1	DEF	018R	29.4	33.3	77
1	DEF	249R	2.9	7.06	84
1	DEF	249R	9.06	13.05	76
1	DEF	249R	13.06	14.48	79
1	DEF	424R	5.77	11.24	69
1	HAN	012R	0	4.93	78
1	HAN	012R	0	5	77
1	HAN	012R	5.73	9.57	74
1	HAN	018R	0	7	79
1	HAN	037R	6.43	12.25	77
1	HAN	103R	0.81	11.41	87
1	HAN	103R	0.9	11.5	86
1	HAN	103R	12.4	16.6	86
1	HAN	103R	19	23	79
1	HAN	186R	0	3.23	72
1	HAN	235R	1.01	7.58	79
1	HAN	235R	1.01	6.52	82
1	HAN	235R	8.3	11.8	86
1	HAN	235R	17.4	21	84
1	HAN	330R	0.96	2.85	84
1	HAN	613R	0	12.5	85
1	HAN	613R	13.56	18.76	79
1	HAN	698R	0	4.01	88
1	HAN	698R	4.7	10.4	81
1	HAN	698R	4.78	10.45	96
1	HAR	053R	1.34	11.98	74

DISTRICT	County	Route	Blog	Elog	Prior PCR
1	HAR	067R	1.58	15.05	73
1	HAR	067R	17.54	18.08	91
1	HAR	067R	18.08	24.77	84
1	HAR	068R	4	8.77	55
1	HAR	081R	4	12.4	78
1	HAR	081R	13	19	80
1	HAR	235R	0	0.41	60
1	HAR	309R	17.9	25.92	80
1	HAR	385R	0	2.26	71
1	HAR	701R	0	9.01	83
1	PAU	111R	0	4.6	76
1	PAU	111R	0	4.66	79
1	PAU	111R	0	4.66	78
1	PAU	114R	0	11.33	84
1	PAU	114R	12.08	16.8	80
1	PAU	500R	0	4.9	78
1	PAU	500R	0	4.85	81
1	PAU	500R	7.21	13.18	69
1	PAU	637R	0	1.7	85
1	PAU	637R	2	6.8	80
1	PUT	012R	10.13	14.44	66
1	PUT	066R	3.46	7.49	71
1	PUT	190R	4.3	7.56	70
1	PUT	634R	0.28	13.59	82
1	PUT	694R	5	11	82
1	PUT	696R	0	1.95	71
1	VAN	081R	11.74	16.76	79
1	VAN	081R	17.5	21.4	87
1	VAN	116R	0	2	77
1	VAN	116R	2.01	9.3	81
1	VAN	116R	9.75	18.26	79
1	VAN	116R	13.91	18.26	72
1	VAN	117R	0	3.1	83
1	VAN	224R	0	0.61	69
1	VAN	224R	0	9.25	75
1	VAN	224R	15.84	25.73	77
1	VAN	637R	0	4.02	69
1	VAN	637R	0	4.02	73
1	WYA	037R	0.48	9.16	71
1	WYA	067R	18.39	29.93	85
1	WYA	103R	7	18	86
1	WYA	199R	0	3.23	76
1	WYA	231R	0	2.21	70
1	WYA	231R	2.21	7.8	70
1	WYA	231R	20.58	23	84

DISTRICT	County	Route	Blog	Elog	Prior PCR
1	WYA	294R	0	3.23	83
1	WYA	294R	0	9.5	79
1	WYA	294R	0.5	11	80
1	WYA	294R	3.21	8.98	73
1	WYA	294R	11.6	15.9	90
1	WYA	294R	17.6	18.4	89
2	OTT	163R	4.05	5.98	
2	OTT	269R	4.29	5.46	77
2	SAN	018R	0	0.79	59
2	SAN	051R	0	2.05	75
2	SAN	600R	0	4.02	59
2	SEN	018R	23.56	34.8	72
2	SEN	019R	6.07	8.58	79
2	SEN	019R	9.58	15.19	79
2	SEN	019R	15.19	19.75	81
2	SEN	228R	0	1.3	82
2	SEN	231R	0	7.08	
2	SEN	635R	0	6.08	85
2	SEN	778R	0	0.43	80
2	WIL	034R	15.7	16	72
2	WOO	105R	10.59	12.11	81
3	ASD	003R	6.8	8.16	73
3	ASD	095R	1.46	13.49	67
3	ASD	095R	10.26	14.07	60
3	ASD	179R	0	9.86	44
3	ASD	179R	0	9.86	60
3	ASD	302R	8.85	10.9	54
3	ASD	302R	11.25	14.29	54
3	ASD	545R	0	4.77	80
3	ASD	604R	0	3.36	58
3	CRA	019R	14.48	17.6	95
3	CRA	019R	16.09	23.31	
3	CRA	039R	0	3.45	70
3	CRA	039R	4.15	7.63	76
3	CRA	096R	3.65	11.4	67
3	CRA	103R	9.92	13.9	72
3	CRA	103R	13.9	14.88	84
3	CRA	103R	14.88	20.22	69
3	CRA	294R	0	5.86	85
3	CRA	294R	0	5.86	85
3	CRA	598R	11.03	15.41	71
3	HUR	060R	2.07	8.48	58
3	HUR	060R	9.07	12.93	60
3	HUR	162R	0	19	59
3	HUR	269R	0	5.62	75

DISTRICT	County	Route	Blog	Elog	Prior PCR
3	HUR	303R	0	3.76	86
3	HUR	303R	0	3.76	
3	HUR	547R	0	7.13	87
3	HUR	598R	0	2.64	86
3	LOR	303R	0	1.92	52
3	RIC	039R	0	1.12	70
3	RIC	071R	14.6	20.64	64
3	RIC	071R	14.6	20.64	64
3	RIC	096R	0	1.14	
3	RIC	309R	6.09	9.04	59
3	RIC	309R	6.09	9.04	65
3	RIC	430R	10.09	12.48	68
3	RIC	545R	2.12	11.54	82
3	RIC	546R	0	8.7	64
3	RIC	598R	0	3.86	87
3	WAY	539R	0	7.96	58
3	WAY	539R	8.77	12.65	64
3	WAY	604R	0	1.03	64
4	ATB	011R	9	14	
4	POR	282R	0	2.68	64
5	GUE	313R	0	1.24	66
5	MUS	313R	0	7.1	64
5	MUS	376R	0	5.29	45
6	DEL	257R	14.2	22.62	70
6	DEL	656R	0	4.69	72
6	MAD	665R	2.47	11.11	88
6	MAR	037R	0	3.4	85
6	MAR	047R	0.6	2	70
6	MAR	095R	0	10	76
6	MAR	100R	0	2.8	64
6	MAR	100R	0	2.8	69
6	MAR	203R	3	7	75
6	MAR	229R	0	1.05	58
6	MAR	231R	0	4.3	59
6	MAR	231R	0	4.3	70
6	MAR	423R	11.4	16.4	59
6	MAR	746R	0	9.9	76
6	MRW	019R	0	10.37	77
6	MRW	042R	0	4.8	74
6	MRW	061R	14.75	22.8	81
6	MRW	097R	0	3.79	78
6	MRW	656R	0	5	67
6	MRW	746R	0	3	65
6	PIC	207R	0	9.57	59
6	UNI	037R	1.95	9.1	65

DISTRICT	County	Route	Blog	Elog	Prior PCR
6	UNI	037R	1.95	9.1	65
6	UNI	037R	10.1	12.3	76
6	UNI	047R	0	5.5	69
6	UNI	047R	5.5	13.5	65
6	UNI	739R	6	11.3	59
6	UNI	739R	14.8	25.6	69
7	AUG	116R	1.58	7.25	85
7	AUG	197R	0	7.44	68
7	AUG	198R	2.67	11.01	75
7	AUG	219R	0	3	71
7	AUG	219R	3.12	6.81	79
7	AUG	274R	0	3.15	69
7	AUG	363R	0	1.01	70
7	AUG	364R	2.62	5.71	89
7	AUG	364R	6	10.7	85
7	AUG	385R	0	3.91	68
7	AUG	720R	0	2.81	73
7	CHP	245R	10.82	17.09	60
7	DAR	503R	0	1.36	78
7	DAR	726R	0	4	73
7	LOG	274R	9.7	10.3	58
7	MER	707R	5	11.5	80
8	CLE	052R	0	25.49	79
8	CLE	052R	0	25.49	78
8	CLE	133R	31.16	34.57	86
9	BRO	131R	3.92	7.83	87
9	HIG	131R	0	7.09	87
9	SCI	348R	0	5.97	81
10	ATH	056R	0	5	75
10	ATH	329R	14.13	19.74	86
10	ATH	356R	0	4.77	77
10	ATH	681R	0	6.61	79
10	MOE	379R	0	8.18	66
10	MRG	060R	9.7	10.7	99
10	MRG	078R	28.46	31.31	73
10	MRG	083R	10.33	15.62	62
10	MRG	329R	0	3.8	87
10	MRG	555R	3.79	15.23	76
10	MRG	555R	11.9	15.4	73
10	NOB	083R	0	6.77	65
10	VIN	328R	0	10.29	90
10	VIN	356R	0	5.97	69
10	VIN	671R	0	4.6	80
10	WAS	026R	22.01	3013	79
11	COL	518R	6.89	11.27	85

Table I-B. Ohio's Micro Surfacing Projects on Priority System

DISTRICT	County	Route	Blog	Elog	Prior PCR
2	LUC	023R	9.63	12.65	77
2	LUC	023R	9.63	12.65	80
2	LUC	475R	8.97	16.42	84
2	LUC	475R	8.97	16.42	84
2	LUC	475R	8.97	16.42	84
2	LUC	475R	8.97	16.42	
2	LUC	475R	8.97	16.42	
2	LUC	475R	8.97	16.42	
2	OTT	002R	26.62	27.2	74
2	OTT	002R	26.62	27.2	80
2	WOO	075R	0.77	5.05	78
2	WOO	075R	0.77	5.05	88
2	WOO	075R	5.05	14.91	
2	WOO	075R	5.05	14.91	83
3	LOR	002R	3.45	7.68	73
3	LOR	002R	3.45	7.68	75
3	MED	076R	0.65	7	69
3	MED	076R	0.65	7	69
3	RIC	030R	12.35	19.13	80
3	RIC	030R	12.35	19.13	80
4	STA	077R	9.05	13.6	73
4	STA	077R	9.05	13.6	73
5	FAI	033R	0	12.58	58
5	FAI	033R	0	12.58	63
5	MUS	070R	5.7	10.63	87
5	MUS	070R	5.7	10.63	87
5	MUS	070R	10.94	11.56	84
5	MUS	070R	10.94	11.56	84
5	MUS	070R	10.94	13.03	
5	MUS	070R	10.94	13.03	87
5	MUS	070R	12.12	27.33	89
5	MUS	070R	12.12	27.33	91
6	FRA	033R	0	3.14	68
6	FRA	033R	0	3.14	67
6	FRA	071R	28.92	29.9	81
6	FRA	071R	28.92	29.9	81
6	FRA	270R	0.6	2.6	73
6	FRA	270R	0.6	2.6	73
6	FRA	270R	9.49	17.47	69
6	FRA	270R	9.49	17.47	75
6	FRA	270R	18.54	18.81	65
6	FRA	270R	18.54	18.81	66
6	FRA	270R	29.11	36.94	
6	FRA	270R	29.11	36.94	97

DISTRICT	County	Route	Blog	Elog	Prior PCR
6	FRA	270R	48.47	52.16	69
6	FRA	270R	48.47	52.16	66
6	FRA	315R	5.19	8.56	73
6	FRA	315R	5.19	8.56	73
6	FRA	315R	8.56	11.37	78
6	FRA	315R	8.56	11.37	80
7	AUG	075R	5.03	12.55	60
7	AUG	075R	5.03	12.55	77
7	LOG	033R	2.01	4.82	84
7	MOT	675R	4	7.42	70
7	MOT	675R	4	7.42	77
7	SHE	075R	9.43	17.54	57
7	SHE	075R	9.43	17.54	62
8	BUT	027R	3.35	5.66	70
8	BUT	075R	0	6.77	65
8	BUT	075R	0	6.77	72
8	BUT	075R	6.77	11.25	63
8	BUT	075R	6.77	11.25	70
8	HAM	027R	9.73	14.19	60
8	HAM	071R	8.39	11.12	60
8	HAM	071R	8.39	11.12	
8	HAM	071R	12.12	19.17	76
8	HAM	071R	12.12	19.17	75
8	HAM	075R	16.42	17.47	60
8	HAM	075R	16.42	17.47	67
8	HAM	126R	1.94	6.04	73
8	WAR	073R	6.77	13.86	83
8	WAR	075R	0	3.35	70
8	WAR	075R	0	3.35	75
8	WAR	075R	3.35	12.2	
8	WAR	075R	3.35	12.2	77
9	SCI	023R	7.43	11.5	94
9	SCI	023R	7.43	11.5	
10	ATH	032R	0	1.42	79
10	ATH	032R	0	1.42	81
10	ATH	033R	5.34	10.4	97
10	ATH	033R	5.34	10.4	97
10	ATH	033R	5.73	10.4	96
10	ATH	033R	5.73	10.4	95
10	ATH	050R	1.75	11.47	72
10	ATH	050R	1.75	11.47	81
10	MEG	007R	11.35	14.59	68
10	NOB	077R	1.56	6.22	91
10	NOB	077R	1.56	6.22	99
10	WAS	007R	21.47	22.72	83

DISTRICT	County	Route	Blog	Elog	Prior PCR
10	WAS	007R	23	23.74	75
11	COL	007R	26.81	28.65	77
11	COL	030R	12.71	22.72	95
11	JEF	007R	33.69	34.3	
11	JEF	007R	33.69	34.3	
11	TUS	077R	25.04	34.97	73
11	TUS	077R	25.04	34.97	73
12	CUY	090R	19.76	23.95	80
12	CUY	090R	19.76	23.95	78
12	CUY	480R	23.52	24.4	54
12	CUY	480R	23.52	24.4	64
12	LAK	271R	0	3.03	76
12	LAK	271R	0	3.03	75

Table I-C. Ohio's Micro Surfacing Projects on General System

DISTRICT	County	Route	Blog	Elog	
2	OTT	105R	1.19	2.71	76
2	OTT	163R	4.01	7.98	76
2	OTT	163R	7.98	13.24	85
2	OTT	163R	27.15	31.21	77
2	SAN	300R	0	6.33	73
2	SAN	412R	0	4.19	77
2	WOO	006R	5.05	11.99	78
2	WOO	023R	6.02	12.05	79
2	WOO	064R	4.12	9.03	74
2	WOO	235R	10.07	14.1	76
3	CRA	098R	0	5.69	76
3	CRA	181R	0	1.21	75
3	ERI	113R	12.81	20.91	84
3	LOR	113R	9.96	12.74	73
3	LOR	113R	9.96	12.74	69
3	LOR	303R	18.76	19.28	74
3	MED	094R	17.75	18.74	76
3	MED	303R	0	6.08	83
3	MED	303R	9.85	11.95	78
3	MED	303R	12.97	15.12	75
3	RIC	181R	0	2.76	72
3	RIC	314R	0	3.77	72
3	WAY	604R	1.03	7.61	73
4	MAH	224R	0	1.2	72
4	MAH	224R	7.6	8.96	74
4	MAH	224R	8.98	11.25	65
4	MAH	289R	8.29	8.44	56
4	MAH	534R	8.62	13.8	64
4	MAH	534R	8.62	13.8	78
4	POR	014R	11.33	15.16	90
4	STA	093R	5.84	8.82	73
4	TRU	007R	8.98	12.66	67
4	TRU	087R	13.42	17.65	67
4	TRU	087R	17.66	22.36	66
5	GUE	265R	0	2.65	56
5	GUE	265R	4.27	6.81	68
5	GUE	265R	11.66	17.88	72
5	GUE	285R	4.67	8.04	65
5	GUE	761R	0	2.44	68
5	PER	757R	0	5.68	80
6	DEL	023R	0	13.25	83
6	DEL	023R	0	13.25	94
6	DEL	605R	0	6.21	90
6	FAY	041R	13.22	23.22	75

DISTRICT	County	Route	Blog	Elog	
6	MAD	038R	21.59	30.03	
6	UNI	036R	13.88	18.89	78
7	AUG	067R	0.32	2.16	64
7	AUG	198R	1.7	2.19	65
7	LOG	047R	0	5.23	86
7	MIA	055R	13.06	16.1	71
7	MIA	571R	14.54	15.22	77
7	MIA	721R	2.75	5.66	75
7	MOT	048R	16.38	18.38	54
7	MOT	048R	16.38	18.38	63
7	MOT	201R	5.4	7.05	93
8	BUT	127R	10.05	16.56	
8	CLE	048R	1.38	5.45	
8	CLE	125R	15.64	18.16	88
8	CLE	132R	10.84	11.79	84
8	CLE	132R	20.6	24.82	85
8	CLE	133R	4.67	12.78	
8	CLE	133R	20.24	21.42	87
8	CLE	222R	25.67	29.14	
8	CLE	276R	0.51	6.1	80
8	CLE	774R	0	4	
8	CLI	022R	0	7.21	77
8	CLI	134R	15.33	22.15	79
8	GRE	042R	3.59	7.99	79
8	GRE	042R	18.28	23.19	
8	GRE	068R	0	8.35	69
8	GRE	380R	0	7	
8	GRE	734R	0	3.23	
8	HAM	004R	7.74	8.23	65
8	PRE	035R	2.38	9.55	
8	PRE	040R	9.93	14.16	91
8	PRE	040R	14.92	17.68	89
8	WAR	022R	11.03	19.78	70
8	WAR	042R	5.17	9.57	72
8	WAR	048R	0.45	4.8	86
8	WAR	048R	16.4	18.01	86
8	WAR	048R	18.43	22.97	
8	WAR	123R	0.06	7.72	89
8	WAR	132R	0	5.06	89
9	PIK	220R	9.7	14.19	86
10	ATH	013R	0.29	6.02	78
10	ATH	078R	3.38	8.35	85
10	ATH	078R	9.37	10.88	87
10	ATH	550R	0.74	6.75	77
10	HOC	180R	0.39	7.52	84

DISTRICT	County	Route	Blog	Elog	
10	MEG	032R	0	3.82	76
10	MEG	032R	0	3.82	85
10	MRG	078R	31.3	37.53	84
10	MRG	266R	4.46	13.96	85
10	WAS	060R	1.19	1.72	71
11	COL	009R	9.96	13.06	83
11	COL	009R	15.84	16.76	97
11	COL	014R	0	11.74	97
11	COL	062R	14.12	14.53	95
11	COL	154R	9.98	16.42	77
11	COL	165R	3.37	4.24	73
11	COL	170R	17.24	20.19	73
11	COL	172R	2.12	3.15	89
11	COL	344R	2.79	7.71	95
11	COL	558R	10.47	12.56	75
11	HOL	515R	0.09	5.51	
12	CUY	322R	14.14	16.71	56
12	CUY	480R	0	1.88	99
12	GEA	168R	7.39	8.45	81
12	GEA	322R	0	2.75	65
12	GEA	322R	5.66	7.5	