CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 08-021
UILU-ENG-2008-2008
ISSN: 0197-9191

EVALUATION OF HMA OVERLAYS IN ILLINOIS

Prepared By

Angela S. Wolters
Todd E. Hoerner
Kurt D. Smith
Applied Pavement Technology, Inc.

Research Report FHWA-ICT-08-021

A report of the findings of

ICT-R27-23
Evaluation of HMA Overlays in Illinois

Illinois Center for Transportation

September 2008

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-ICT-08-021		

4. Title and Subtitle	5. Report Date
Evaluation of HMA Overlays in Illinois	September 2008
	6. Performing Organization Code
7. Author(s) Wolters, Hoerner, Smith	8. Performing Organization Report No. FHWA-ICT-08-021 UILU-ENG-2008-2008
9. Performing Organization Name and Address Applied Pavement Technology, Inc. 115 W. Main St, Suite 400 Urbana, IL 61801	10. Work Unit (TRAIS)
	11. Contract or Grant No. ICT-R27-23
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, IL 62704-4766	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Illinois Department of Transportation (IDOT) has evaluated the performance of the pavements in Illinois in a variety of studies over the years. Since those studies were conducted, several changes in IDOT practices, policies, and procedures have sparked the need to reassess the performance of HMA overlays in Illinois.

The purpose of this study was to examine the performance of HMA overlays in Illinois. The service life of the overlays is affected by a variety of factors that were examined in this study. Specifically, the following attributes were examined:

- Construction year period
- Location
- Condition before overlay placement
- Presence of D-cracking on rigid pavement sections before overlay
- Underlying concrete type
- Estimated overlay number
- Overlay type

The service life trends observed in the 231 examined datasets were as expected for the majority of the datasets. However, there were some inconsistencies or unexpected trends in the results for several data sets. For those cases, the data were reviewed and the reasons for the inconsistent or unexpected trends were often obvious. The data causing the unexpected trends were not removed from the datasets as the data was true CRS data. Based upon the service life results, the impact of the evaluated variables on the performance of the HMA overlays were documented in the report. The database of information developed as part of the study contains a wealth of information that can be used to further analyze the effects of various attributes on the performance of HMA overlays.

17. Key Words	18. Distribution Statement
	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENT

This publication is based on the results of ICT-R27, Evaluation of HMA Overlays in Illinois. ICT-R27 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation (IDOT); and the U.S. Department of Transportation (US DOT), Federal Highway Administration (FHWA).

Members of the Technical Review Panel are the following:

Jeffrey South, IDOT – Office of Program and Planning (OPP), Chair
Patty Broers, IDOT - Bureau of Materials and Physical Research (BMPR)
David Felts, IDOT – OPP
Andrew Grossrow – IDOT, OPP
Laura Heckel, Heckel Engineering Research and Education, Inc. (HERE)
David Lippert, IDOT - BMPR
Brian Pfeifer – FHWA, Illinois
Rob Robinson – IDOT, OPP
LaDonna Rowden, IDOT, BMPR

EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) has evaluated the performance of the pavements in the state in a variety of studies over the years. Since those studies were conducted, several changes in IDOT practices, policies, and procedures have sparked the need to reassess the performance of HMA overlays in Illinois.

The purpose of this study was to examine the performance of HMA overlays in Illinois. The service life of the overlays is affected by a variety of factors that were examined in this study. Specifically, the following attributes were examined:

- Construction year period
- Location
- Condition before overlay placement
- Presence of D-cracking on rigid pavement sections before overlay
- Underlying concrete type
- Estimated overlay number
- Overlay type

The service life trends observed in the 231 examined datasets were as expected for the majority of the datasets. However, there were some inconsistencies or unexpected trends in the results for several data sets. For those cases, the data were reviewed and the reasons for the inconsistent or unexpected trends were often obvious. The data causing the unexpected trends were not removed from the datasets as the data was true CRS data. Based upon the service life results, the impact of the evaluated variables on the performance of the HMA overlays were documented in the report. The database of information developed as part of the study contains a wealth of information that can be used to further analyze the effects of various attributes on the performance of HMA overlays.

CONTENTS

CHAPTER 1 INTRODUCTION

Over the years, the Illinois Department of Transportation (IDOT) has periodically evaluated the longevity of interstate and freeway pavements under its jurisdiction, with the more recent study performed for new and overlay pavements constructed prior to 2000 (Gharaibeh and Darter 2002). Since the conduct of that study, several changes in IDOT practices, policies, and procedures have sparked the need to reassess the specific performance of hot-mix asphalt (HMA) overlays in Illinois. Some of the changes include the full adoption of SUPERPAVE for all state highway mix designs in 2001 and the adoption of material transfer devices (MTD) in early 2000 for new interstate pavement construction. Furthermore, there is interest in assessing the performance of these overlays because they are being exposed to ever-increasing truck traffic volumes.

Given these changes and the application of increased traffic loadings, a reassessment of performance of HMA overlays on Illinois highways was needed. Therefore, the performance of overlaid pavement sections for a variety of subsets of the pavement network was evaluated and detailed in this report. The analysis focused on evaluations of the performance of overlays on interstate and off-interstate, marked routes that were constructed in four different time periods: 1975 to 1980, 1981 to 1987, 1988 to 2000 and 2001 to 2006 for pavement sections with underlying flexible and rigid pavement structures. The analysis also compares the performance of 3P (Pavement Preservation Program) policy and SMART (Surface Maintenance at the Right Time) overlays. For years, the use of 3P policy overlays began in the early 1980's. Prior to that time, the standard practice used by IDOT was to design structural overlays. 3P Policy overlays were implemented as a cost savings measure to address the increasing backlog of roadways needing rehabilitation. Initially, the standard overlay policy was defined as the following:

- First resurfacing on Interstate system – 3.0 inches
- First resurfacing on non-interstate system – 2.5 inches
- Subsequent overlays – 2 inches

A provision was created for roadways in need of thicknesses beyond the policy overlay thickness. With changes in bituminous concrete mixtures, a change was made in the policy overlay thickness around 1988 that increased allowable thicknesses on the interstate system to 3.25 inches and subsequent overlays on the primary system to 2.25 inches. Those policy thicknesses for the interstate pavements were adjusted to 3.75 inches in 2003 to provide 3 times the nominal maximum aggregate size of the new SUPERPAVE mixes (Schutzbach 1995).

As another cost savings effort, the SMART policy overlay was initiated in 1986 by IDOT. The overlay is a thin lift, single pass of 1.5 inches of bituminous concrete. The purpose of the SMART overlay is to restore functionality to roads with lower volume that are exhibiting distresses due to age as opposed to structural deficiencies (Reed 1992). The behavior of both of these policy overlays is examined in the study.

Also the analysis focused on overlays placed in the north and south portions of the state, overlays that were placed on pavements with varying condition, and overlays that were placed on concrete pavements that were and were not affected by D-cracking prior to overlay placement.

The results of this performance analysis provide an assessment of various pavement subsets of the time and cumulative traffic levels between overlay placements. These values can be used to represent a service life of the pavement. The comparison of the service life of various pavement subsets can be used to evaluate the impact of previous policies and/or procedures and to address the need for future changes or updates.

CHAPTER 2 BACKGROUND

Several studies related to the performance of pavement sections in the State of Illinois have been conducted over the years. The performance of the interstate pavements in Illinois was well documented in studies conducted between 1990 and 2002. Specifically, the service life and overall performance of these pavements were assessed in studies conducted in 1990 (Dwiggins et. al. 1989), 1993 (Hall, Darter, and Rexroad 1993), 1997 (Gharaibeh et. al.), and 2002 (Gharaibeh and Darter 2002). In the most recent study, which included traffic and condition data through the year 2000, a survival analysis of 2000 centerline miles of interstate pavements (including sections with HMA overlays over full-depth HMA pavements, HMA overlays over jointed concrete pavements [jointed plain concrete pavements {JPCP} or jointed reinforced concrete pavements {JRCP}], and HMA overlays over continuously reinforced concrete pavements [CRCP]) was conducted to obtain associated service lives and load-carrying capabilities (Gharaibeh and Darter 2002). Relative to overlay performance, results of the study showed that the original pavement type, the presence of D-cracking in the original pavement surface, the HMA overlay thickness, the geographic location, and the HMA overlay generation (first versus second versus third) all significantly affected the overlay service life based on a survival analysis.

In addition to examining the performance of HMA overlays on each original surface type individually, Gharaibeh and Darter (2000) also conducted additional analyses to assess the service life associated with thin (less than 4 inches) and thick (4 inches and greater) HMA overlays. Based on that evaluation, a summary of the longevity and load-carrying capacity of HMA overlays constructed prior to 2000 is provided in table 1.

Table 1. Summary of Longevity and Load Carrying Capacity of HMA (AC) Overlays of Illinois Interstate and Other Freeway Pavements (Gharaibeh and Darter 2002)

Overlay Design	**Existing Pavement**	**50th Percentile Age, years**		**50th Percentile ESALs, million**	
		With DC	**Without DC**	**With DC**	**Without DC**
Thin AC Overlay	**JRCP**	First OL: 12 Second OL: NA	15 11	15 NA	22 32
	CRCP	First OL: 12 Second OL: NA	13 10.5	22 NA	34 27.5
	HMAC	First OL: 15.5 Second OL: NA		12 NA	
Thick AC Overlay	**JRCP (Poor condition)**	First OL: 11 Second OL: NA	15 12	13 NA	25 29
	CRCP (Poor Condition)	First OL: 13 Second OL: NA	15 NA	10 NA	21 NA
	HMAC (Poor Condition)	First OL: 8.5 Second: NA		6 NA	

First/Second OL: Refers to first AC overlay and second AC overlay
DC: D-Cracking of underlying concrete; NA: Data not available

The study, which utilized information from the detailed Illinois Pavement Feedback System (IPFS) database, showed that second generation overlays typically had a 2.5 to 4 year reduction in age when comparing the 50^{th} percentile survival curve to the same curve for first generation overlays. Other notable performance trends include the reduction in age and ESAL applications to reach the 50^{th} percentile survival curve when D-cracking is present in the original pavement prior to overlay placement.

A previous study conducted by IDOT to examine the service life of IDOT's HMA policy overlays and procedures associated with the use of exceptions to the policy overlay thicknesses focused on a project-by-project analysis for twelve pavement sections (Schutzbach 1995). The pavement sections included in that study are summarized in table 2. The overlays placed on the pavement sections were categorized as one of six categories: policy first overlays on rigid pavements (Policy-1^{st}), additional thickness first overlays on rigid pavements (Additional-1^{st}), policy subsequent overlays on rigid pavements (Policy-2^{nd}), additional thickness subsequent overlays on rigid pavements (Additional 2^{nd}), policy overlays on flexible base pavements (Policy-Flex), and additional thickness overlays on flexible base pavements (Additional-Flex) (Schutzbach 1995).

Table 2. Summary of Pavement Sections Included in IDOT's HMA Policy Overlay Study (Schutzbach 1995).

Contract	Route	Year of Rehabilitation	Type of Overlay
38699	IL 115	1985	Policy-2^{nd}
36574	US 136	1984	Policy-2^{nd}, Policy-Flex
36907	IL 91	1984	Policy-2^{nd}, Additional-2^{nd}
38137	US 24	1984	Policy-1^{st}, Additional-1^{st}
38186	CH 5	1984	Additional-2^{nd}
40820	IL 15	1986	Policy-2^{nd}, Policy-Flex, Additional-Flex
40218	IL 16	1986	Additional-Flex
40269	IL 97	1986	Policy-1^{st}
42411	IL 97	1987	Additional-1^{st}
38362	IL 78	1984	Policy-1^{st}, Policy-2^{nd}
36101	IL 1	1983	Policy-1^{st}
38296	IL 116	1985	Policy-1^{st}, Additional-1^{st}

The main purpose of that study was to evaluate the life span of those overlays and to determine if the policy overlay thickness was adequate to meet the expected minimum 5-year performance period for federal-aid projects as established by the FHWA. The performance of eleven selected projects that had received standard IDOT 3P policy HMA overlays (3.25 inches on the interstate system and 2.25 inches on the primary system) was assessed (Schutzbach 1995). The study concluded that service lives exceeded the minimum 5-year requirement and IDOT was successfully achieving its goal of a 6- to 10-year rehabilitation performance period. The summary of the calculated services lives of the various pavement sections are shown in table 3 (Schutzbach 1995).

Table 3. Summary of Service Life of HMA Policy Overlays of Illinois (Schutzbach 1995).

Pavement Families	Number of Data Points	Average Overlay Life Span (Years)
All Sections	11	12.2
Rigid Pavement, First Overlay	6	13.9
Rigid Pavement, Subsequent Overlay	5	9.1
Flexible Pavement	3	11.3

Thus, both studies quantified the performance and related service life of various HMA overlays in Illinois. Since the conduct of those studies, there have been various changes in IDOT's practices, including the use of SUPERPAVE. Therefore, the analysis conducted as part of this study is needed to address the issue of the performance of the HMA overlays by evaluating the service lives associated with overlay technologies under various parameters and ever-increasing truck traffic loading.

CHAPTER 3 DATA COMPILATION

INTRODUCTION

Data for the analysis were obtained from Illinois Roadway Information System (IRIS) by staff from the Office of Programming and Planning. Road inventory data were available for the years 1975 to 2006. The condition rating survey (CRS) data and the construction history information were provided in separate Access® databases for each year of available data.

The project team worked with IDOT to finalize the data fields needed for the project analysis. The IRIS data fields included in the CRS files were the following:

- IRIS year.
- Key route identification.
- Beginning and ending locations and references.
- Marked route.
- District.
- County.
- Marked route.
- Surface type.
- Municipality.
- Street/road name.
- Annual average daily traffic and year.
- Annual average daily multiple unit volume and year.
- Annual average daily single unit volume and year.
- Annual average daily heavy commercial volume and year.
- Original construction date.
- Surface construction date.
- Lane number.
- Condition rating survey and date.
- Pavement distress.
- International Roughness Index (IRI).
- Rut depth.
- Jurisdiction.
- Township or road district.
- Built by.
- County highway number.
- Functional classification.
- Urban or rural classification.

CRS data files were provided by IDOT in two forms: project segments as identified by IDOT and 0.01-mile increments. In addition to providing necessary CRS and traffic data, the CRS data files also contained a wealth of information that was used to compile data into time-series data sets for analysis.

The project team also worked with IDOT to finalize work history information needed for the project analysis. The final work history files included the following data fields:

- Key route identification.
- Beginning and ending stations.
- County or municipality name.
- District.
- Construction direction of traffic.
- Construction route.
- Construction section.
- Construction type.
- Construction year.
- Construction contract number.
- Construction microfilm number.
- Original pavement design.
- Original pavement width.
- Original pavement reinforcement.
- Construction remarks.
- Construction resurfacing thickness.
- Original pavement subbase thickness.

Construction history information was critical for determining the sequencing of overlays that occurred over the life of each pavement section. The construction history information also provided some insight into the overlay thicknesses applied to a pavement so that overlay types (SMART versus 3P) could be broken out and examined in the analysis. It should be noted, however, that all data was not populated for all projects.

The purpose of the data compilation task was to match the CRS and work history information for as many unique sections as possible in order to produce an analysis database containing time-series CRS, traffic loading, and overlay history information. The processing of the data represented a significant work effort within this study. The detailed data processing steps are provided in the remainder of this section.

DEFINITION OF UNIQUE PROJECTS AND SECTIONS FOR THE ANALYSIS

The first step in the data compilation process was to analyze the 31 years of CRS data (from 1975 through 2006) to determine what unique projects and sections could be used in the analysis. This process started by identifying the milepost boundaries of each "project" included in the data. For this analysis, a *project* is defined as a unique combination of County ID (i.e., "Key_County/Muni"), Key Route ID, and direction. For each project, the minimum milepost (typically "0") and maximum milepost values define the boundaries of the project.

Each project in the CRS data files is made up of one or more IDOT-defined "sections." For this analysis, a *section* is defined as an identified length of roadway within a project that has similar characteristics along its length (i.e., consistent condition information for any given year, similar traffic, and similar work history). For clarity, the relationship between project and section boundaries is illustrated in figure 1 for a 5.1-mile long example project. Each section that is broken out in figure 1 is part of the overall project but differs in terms of an attribute such as cross section, traffic, or condition.

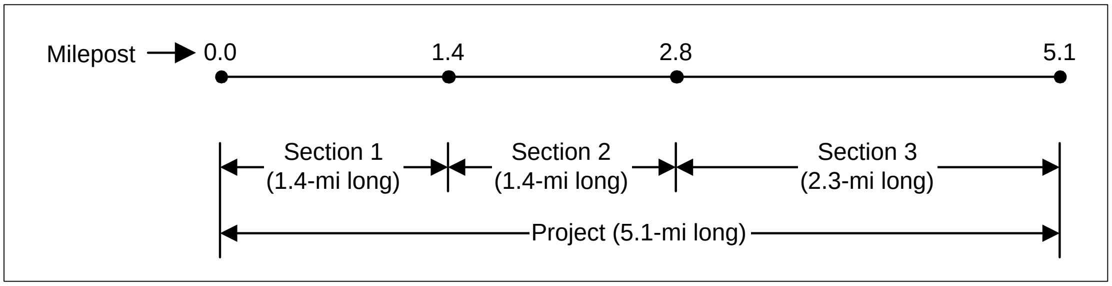

Figure 1. Example illustrating the relationship between projects and sections.

In this study, the process for identifying all unique sections for analysis required that all 31 years of CRS data be analyzed sequentially (from 1975 to 2006) in order to 1) identify the project boundaries at each year, and 2) determine all of the identified section boundaries within each project. If the project length did not change over time, the next task was to determine if the section boundaries matched from year to year. It was not uncommon to find that section boundaries did not match from year to year. Because there are no indications in the data files as to why the section boundaries may have changed, it was assumed that any observed year-to-year section boundary changes resulted in the subdivision of existing sections into smaller sections (provided that the total length of the project did not change). This process is best explained with an example.

First assume that the example 5.1-mile project shown in figure 1 was originally divided into three different sections in 1975. Now, also assume that the CRS data files show that these section breaks exist in the data from 1975 through 1985. However, the 1986 CRS data files indicate that, although the project length has not changed, the two sections between mileposts 1.4 and 5.1 are now divided into three different sections (see figure 2). In order to be able to analyze all 31 years of data available for this project, all observed section breaks were used to break the project into smaller lengths for which all characteristics were common over the section length. For this example, recognizing all observed section breaks results in a total of five different sections that are used in the analysis, as illustrated at the bottom of figure 2.

While the above example assumed that the total project length did not change over time, the length of many projects in the IDOT database did in fact change over time. The problem that this situation presents is that there is not enough information available to clearly define how project (and section) endpoints should be matched up before and after the observed length change. For example, assume that a 4-mile project (mileposts 0.0 to 4.0) existed between 1975 and 1982, and is divided into four 1-mi long sections. In 1982 assume that the data files show that the project length has increased to 5 miles (mileposts 0.0 to 5.0) and now contains five 1-mi long sections. Because both sets of data have a starting milepost of 0.0, one may initially assume that the additional mile of pavement has been added at the *end* of the project (i.e., from milepost 4.0 to 5.0). However, discussions with IDOT personnel indicated that this assumption may not always be true. The additional mile of length may have in fact been added at the *start* of the project, and the milepost values may have been readjusted.

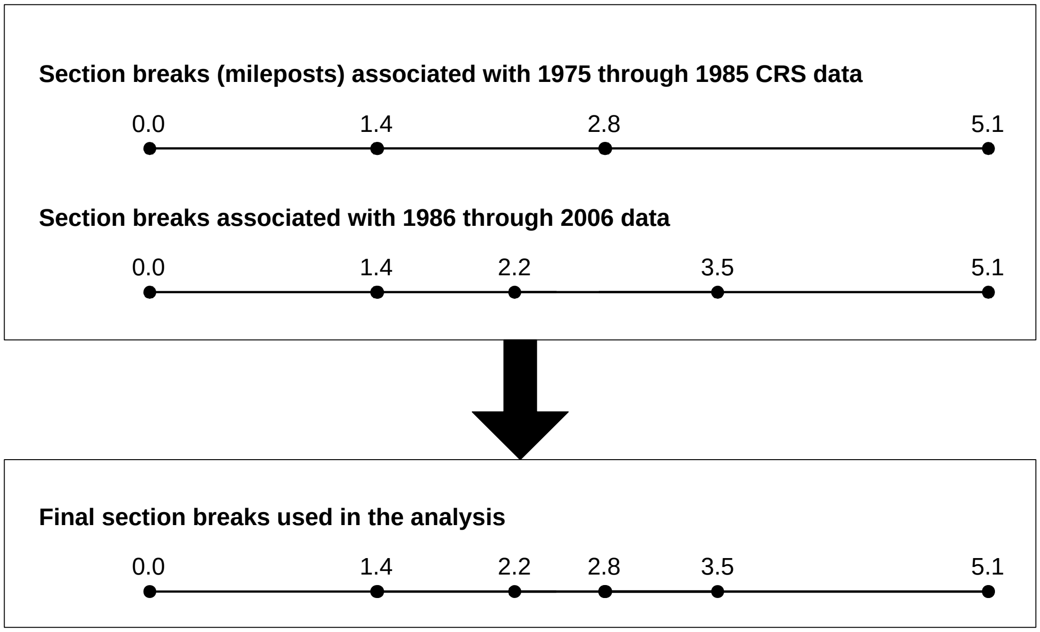

Figure 2. Example of how observed section breaks over time influence the selection of the final section breaks for analysis.

These two possible scenarios (length added to end of the project and length added to the beginning of the project) are illustrated in figure 3. Note that in Scenario 1, the data from mileposts 0.0 to 4.0 matches up before and after the length change because the mileposts have not been readjusted. However, the same cannot be said for Scenario 2 as all mileposts have been readjusted back a mile (i.e., milepost 0.0 in 1982 is now milepost 1.0 in 1983). In Scenario 2, it is incorrect to match the pre-1983 CRS data from mileposts 0.0 to 1.0 to the post-1983 CRS data from mileposts 0.0 to 1.0 because they don't represent the same section of roadway. To be correct, the pre-1983 data from mileposts 0.0 to 1.0 must be matched with the post-1983 data from mileposts 1.0 to 2.0. But, because there is no easy way to determine where the additional length has been added, that adjustment could not be easily determined when processing the data. Because of this problem, the data before and after the length change was divided into separate projects for the analysis. This practice was necessary to instill confidence in all of the time-series data used for analysis in the study (i.e., CRS data, traffic data, distress data, and so on).

With the additional consideration of length changes, final projects included in the analysis are defined as unique combinations of the following variables:

- County ID (i.e., 'Key_County/Muni').
- Key Route ID.
- Direction (Main vs. Opposing).
- Section Endpoints (i.e., beginning and ending mileposts).
- An indicator of whether or not a length change has been observed (i.e., '00' = time from initial construction until first observed length change, '01' = data after first observed length change until the next observed length change, etc.).

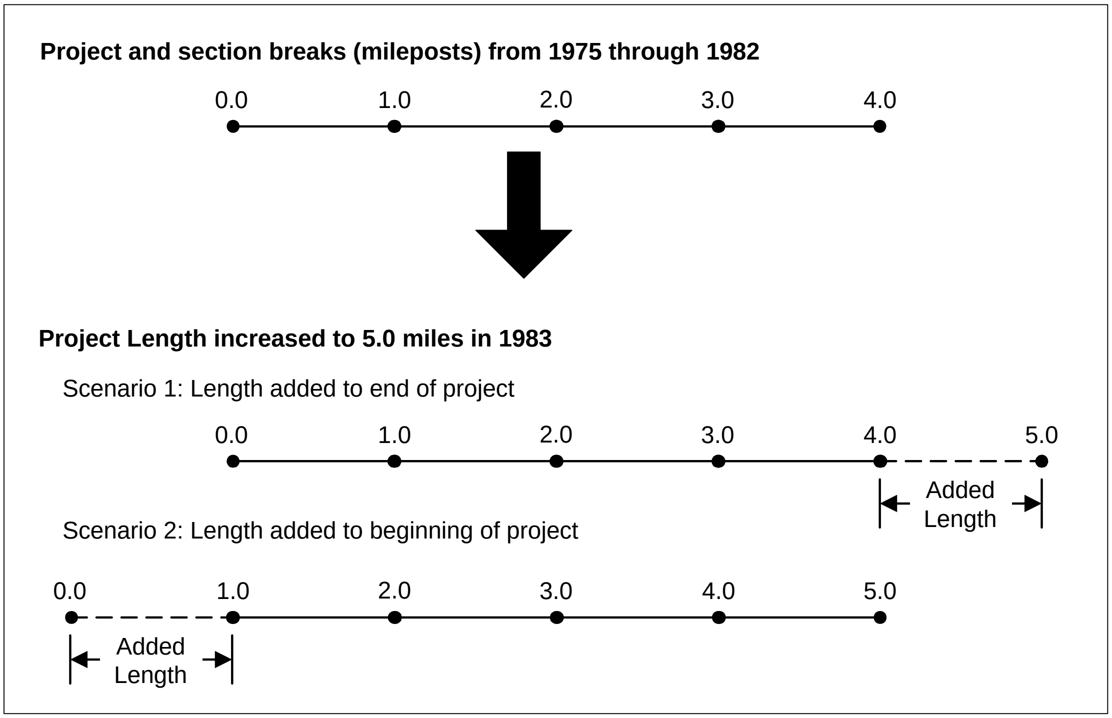

Figure 3. Different possible scenarios resulting from an observed project length change.

DATA PROCESSING STEPS

In order to produce meaningful data sets for the analysis, performance data sets depicting CRS as a function of age and traffic (specifically 18-kip equivalent single-axle load [ESAL] applications) were needed. Therefore, the required data had to be extracted from available IDOT CRS and work history databases, matched up by section boundaries, and compiled into the correct format for analysis. This process required the completion of the following general steps:

1. Process the CRS data.
2. Process the work history data.
3. Resolve differences between the CRS- and work history-related section breaks.
4. Create time-series data tables for selected variables in the CRS data tables.
5. Identify CRS-based construction events.
6. Compile time-series cumulative ESALs for CRS-based overlay events.
7. Compile final data sets for analysis.

All of these data compilation steps were carried out in Microsoft Access with the use of Visual Basic Application (VBA) code. The remainder of this section discusses the above outlined data compilation steps in more detail.

Step 1: Process the CRS Data

The very first step of the data compilation process involved collecting data from all 31 years of CRS data, organizing that data, and compiling it into one data table for this study. The specific steps used to accomplish that task are the following:

1. All years of CRS data (1975 to 2006) were used to create the starting data set. The base data set used for data summary was the aggregated project data sets provided by IDOT (as compared to the 0.01-mile data sets).
2. Data from both travel directions (i.e., the “main” and “opposing” direction) were included and analyzed independently. That is, one project with CRS data in both directions was viewed as two separate projects in the analysis.
3. Roads with an appurtenance type of mainline (0), alternate (1), or frontage road (5) were used while the other appurtenance types were not included.
4. The data with county IDs less than or equal to 102 were used in the data set. This eliminated a small amount of municipal data.

The initial processing of the CRS data identified 9,716 projects as unique combinations of County ID and Key Route ID. When other criteria such as direction and changes in project length were considered, the number of unique projects increased; specifically, it was observed that:

- 1,177 of the 9,716 projects (12 percent) contained data in both the main and opposing directions. Therefore, the data processing determined 10,893 unique combinations of County ID, Key Route ID, and direction.

- 2,092 of the 9,716 projects (22 percent) were observed to have at least one project length change between 1975 and 2006. A total of 13,484 unique combinations of County ID, Key Route ID, and number of length changes over time were identified in this data compilation step (note: directional data are not considered in this count).

When considering unique combinations of all criteria together (i.e., County ID, Key Route ID, direction, and number of length changes over time), a total of **15,084** unique projects were identified for inclusion in the analysis. Associated with these identified projects were a total of **602,340** unique sections that were identified for inclusion in the data analysis.

Step 2: Process the Work History Data

In this step, data were gathered and processed from the provided individual yearly IDOT work history tables (e.g., these tables had names such as “CST01_1993”), and compiled into one master work history table. The specific data manipulation and data filter information associated with this step included the following:

1. Rows of data were retrieved from the yearly construction history tables.
2. All rows with a construction type code (i.e., the ‘CONST_TYPE’ field) of ‘N’ were excluded during this step as this code is described in the IDOT documentation as “Reconstruction w/o thru-traffic lane resurfacing (surface sealant, patching, shoulder, lighting, etc.).”
3. Duplicate construction events were removed during the process.

As a result of this step, a total of **278,212** construction events were identified as unique documented work history events in the IDOT work history tables. A summary of these 278,212 construction events by type is summarized in table 4.

Table 4. Summary of Unique Work History Events Identified in the IDOT Work History Tables

'CONST_TYPE' Field Code	Construction Event Description	Number of Identified Construction Events
O	Original construction	131,767
R	Reconstruction w/thru-traffic lane resurfacing (widening, widening & resurfacing, etc.)	145,983
S	Additional original construction (additional pavement, major cross section change, etc.)	248
H	Historical original for pavement removal and new pavement construction	214

Step 3: Resolve Differences between the CRS- And Work History-Related Section Breaks

Because the CRS and work history data were retrieved from two different IDOT data sources, the project and section boundaries defined in each did not typically match up exactly. Therefore, work was completed to align the available work history information with the previously defined 602,340 unique sections defined from the processing of the CRS data. During this process, some construction event endpoints created the need to divide existing unique CRS-based sections into one or more new sections. Therefore, the processing and alignment of these data tables in this step resulted in a total of **797,695** unique sections after this data compilation step.

Step 4: Create Time-Series Data Tables for Selected Variables in the CRS Data Tables

The fourth step of the data compilation process was to create individual time-series data tables (i.e., yearly data placed in columns for each unique section) for various data elements in the IDOT CRS data tables. Each resulting table contained 797,695 rows of data (one row associated with each unique section) and columns of time-series data values associated with different years (i.e., 1975 value, 1976 value, 1977 value, and so on). An example of the general format for the time-series table is shown in table 5.

Table 5. General format used for the time-series data tables.

Section ID Information	1975 Value	1976 Value	→	2006 Value
Section 1				
Section 2				
↓				
Section 797,695				

For this analysis, time-series data tables were produced for the following variables: CRS, functional class, number of lanes, surface type, environment (urban or rural), traffic data, and distress data. Each of these data elements or categories is discussed separately below.

Time-Series CRS Data

Time-series CRS data is the basis of this analysis as it allows the ability to track overlay performance as a function of time. For each identified unique pavement section, all of the CRS values were collected and organized into the appropriate year-based columns.

Time-Series Functional Class Data

The functional class of each section is needed over time in order to compute estimated ESAL values at each year. Functional class is stored in the "FC" data field in the CRS data tables and can have one of the following 10 different integer values:

- 10 = Interstate.
- 20 = Freeway and expressway (urban only).
- 30 = Other principal arterial.
- 40 = Minor arterial (non-urban).
- 50 = Major collector (non-urban).
- 55 = Minor collector (non-urban).
- 60 = Local road or street (non-urban).
- 70 = Minor arterial (urban).
- 80 = Collector (urban).
- 90 = Local road or street (urban).

Time-Series Number of Lanes Data

The number of lanes in each section is also needed over time in order to compute estimated ESAL values at each year. The number of lanes is an integer value that is stored in the "Lanes" data field in the CRS data tables.

Time-Series Surface Type Data

Time-series surface type for each section is needed to determine what formulas need to be used (i.e., Rigid or Flexible) to compute ESALs at a given year. The surface type code is a three digit string value that is stored in the "Surface" data field in the CRS data tables. Specifically, the surface type code values are divided into the following categories:

- 000 to 099 = Unimproved or graded and drained.
- 100 to 199 = Soil surfaced.
- 200 to 299 = Gravel or stone.
- 300 to 399 = Bituminous surface-treatments with thicknesses less than 1-inch.
- 400 to 499 = Bituminous surface-treatments with thicknesses greater than 1-inch.
- 500 to 599 = High-type bituminous treatments (flexible base).
- 600 to 699 = High-type bituminous treatments (rigid base).
- 700 to 799 = Portland cement concrete (PCC) with no bituminous overlay.
- 800 = Brick, block, or other.
- >=900 = Combination of surface types within a section.

In the computation of ESALs, flexible load equivalency factors were used for surface type codes from 400 to 599 and rigid load equivalency factors were used for surface type codes from 600 to 800. ESALs were not computed for surface type codes from 000 to 399. Any combination codes were deciphered to determine the surface type making up the majority of the section length. That surface type was used to determine whether no ESALs, flexible ESALs, or rigid ESALs were computed for the given section. The process for the computation of ESALs is described in step 6.

Time-Series Environment (Urban or Rural) Data

The urban/rural environment for each section was also needed over time in order to compute estimated ESAL values at each year. The urban/rural value is a one character string (R or U) that is stored in the “UrbanRural” data field in the CRS data tables.

Time-Series Traffic Data

The following four traffic count types are available in the individual CRS tables:

- Annual average daily traffic (AADT).
- Annual average daily multiple unit volume (MU).
- Annual average daily single unit volume (SU).
- Annual average daily heavy commercial volume (HCV).

These traffic count variables are stored in the CRS data tables in the “AADT,” “MU_Count,” “SU_Count,” and “HCV_Count” fields, respectively. Time-series data for all four of these traffic count types were needed to compute yearly ESAL values.

Time-Series Distress Data

The distress-related information included in the CRS tables and of interest to this analysis included the pavement distress code, International Roughness Index (IRI) values, and measured rut depth. These distress-related variables are stored in the CRS data tables in the “Pavement_Distress,” “IRI,” and “Rut_Depth” fields, respectively. Each of these different distress-related variables is described in more detail below:

- Pavement distress code—The “Pavement_Distress” code provides a summary of the primary distresses recorded at each year on an individual pavement section. The information in this code that was used in the analysis was the information about whether or not D-cracking was observed on the concrete pavements prior to overlay.
- International Roughness Index (IRI)—The “IRI” field stores the average IRI value for the section based on data measured with the automated data collection vans.
- Rut depth—The “Rut_Depth” field stores the average depth (in inches) of wear occurring in the wheel path as measured by the automated data collection vans. Measurements of rut depth are recorded to the nearest 0.01 inch.

Step 5: Identify CRS-based Construction Events

After a collective review of the work history information and CRS data tables, it was decided that construction events used for the analysis were best identified by processing the CRS time-series data for each identified section. The primary reason for this decision was two-fold: 1) the suspected construction events in the CRS data very often did not match up with the CRS construction events included in the work history information, and 2) conversations with IDOT personnel indicated that the entry of work history information was the responsibility of each district and was not fully populated throughout the state. Therefore, the yearly CRS values were processed sequentially (i.e., 1975 CRS value, 1976 CRS value, and so on) to locate significant year-to-year changes in CRS. Any time the CRS value was found to be greater than or equal to 8.8, an overlay was assumed to be applied at that year. CRS jumps of 0.5 points and greater (regardless of whether or not the CRS jumped to or above 8.8) were also identified as significant maintenance construction events, but they were recorded separately so as to not be confused with an overlay event. Finally, there were also a significant number of cases in which a CRS jump greater than 0.5 occurred and the resulting CRS value was greater than or equal to 8.0, but not greater than or equal to 8.8. It was unclear if these recorded events were actually the result of overlays or other maintenance, so they were recorded, but not marked as overlay events but rather as maintenance events.

Another item worth noting is that overlay construction events were not triggered in the cases where CRS was greater than or equal to 8.8 for consecutive years. In fact, a new resurfacing event (CRS >= 8.8) is only triggered when the current year CRS value is greater than 8.8, and the current year minus the start year is greater than 3. For example, if a CRS of 9.0 was observed in 1987 and a CRS of 8.8 was observed in 1990, a new event would **not** be triggered because the current year (1990) minus the start year (1987) equals 3 (i.e., a new event requires current year minus start year to be > 3). This rule was adopted to avoid estimating multiple overlays on a pavement when a newly overlaid pavement was just performing very well (i.e., the CRS staying above 8.8) for the first few years.

The sequential processing of the CRS data for all sections with CRS data resulted in a total of **483,980** estimated construction events associated with the unique sections included in the study. Of these 483,980 estimated events, the break down of the types of triggered events included consists of the following:

- **342,454** estimated overlay events triggered by a CRS value >= 8.8.
- **90,392** events were triggered by a yearly jump in CRS value > 0.5 <u>without</u> the resulting CRS value being >= 8.8.
- **51,134** events were triggered by a yearly jump in CRS value > 0.5, and the resulting CRS value being >= 8.0.

The final part of this data compilation step was to organize all of the useful data associated with these final identified construction events into a single table. The “Construction Events” table contained the following specific types of information associated with each identified CRS-based construction event:

- <u>General section identification data</u>—All general section identification information such as ‘Key_County/Muni’, ‘Key/RouteID’, ‘Direction’, beginning and ending mileposts, and the starting and ending years of available CRS data are stored for each section. Note that these beginning and ending milepost values allow the data in this table to be easily linked to the data in the other time-series data tables.
- <u>Information about the last original construction event identified in the work history table</u>. As part of this process, the construction events identified from the work history tables were processed (backwards in time) to determine the last time the construction event type was identified to be an original construction event (i.e., event type either equals “O” or “S”). The last original construction year and type (O or S) are reported in the ‘Construction Events’ table.
- <u>Information about the last resurfacing events identified in the work history table as occurring before 1975 (i.e., before CRS data were available)</u>. After the last original construction event was located in the work history information, the data were processed moving forward in time to determine how many resurfacing events (i.e., construction event equal to “R”) are identified in the work history data as occurring

before 1975. The number of these events are counted and reported in the table (i.e., they are assumed as real overlays). The year of the last event before 1975 is also recorded in the table.

- Number of years since last original construction event. The number of years since the last original construction event is calculated as the current CRS event start year minus the year of the last original construction event. Note that there are some events that occur before the last original construction event. These can be assumed to be part of the condition history before the last identified original construction event, and can easily be identified because a field indicating the number of years since the last original construction year has a negative value in these cases. If no original construction year was found, a dummy value of '1111' was recorded in the Construction Events table. Any other age-related values impacted by not knowing the actual original construction data are also set to '1111' when the true value would be unknown.
- Information about the last recorded CRS value before an identified construction event. When a new construction event was identified, the last recorded CRS value before the event (and its year) was recorded. The number of years between the current CRS start year and the last recorded CRS value was also calculated (this value was helpful when trying to determine if the last CRS value is really representative of the condition at time of overlay).
- Details of construction events found in the work history information where the year is within 2 years of the CRS event start year. When the CRS data triggered a new construction event, the year of that new event was recorded as the CRS start year. As part of this step, the recorded IDOT work history information was processed to see if there was a recorded work history year that matches the identified CRS start year exactly. If there was an exact year match, that information was recorded as a "Match" in the Construction Events table. During a review of the data, it was observed that although many work history event years were not an exact match, the work history year and predicted overlay construction event year often differed by only 1 or 2 years. Based on this observation, it was assumed that any actual work history information within 2 years of the predicted CRS overlay event would be associated with that event. For all cases where the construction event year was within 2 years of actual work history information, the event year, construction type, and resurfacing thickness (i.e., the 'RESTHICK' field) associated with actual work history event were recorded in the Construction Events table.
- Estimated overlay number since last original construction year. The estimated overlay number since original construction was computed by analyzing the number of resurfacing events since the last construction year. Note that when the original construction year matched that of the current CRS event, the CRS data was assumed to be associated with the original construction event. The overlay number value for these cases was set equal to 0 so it could be filtered out when making final data sets for analysis. Also note that only events where CRS values >= 8.8 were used to signify a new overlay number (i.e., events such as "CRS jump > 0.5" are ignored in this sequence).
- Starting and ending event trigger types. The starting and ending event trigger types are stored for each identified CRS event. The three starting event types are ">= 8.8," "CRS jump > 0.5, but CRS >=8," and "CRS jump > 0.5." One last event type that is used to identify when the data processing has reached 2006 without finding a new triggered event is "None (>2006)." If the CRS data end because the IRIS End Year

(i.e., the last year with recorded CRS data in the CRS tables) is reached before 2006, the event end type is recorded as “None (IRIS End Year).”

- CRS event start year and end year. The CRS end year is the year in which a next construction event is identified. If there is no new triggered event and the data processing is allowed to go to 2006, the end year is set equal to a dummy variable of ‘9999’.
- Time-series CRS values in terms of the construction event age. Each set of construction event CRS time-series data was put in the context of *event* age rather than *pavement* age (pavement age would be determined from time of last original construction date) so that final trends of CRS vs. overlay age could be produced.

Step 6: Compile Time-Series Cumulative ESALs for CRS-Based Overlay Events

Because it is also important to investigate relationships between CRS and cumulative ESALs in this study, annual ESALs needed to be determined for each year over the life of each unique section. To compute ESALs at a given year, the following types of information are required:

- Average annual daily traffic (AADT) (note: AADT and ADT [average daily traffic] values are used interchangeably in the computation of ESALs discussion).
- Annual average daily multiple unit volume (MU).
- Annual average daily single unit volume (SU).
- Facility classification.
- Number of lanes.
- Environmental setting (i.e., Urban or Rural).

Note that all AADT, MU, and SU values represent two-way totals (that is, total traffic traveling in both directions of a roadway facility). Available time-series data for all of these data elements were compiled in step 4 above. The detailed process used to compute time-series ESAL data is outlined below:

1. **Determine AADT values for all years**—Although all of the available AADT data was compiled into a time-series data table in a previous data compilation step, that table contains blanks for those years in which *actual* AADT data were not available. For years with missing data, values were determined by populating blank cells with the most recent recorded value. For example, if AADT was recorded as 500 for 1994 but missing for 1995, the 1995 value would be assumed to be 500 also.
2. **Determine the number of lanes information for all years**—This needed data item was available in the previously created number of lanes time-series data table. Any missing data were assumed to be the same as the last recorded value.
3. **Determine facility class for all years**—Different parts of the ESAL calculations require the “Facility Class” of the section. The known number of lanes and the available AADT information were used with the criteria outlined in the IDOT BDE Manual (p. 54-1(2)) to determine the facility class of each section, for each year (IDOT 2002). The specific criteria used to determine facility class were the following (IDOT 2002):

    a. Class I roads and streets—Roads and streets designed as a facility, or as part of a future facility, with **four or more lanes**, and all one-way streets with structural design traffic greater than 3500 ADT.

b. Class II roads and streets—Roads and streets designed as a **two-lane facility with structural traffic greater than 2000 ADT**, and all one-way streets with structural design traffic less than 3500 ADT.
c. Class III roads and streets—Roads and streets with structural traffic **between 750 ADT and 2000 ADT**.
d. Class IV roads and streets—Roads and streets with structural traffic **less than 750 ADT**.

4. **Determine MU values for all years**—MU values are required at each year to compute ESALs. Similar to the AADT data, actual data was recorded in the previously defined time-series traffic data table, but many years had missing MU data. If the values were missing for a given year, the missing values were either 1) estimated from other available MU values, or 2) estimated from ADT values (on Class III and Class IV facilities only). If at least one MU value was recorded for the section, option "1" was used to populate blank cells with the last recorded value before the missing value. If no MU data were available for the section, option 2 was used to estimate MU as a function of ADT and the "Percent of Total ADT" percentage included in table 6. Note that option 2 is only appropriate for Class III and IV facilities. Note: ESALs could not be computed for sections where MU values could not be determined.

Table 6. Vehicular Classification for Structural Design Traffic
(Class III and Class IV Facilities) (IDOT 2002)

Facility Class	Percent of Total ADT		
	PV	**SU**	**MU**
Class III	88%	7%	5%
Class IV	88%	9%	3%

5. **Determine SU values for all years**—SU values at each year are determined in exactly the same manner as MU values as described above. If the values were missing for a given year, the values were either estimated from 1) other available SU values in the time-series table, or 2) estimated from ADT values (on Class III and Class IV facilities only) and the "Percent of Total ADT" percentages presented in table 6. Note: ESALs could not be computed for sections where SU values could not be determined.
6. **Determine passenger vehicle (PV) values for all years**—The two-way total of number of passenger vehicles at each year is computed for each year as a function of AADT, MU, and SU. Specifically, PV = AADT – MU – SU. Similar to MU and SU, ESALs could not be computed for sections where PV values could not be determined.
7. **Determine the urban/rural information for all years**—These data were available in the previously created environment (urban/rural) time-series data table. Any missing data were populated by assuming that missing values were the same as the last recorded value in the time-series.
8. **Determine design lane distribution factor for all years**—Design lane distribution factors determine the percentage of two-way vehicle counts that are included in the

design lane of the pavement. Design lane distribution factors are determined using table 7 below (figure 54-2B, p. 54-2(3) in the IDOT BDE Manual) and are a function of the total number of lanes in a facility and the urban/rural designation.

Table 7. Design Lane Distribution Factors for Structural Design Traffic (IDOT 2002)

	Rural			Urban		
# of Facility Lanes	**PV**	**SU**	**MU**	**PV**	**SU**	**MU**
2 or 3	50%	50%	50%	50%	50%	50%
4	32%	45%	45%	32%	45%	45%
>=6	20%	40%	40%	8%	37%	37%

9. **Determine the pavement type for all years**—Available surface type code information is reported in the previously compiled surface type time-series data table. Any missing data in that table were populated by assuming that missing values were the same as the last recorded value in the time-series. In the ESAL calculation process, the surface type codes were converted into pavement types of either “Rigid” or “Flexible” since ESALs are computed differently for rigid and flexible pavements. To do this, the surface type codes were interpreted using the following guidelines:

    - No ESALs were computed for surface codes from 000 to 399 as the pavement type was either unpaved or a bituminous surface-treatment with a thickness less than 1 inch.
    - Flexible ESALs were computed for surface type codes of 400 to 599.
    - Rigid ESALs were computed for surface type codes of 600 to 800.
    - Any combination codes were deciphered to determine the surface type making up the majority of the section length.

10. **Compute ESALs at each year**—The computation of ESALs at each year is dependent on the determined pavement type in the last step (i.e., rigid or flexible) and the determined facility class. Because the specific steps differ by pavement type, each of these procedures is discussed separately below.

    Computing Rigid ESALs

    To compute ESALs for rigid pavements, the appropriate equivalency factors are first selected from table 8 based on the section’s facility class. Next, rigid ESALs for each year are computed using the appropriate traffic factor equation from table 9. The traffic factor equations are functions of the recorded facility class, the representative total two-way traffic values at each year (i.e., PV, SU, and MU), and the determined design lane distribution factors (P, S, and M). The output of these equations is the total ESALs for a given year.

Table 8. Equivalency Factors (rigid pavements) (IDOT 2002)

	18-kip ESAL Applications Per Vehicle		
Facility Class	**PV**	**SU**	**MU**
Class I	0.0004	0.394	1.908
Class II	0.0004	0.372	1.554
Class III	0.0004	0.355	1.541
Class IV	0.0004	0.350	1.523

Table 9. Traffic Factor Equations (rigid pavements) (IDOT 2002)

Facility Class	Traffic Factor Equation (ESALs for a given year)	IDOT Eq. Number
Class I	TF = (0.15*P*PV) + (143.81*S*SU)+(696.42*M*MU)	54-4.1
Class II	TF = (0.15*P*PV) + (135.78*S*SU)+(567.21*M*MU)	54-4.2
Class III	TF = (0.15*P*PV) + (129.58*S*SU)+(562.47*M*MU)	54-4.3
Class IV	TF = (0.15*P*PV) + (127.75*S*SU)+(555.90*M*MU)	54-4.4

PV, SU, MU = design traffic expressed as the number of two-way PV, SU, and MU vehicles.

P, S, M = lane distribution factors for PV, SU, and MU, respectively, expressed as decimals.

Computing Flexible ESALs

To compute ESALs for flexible pavements, the appropriate equivalency factors are selected from table 10 based on the section's facility class. Next, flexible ESALs for each year are computed using the appropriate traffic factor equation from table 11. The traffic factor equations are functions of the recorded facility class, the representative total two-way traffic values at each year (i.e., PV, SU, and MU), and the determined design lane distribution factors (P, S, and M). The output of these equations is the total ESALs for a given year.

Table 10. Equivalency Factors (flexible pavements) (IDOT 2002)

	18-kip ESAL Applications Per Vehicle		
Facility Class	**PV**	**SU**	**MU**
Class I	0.0004	0.363	1.322
Class II	0.0004	0.307	1.056
Class III	0.0004	0.299	1.053
Class IV (ADT > 400)	0.0004	0.299	1.053
Class IV (ADT < 400)	0.0004	0.027	0.216

Table 11. Traffic Factor Equations (flexible pavements) (IDOT 2002)

Facility Class	Traffic Factor Equation (ESALs for a given year)	IDOT Eq. Number
Class I	TF = (0.15*P*PV) + (132.50*S*SU)+(482.53*M*MU)	54-5.1
Class II	TF = (0.15*P*PV) + (112.06*S*SU)+(385.44*M*MU)	54-5.2
Class III and Class IV (ADT > 400)	TF = (0.15*P*PV) + (109.14*S*SU)+(384.35*M*MU)	54-5.3
Class IV (ADT < 400)	TF = (0.15*P*PV) + (9.86*S*SU)+(78.84*M*MU)	54-5.4

PV, SU, MU = design traffic expressed as the number of two-way PV, SU, and MU vehicles.

P, S, M = lane distribution factors for PV, SU, and MU, respectively, expressed as decimals.

Note that after all of the processing, there were still sections that did not have enough available data to compute yearly ESALs. Those sections without enough data to compute ESALs were marked as such in the data table. Sections without yearly ESAL data were obviously not able to be included in the final CRS vs. cumulative ESAL data sets used in the analysis.

11. **Compute cumulative ESALs**—The final step of the traffic data compilation step was to compile the yearly ESAL values into cumulative ESAL values. For each section, the computation of cumulative ESALs started at the recognized overlay construction year. Of the **483,980** total construction events identified in the analysis of CRS data, cumulative ESALs were computed for 358,468 sections (74 percent). The final computed cumulative ESAL vs. overlay age data was stored in the Construction Events table, organized in columns associated with overlay age.

Step 7: Compile Final Data Sets for Analysis

The final step of the data compilation process involved querying the “Construction Events” table to produce final data sets for analysis. Up to this point, care was taken to not exclude any overlay events that could potentially be useful to the study. Therefore, the final “Construction Events” table contains the 483,980 identified construction events that were discussed previously. However, the examination and manipulation of the data clearly indicate that not all of those are true overlay events, so those non-applicable events must be removed. In this final data preparation step, the following criteria were applied to remove events believed not to be useful to the study:

- <u>Inclusion of construction events clearly identified as CRS >= 8.8 events</u>—During the data compilation process, the construction events triggered by CRS jumps to values greater than or equal to 8.8 were believed to be actual overlay events. Therefore, only construction events triggered by this criterion are used in the final data set. The application of this criterion reduced the data set to 342,454 records.
- <u>Removal of construction events believed to be original construction events</u>—As indicated in step 5 of the data compilation discussion, the overlay number since original construction was computed. During that process, any construction event that was estimated to be an original construction event and not an overlay event was assigned an overlay number of “0.” In this final data preparation step, all construction events with “0” overlay numbers were removed from the data set. The application of this second criterion reduced the data set to 335,511 records.
- <u>Removal of construction events that have an ending trigger type associated with a CRS jump > 0.5, but the final CRS value is not >= 8.8</u>—Every construction event in the “Construction Event” table has both a CRS event starting trigger type and ending trigger type indicated in the table. For example, if a particular construction event is triggered by a CRS jump above 8.8 in 1984 and ends due to another observed CRS jump above 8.8 in 1994, then the starting and ending trigger types would both be recorded as ‘CRS >= 8.8’ in the “Construction Events” table. Thus, in that example, there is confidence that this was an actual overlay that lasted 10 years before a second overlay was applied in 1994. However, there are cases where the ending trigger event is not due to a CRS jump above 8.8, but rather due to an observed ‘CRS jump > 0.5’, where the resulting CRS value is still below 8.8. As indicated previously, such events are most likely due to some significant maintenance activities rather than an overlay event. Therefore, it was decided to remove these events so as not to confuse the data needed to estimate survival curves for the different data sets. The application of this third criterion reduced the data set to 321,508 records.

After the completion of these final data cleaning steps, an updated “Construction Events” table containing **321,508** records was used as the final data source for the data analysis activities.

CONCLUSION

The data compilation portion of this project represented a very significant effort in this study. The process consisted of the collection and organization of CRS, traffic, distress, and work history information from existing IDOT databases. Because the data were generated from a number of different sources, work had to be conducted to manage sectioning so that all data could be successfully matched up for use as a final analysis data set. While this process was successful in the end, strategies needed to be developed along the way to overcome encountered obstacles. Examples of obstacles that were overcome include the handling of recognized project length changes over time, the estimation of missing traffic data needed for ESAL computation, and the merging of actual work history information with the predicted CRS-based construction events. As a result of this data compilation process, a total of **321,508** estimated overlay events were summarized and queried to produce the final analysis data set.

CHAPTER 4 DATA ANALYSIS

With data summarized from the data compilation task, the analysis was conducted to compare various pavement groups. The intent of the study was to compare the performance of various subgroups of HMA overlays in Illinois. The study focused on two levels of pavement families. The first set of pavement families was used to create the 16 original data sets for the analysis. Initially, the study was focused on comparing the performance of HMA overlays for the following pavement families:

- **Facility type**: Interstate versus non-interstate

  Interstate and non-interstate facilities were separated as each facility type has received "standard" overlay thicknesses during various time periods. Also these facilities receive varying traffic levels that impact performance.

- **Construction year period**: 1975 to 1980 versus 1981 to 1987 versus 1988 to 2000 versus 2001 to 2006

  The construction year periods were selected as they represent various periods of construction practice in the state. In the early 1980s, IDOT began the use of policy overlays instead of designing structural overlays and, in 1988, a change was made in the in the policy overlay thickness. By 2001, all overlays were being constructed with SUPERPAVE mixtures. Each of these major changes in construction practices led to the creation of the construction year periods noted.

- **Underlying pavement type**: Flexible versus rigid

  The underlying pavement type of an overlay has a significant effect on the overall performance of an overlay. Therefore, pavements with underlying flexible and rigid pavements were divided into separate subgroups.

The pavement family combinations of facility type, construction year period, and underlying pavement type resulted in the creation of 16 data sets. Each pavement family represents portions of the pavement network that are expected to perform in a similar manner.

These pavement families represent the major category of pavement types in the analysis. Nevertheless, there was a need to evaluate additional characteristics as defined by as part of this study. Therefore, the following pavement family subsets were created for each of the 16 data sets:

- **Location**: North versus South

  The location of each pavement family can have an effect on the overall overlay performance. Overlays in Districts 1 through 4 are considered part of the North subset while those in Districts 5 through 9 are considered part of the South subset.

- **Condition before overlay placement in terms of CRS range**: 9 to 7.6 versus 7.5 to 6.1 versus 6.0 to 4.6 versus 4.5 to 1.0

  The condition before an overlay is placed can affect the future performance of the new overlay. Therefore, four subsets of pavement performance *(excellent, satisfactory, fair, and poor) were created so the effect of CRS before overlay placement can be assessed.*

- **Presence of D-cracking on rigid pavement sections before overlay**: D-cracking versus no D-cracking

  For rigid pavement sections, the presence of D-cracking can affect the life of an HMA overlay placed on top. Therefore D-cracked and non D-cracked pavement subsets were created for comparison.

- **Underlying concrete type**: JPCP versus JRCP versus CRCP

  For rigid pavement sections, the underlying concrete type can affect the life of an HMA overlay. Therefore JPCP, JRCP, and CRCP pavement subsets were created for comparison.

- **Estimated overlay number**: Overlay number 1 versus overlay number 2 versus overlay number 3 versus overlay number greater than 3

  The performance of an overlay can depend upon the number of overlays placed on the pavement section prior to its placement. Therefore, the overlay number or the generation of the overlay is compared.

- **Overlay type**: SMART versus 3P

  The SMART overlay is defined as an 1.5-in overlay. If constructed prior to 1988, the 3P overlays were greater than 2.0 inches on non-Interstate and 3.0 inches on Interstates. If constructed since 1988, the overlay thickness is greater than 2.25 inches on non-interstates and 3.25 on Interstates. The difference in these overlay thicknesses made it critical to create these pavement family subsets.

In combination with the 16 original pavement families, these additional subsets resulted in a total of 182 pavement families. With the specific subsets developed, an additional 72 datasets were created for further analysis, which resulted in a total 254 analysis datasets. The subsets were created to provide more general datasets that incorporated the full range of overlay construction periods (1975 to 2006). The first 40 of the datasets (183 to 222) allowed for larger data sets to be examined for each of the analysis characteristics (location, overlay type, condition before overlay, presence of D-cracking, estimated overly number, and underlying concrete type). The remaining 32 of the datasets provided datasets for the detailed analysis of the service lives of pavement families that have received a specific generation SMART or 3P overlay.

PAVEMENT FAMILIES

A summary of the attributes of each pavement family data set is provided in table 12. The table also includes a summary of the number of data records associated with each dataset.

Table 12. Pavement Family Summary

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 1	29	Interstate	Flexible	>=1975 and <=1980										
Data Set 2	102	Interstate	Flexible	>=1981 and <=1987										
Data Set 3	415	Interstate	Flexible	>=1988 and <=2000										
Data Set 4	624	Interstate	Flexible	>=2001 and <=2006										
Data Set 5	2,596	Interstate	Rigid	>=1975 and <=1980										
Data Set 6	9,294	Interstate	Rigid	>=1981 and <=1987										
Data Set 7	22,311	Interstate	Rigid	>=1988 and <=2000										
Data Set 8	8,826	Interstate	Rigid	>=2001 and <=2006										
Data Set 9	474	Non-Interstate	Flexible	>=1975 and <=1980										
Data Set 10	2,230	Non-Interstate	Flexible	>=1981 and <=1987										
Data Set 11	9,145	Non-Interstate	Flexible	>=1988 and <=2000										
Data Set 12	4,242	Non-Interstate	Flexible	>=2001 and <=2006										
Data Set 13	38,219	Non-Interstate	Rigid	>=1975 and <=1980										
Data Set 14	52,521	Non-Interstate	Rigid	>=1981 and <=1987										
Data Set 15	118,782	Non-Interstate	Rigid	>=1988 and <=2000										
Data Set 16	50,039	Non-Interstate	Rigid	>=2001 and <=2006										
Data Set 17	8	Interstate	Flexible	>=1975 and <=1980	X									
Data Set 18	84	Interstate	Flexible	>=1981 and <=1987	X									
Data Set 19	98	Interstate	Flexible	>=1988 and <=2000	X									
Data Set 20	163	Interstate	Flexible	>=2001 and <=2006	X									
Data Set 21	2,112	Interstate	Rigid	>=1975 and <=1980	X									
Data Set 22	4,791	Interstate	Rigid	>=1981 and <=1987	X									
Data Set 23	10,369	Interstate	Rigid	>=1988 and <=2000	X									
Data Set 24	3,594	Interstate	Rigid	>=2001 and <=2006	X									
Data Set 25	386	Non-Interstate	Flexible	>=1975 and <=1980	X									
Data Set 26	549	Non-Interstate	Flexible	>=1981 and <=1987	X									
Data Set 27	3,447	Non-Interstate	Flexible	>=1988 and <=2000	X									
Data Set 28	1,236	Non-Interstate	Flexible	>=2001 and <=2006	X									
Data Set 29	17,327	Non-Interstate	Rigid	>=1975 and <=1980	X									
Data Set 30	26,170	Non-Interstate	Rigid	>=1981 and <=1987	X									
Data Set 31	55,893	Non-Interstate	Rigid	>=1988 and <=2000	X									
Data Set 32	22,046	Non-Interstate	Rigid	>=2001 and <=2006	X									

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 33	21	Interstate	Flexible	>=1975 and <=1980		X								
Data Set 34	18	Interstate	Flexible	>=1981 and <=1987		X								
Data Set 35	317	Interstate	Flexible	>=1988 and <=2000		X								
Data Set 36	461	Interstate	Flexible	>=2001 and <=2006		X								
Data Set 37	1,484	Interstate	Rigid	>=1975 and <=1980		X								
Data Set 38	4,503	Interstate	Rigid	>=1981 and <=1987		X								
Data Set 39	11,942	Interstate	Rigid	>=1988 and <=2000		X								
Data Set 40	5,232	Interstate	Rigid	>=2001 and <=2006		X								
Data Set 41	88	Non-Interstate	Flexible	>=1975 and <=1980		X								
Data Set 42	1,681	Non-Interstate	Flexible	>=1981 and <=1987		X								
Data Set 43	5,698	Non-Interstate	Flexible	>=1988 and <=2000		X								
Data Set 44	3,006	Non-Interstate	Flexible	>=2001 and <=2006		X								
Data Set 45	20,892	Non-Interstate	Rigid	>=1975 and <=1980		X								
Data Set 46	26,351	Non-Interstate	Rigid	>=1981 and <=1987		X								
Data Set 47	62,889	Non-Interstate	Rigid	>=1988 and <=2000		X								
Data Set 48	27,993	Non-Interstate	Rigid	>=2001 and <=2006		X								
Data Set 49	0	Interstate	Flexible	>=1975 and <=1980			X							
Data Set 50	0	Interstate	Flexible	>=1981 and <=1987			X							
Data Set 51	22	Interstate	Flexible	>=1988 and <=2000			X							
Data Set 52	18	Interstate	Flexible	>=2001 and <=2006			X							
Data Set 53	0	Interstate	Rigid	>=1975 and <=1980			X							
Data Set 54	0	Interstate	Rigid	>=1981 and <=1987			X							
Data Set 55	944	Interstate	Rigid	>=1988 and <=2000			X							
Data Set 56	536	Interstate	Rigid	>=2001 and <=2006			X							
Data Set 57	0	Non-Interstate	Flexible	>=1975 and <=1980			X							
Data Set 58	0	Non-Interstate	Flexible	>=1981 and <=1987			X							
Data Set 59	1,787	Non-Interstate	Flexible	>=1988 and <=2000			X							
Data Set 60	869	Non-Interstate	Flexible	>=2001 and <=2006			X							
Data Set 61	1	Non-Interstate	Rigid	>=1975 and <=1980			X							
Data Set 62	47	Non-Interstate	Rigid	>=1981 and <=1987			X							
Data Set 63	27,892	Non-Interstate	Rigid	>=1988 and <=2000			X							
Data Set 64	11,656	Non-Interstate	Rigid	>=2001 and <=2006			X							

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 65	0	Interstate	Flexible	>=1975 and <=1980				X						
Data Set 66	0	Interstate	Flexible	>=1981 and <=1987				X						
Data Set 67	122	Interstate	Flexible	>=1988 and <=2000				X						
Data Set 68	0	Interstate	Flexible	>=2001 and <=2006				X						
Data Set 69	0	Interstate	Rigid	>=1975 and <=1980				X						
Data Set 70	199	Interstate	Rigid	>=1981 and <=1987				X						
Data Set 71	7,770	Interstate	Rigid	>=1988 and <=2000				X						
Data Set 72	2,695	Interstate	Rigid	>=2001 and <=2006				X						
Data Set 73	0	Non-Interstate	Flexible	>=1975 and <=1980				X						
Data Set 74	3	Non-Interstate	Flexible	>=1981 and <=1987				X						
Data Set 75	1,279	Non-Interstate	Flexible	>=1988 and <=2000				X						
Data Set 76	1,133	Non-Interstate	Flexible	>=2001 and <=2006				X						
Data Set 77	110	Non-Interstate	Rigid	>=1975 and <=1980				X						
Data Set 78	260	Non-Interstate	Rigid	>=1981 and <=1987				X						
Data Set 79	26,552	Non-Interstate	Rigid	>=1988 and <=2000				X						
Data Set 80	16,893	Non-Interstate	Rigid	>=2001 and <=2006				X						
Data Set 81	0	Interstate	Flexible	>=1975 and <=1980					X					
Data Set 82	17	Interstate	Flexible	>=1981 and <=1987					X					
Data Set 83	0	Interstate	Flexible	>=1988 and <=2000					X					
Data Set 84	15	Interstate	Flexible	>=2001 and <=2006					X					
Data Set 85	82	Interstate	Rigid	>=1975 and <=1980					X					
Data Set 86	285	Interstate	Rigid	>=1981 and <=1987					X					
Data Set 87	1,092	Interstate	Rigid	>=1988 and <=2000					X					
Data Set 88	853	Interstate	Rigid	>=2001 and <=2006					X					
Data Set 89	5	Non-Interstate	Flexible	>=1975 and <=1980					X					
Data Set 90	31	Non-Interstate	Flexible	>=1981 and <=1987					X					
Data Set 91	612	Non-Interstate	Flexible	>=1988 and <=2000					X					
Data Set 92	167	Non-Interstate	Flexible	>=2001 and <=2006					X					
Data Set 93	524	Non-Interstate	Rigid	>=1975 and <=1980					X					
Data Set 94	1,494	Non-Interstate	Rigid	>=1981 and <=1987					X					
Data Set 95	3,609	Non-Interstate	Rigid	>=1988 and <=2000					X					
Data Set 96	1,777	Non-Interstate	Rigid	>=2001 and <=2006					X					

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 97	0	Interstate	Flexible	>=1975 and <=1980						X				
Data Set 98	0	Interstate	Flexible	>=1981 and <=1987						X				
Data Set 99	96	Interstate	Flexible	>=1988 and <=2000						X				
Data Set 100	28	Interstate	Flexible	>=2001 and <=2006						X				
Data Set 101	437	Interstate	Rigid	>=1975 and <=1980						X				
Data Set 102	1,206	Interstate	Rigid	>=1981 and <=1987						X				
Data Set 103	4,949	Interstate	Rigid	>=1988 and <=2000						X				
Data Set 104	1,827	Interstate	Rigid	>=2001 and <=2006						X				
Data Set 105	11	Non-Interstate	Flexible	>=1975 and <=1980						X				
Data Set 106	103	Non-Interstate	Flexible	>=1981 and <=1987						X				
Data Set 107	782	Non-Interstate	Flexible	>=1988 and <=2000						X				
Data Set 108	473	Non-Interstate	Flexible	>=2001 and <=2006						X				
Data Set 109	900	Non-Interstate	Rigid	>=1975 and <=1980						X				
Data Set 110	2,741	Non-Interstate	Rigid	>=1981 and <=1987						X				
Data Set 111	8,026	Non-Interstate	Rigid	>=1988 and <=2000						X				
Data Set 112	5,115	Non-Interstate	Rigid	>=2001 and <=2006						X				
Data Set 113	0	Interstate	Flexible	>=1975 and <=1980							X			
Data Set 114	54	Interstate	Flexible	>=1981 and <=1987							X			
Data Set 115	157	Interstate	Flexible	>=1988 and <=2000							X			
Data Set 116	559	Interstate	Flexible	>=2001 and <=2006							X			
Data Set 117	318	Interstate	Rigid	>=1975 and <=1980							X			
Data Set 118	4,765	Interstate	Rigid	>=1981 and <=1987							X			
Data Set 119	13,734	Interstate	Rigid	>=1988 and <=2000							X			
Data Set 120	6,000	Interstate	Rigid	>=2001 and <=2006							X			
Data Set 121	12	Non-Interstate	Flexible	>=1975 and <=1980							X			
Data Set 122	1030	Non-Interstate	Flexible	>=1981 and <=1987							X			
Data Set 123	3713	Non-Interstate	Flexible	>=1988 and <=2000							X			
Data Set 124	1742	Non-Interstate	Flexible	>=2001 and <=2006							X			
Data Set 125	4449	Non-Interstate	Rigid	>=1975 and <=1980							X			
Data Set 126	21992	Non-Interstate	Rigid	>=1981 and <=1987							X			
Data Set 127	61908	Non-Interstate	Rigid	>=1988 and <=2000							X			
Data Set 128	28303	Non-Interstate	Rigid	>=2001 and <=2006							X			

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 129	4	Interstate	Flexible	>=1975 and <=1980								X		
Data Set 130	25	Interstate	Flexible	>=1981 and <=1987								X		
Data Set 131	38	Interstate	Flexible	>=1988 and <=2000								X		
Data Set 132	5	Interstate	Flexible	>=2001 and <=2006								X		
Data Set 133	319	Interstate	Rigid	>=1975 and <=1980								X		
Data Set 134	1612	Interstate	Rigid	>=1981 and <=1987								X		
Data Set 135	1434	Interstate	Rigid	>=1988 and <=2000								X		
Data Set 136	125	Interstate	Rigid	>=2001 and <=2006								X		
Data Set 137	81	Non-Interstate	Flexible	>=1975 and <=1980								X		
Data Set 138	613	Non-Interstate	Flexible	>=1981 and <=1987								X		
Data Set 139	1764	Non-Interstate	Flexible	>=1988 and <=2000								X		
Data Set 140	846	Non-Interstate	Flexible	>=2001 and <=2006								X		
Data Set 141	9004	Non-Interstate	Rigid	>=1975 and <=1980								X		
Data Set 142	22439	Non-Interstate	Rigid	>=1981 and <=1987								X		
Data Set 143	29608	Non-Interstate	Rigid	>=1988 and <=2000								X		
Data Set 144	10194	Non-Interstate	Rigid	>=2001 and <=2006								X		
Data Set 145	0	Interstate	Rigid	>=1975 and <=1980									X	
Data Set 146	0	Interstate	Rigid	>=1981 and <=1987									X	
Data Set 147	2116	Interstate	Rigid	>=1988 and <=2000									X	
Data Set 148	2327	Interstate	Rigid	>=2001 and <=2006									X	
Data Set 149	0	Non-Interstate	Rigid	>=1975 and <=1980									X	
Data Set 150	0	Non-Interstate	Rigid	>=1981 and <=1987									X	
Data Set 151	1832	Non-Interstate	Rigid	>=1988 and <=2000									X	
Data Set 152	1463	Non-Interstate	Rigid	>=2001 and <=2006									X	
Data Set 153	2596	Interstate	Rigid	>=1975 and <=1980										X
Data Set 154	9294	Interstate	Rigid	>=1981 and <=1987										X
Data Set 155	20195	Interstate	Rigid	>=1988 and <=2000										X
Data Set 156	6499	Interstate	Rigid	>=2001 and <=2006										X
Data Set 157	38219	Non-Interstate	Rigid	>=1975 and <=1980										X
Data Set 158	52521	Non-Interstate	Rigid	>=1981 and <=1987										X
Data Set 159	116950	Non-Interstate	Rigid	>=1988 and <=2000										X
Data Set 160	48576	Non-Interstate	Rigid	>=2001 and <=2006										X

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs.	Pavement Type (Flexible vs.	Overlay Construction Period	Estimated Overlay Number				Underlying Concrete Type		
					1	2	3	>3	JPCP	JRCP	CRCP
Data Set 161	677	Interstate	Flexible	>=1975 and <=2006	X						
Data Set 162	309	Interstate	Flexible	>=1975 and <=2006		X					
Data Set 163	97	Interstate	Flexible	>=1975 and <=2006			X				
Data Set 164	87	Interstate	Flexible	>=1975 and <=2006				X			
Data Set 165	23,886	Interstate	Rigid	>=1975 and <=2006	X						
Data Set 166	13,845	Interstate	Rigid	>=1975 and <=2006		X					
Data Set 167	3,393	Interstate	Rigid	>=1975 and <=2006			X				
Data Set 168	1,903	Interstate	Rigid	>=1975 and <=2006				X			
Data Set 169	7,091	Non-Interstate	Flexible	>=1975 and <=2006	X						
Data Set 170	4,855	Non-Interstate	Flexible	>=1975 and <=2006		X					
Data Set 171	1,302	Non-Interstate	Flexible	>=1975 and <=2006			X				
Data Set 172	2,843	Non-Interstate	Flexible	>=1975 and <=2006				X			
Data Set 173	112,960	Non-Interstate	Rigid	>=1975 and <=2006	X						
Data Set 174	73,066	Non-Interstate	Rigid	>=1975 and <=2006		X					
Data Set 175	23,755	Non-Interstate	Rigid	>=1975 and <=2006			X				
Data Set 176	49,780	Non-Interstate	Rigid	>=1975 and <=2006				X			
Data Set 177	711	Interstate	Rigid	>=1975 and <=2006					X		
Data Set 178	5,427	Interstate	Rigid	>=1975 and <=2006						X	
Data Set 179	13,340	Interstate	Rigid	>=1975 and <=2006							X
Data Set 180	158,932	Non-Interstate	Rigid	>=1975 and <=2006					X		
Data Set 181	40,188	Non-Interstate	Rigid	>=1975 and <=2006						X	
Data Set 182	2,643	Non-Interstate	Rigid	>=1975 and <=2006							X

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Location		Overlay Type		Condition Before Overlay				Presence of D-Cracking	
					North	South	SMART	3P	Good	Satisfactory	Fair	Poor	D-crack	No D-crack
Data Set 183	1,170	Interstate	Flexible	>=1975 and <=2006										
Data Set 184	43,027	Interstate	Rigid	>=1975 and <=2006										
Data Set 185	16,091	Non-Interstate	Flexible	>=1975 and <=2006										
Data Set 186	259,561	Non-Interstate	Rigid	>=1975 and <=2006										
Data Set 187	353	Interstate	Flexible	>=1975 and <=2006	X									
Data Set 188	19,866	Interstate	Rigid	>=1975 and <=2006	X									
Data Set 189	5,618	Non-Interstate	Flexible	>=1975 and <=2006	X									
Data Set 190	121,436	Non-Interstate	Rigid	>=1975 and <=2006	X									
Data Set 191	817	Interstate	Flexible	>=1975 and <=2006		X								
Data Set 192	23,161	Interstate	Rigid	>=1975 and <=2006		X								
Data Set 193	10,473	Non-Interstate	Flexible	>=1975 and <=2006		X								
Data Set 194	138,125	Non-Interstate	Rigid	>=1975 and <=2006		X								
Data Set 195	40	Interstate	Flexible	>=1975 and <=2006			X							
Data Set 196	1,480	Interstate	Rigid	>=1975 and <=2006			X							
Data Set 197	2,656	Non-Interstate	Flexible	>=1975 and <=2006			X							
Data Set 198	39,596	Non-Interstate	Rigid	>=1975 and <=2006			X							
Data Set 199	122	Interstate	Flexible	>=1975 and <=2006				X						
Data Set 200	10,513	Interstate	Rigid	>=1975 and <=2006				X						
Data Set 201	2,412	Non-Interstate	Flexible	>=1975 and <=2006				X						
Data Set 202	43,811	Non-Interstate	Rigid	>=1975 and <=2006				X						
Data Set 203	32	Interstate	Flexible	>=1975 and <=2006					X					
Data Set 204	2,312	Interstate	Rigid	>=1975 and <=2006					X					
Data Set 205	815	Non-Interstate	Flexible	>=1975 and <=2006					X					
Data Set 206	7,404	Non-Interstate	Rigid	>=1975 and <=2006					X					
Data Set 207	124	Interstate	Flexible	>=1975 and <=2006						X				
Data Set 208	8,419	Interstate	Rigid	>=1975 and <=2006						X				
Data Set 209	1,369	Non-Interstate	Flexible	>=1975 and <=2006						X				
Data Set 210	16,782	Non-Interstate	Rigid	>=1975 and <=2006						X				
Data Set 211	770	Interstate	Flexible	>=1975 and <=2006							X			
Data Set 212	24,817	Interstate	Rigid	>=1975 and <=2006							X			
Data Set 213	6,497	Non-Interstate	Flexible	>=1975 and <=2006							X			
Data Set 214	116,652	Non-Interstate	Rigid	>=1975 and <=2006							X			
Data Set 215	72	Interstate	Flexible	>=1975 and <=2006								X		
Data Set 216	3,490	Interstate	Rigid	>=1975 and <=2006								X		
Data Set 217	3,304	Non-Interstate	Flexible	>=1975 and <=2006								X		
Data Set 218	71,245	Non-Interstate	Rigid	>=1975 and <=2006								X		
Data Set 219	4,443	Interstate	Rigid	>=1975 and <=2006									X	
Data Set 220	3,295	Non-Interstate	Rigid	>=1975 and <=2006									X	
Data Set 221	38,584	Interstate	Rigid	>=1975 and <=2006										X
Data Set 222	256,266	Non-Interstate	Rigid	>=1975 and <=2006										X

Table 12. Pavement Family Summary (continued)

Pavement Family	Number of Records	Facility Type (Interstate vs. Non-Interstate)	Pavement Type (Flexible vs. Rigid)	Overlay Construction Period	Estimated Overlay Number				Overlay Type	
					1	2	3	>3	SMART	3P
Data Set 223	22	Interstate	Flexible	>=1975 and <=2006	X				X	
Data Set 224	89	Interstate	Flexible	>=1975 and <=2006	X					X
Data Set 225	0	Interstate	Flexible	>=1975 and <=2006		X			X	
Data Set 226	23	Interstate	Flexible	>=1975 and <=2006		X				X
Data Set 227	18	Interstate	Flexible	>=1975 and <=2006			X		X	
Data Set 228	10	Interstate	Flexible	>=1975 and <=2006			X			X
Data Set 229	0	Interstate	Flexible	>=1975 and <=2006				X	X	
Data Set 230	0	Interstate	Flexible	>=1975 and <=2006				X		X
Data Set 231	701	Interstate	Rigid	>=1975 and <=2006	X				X	
Data Set 232	3,743	Interstate	Rigid	>=1975 and <=2006	X					X
Data Set 233	555	Interstate	Rigid	>=1975 and <=2006		X			X	
Data Set 234	4,898	Interstate	Rigid	>=1975 and <=2006		X				X
Data Set 235	199	Interstate	Rigid	>=1975 and <=2006			X		X	
Data Set 236	1,046	Interstate	Rigid	>=1975 and <=2006			X			X
Data Set 237	25	Interstate	Rigid	>=1975 and <=2006				X	X	
Data Set 238	826	Interstate	Rigid	>=1975 and <=2006				X		X
Data Set 239	838	Non-Interstate	Flexible	>=1975 and <=2006	X				X	
Data Set 240	1,006	Non-Interstate	Flexible	>=1975 and <=2006	X					X
Data Set 241	1,207	Non-Interstate	Flexible	>=1975 and <=2006		X			X	
Data Set 242	925	Non-Interstate	Flexible	>=1975 and <=2006		X				X
Data Set 243	209	Non-Interstate	Flexible	>=1975 and <=2006			X		X	
Data Set 244	264	Non-Interstate	Flexible	>=1975 and <=2006			X			X
Data Set 245	402	Non-Interstate	Flexible	>=1975 and <=2006				X	X	
Data Set 246	217	Non-Interstate	Flexible	>=1975 and <=2006				X		X
Data Set 247	13,328	Non-Interstate	Rigid	>=1975 and <=2006	X				X	
Data Set 248	17,434	Non-Interstate	Rigid	>=1975 and <=2006	X					X
Data Set 249	16,865	Non-Interstate	Rigid	>=1975 and <=2006		X			X	
Data Set 250	17,607	Non-Interstate	Rigid	>=1975 and <=2006		X				X
Data Set 251	5,064	Non-Interstate	Rigid	>=1975 and <=2006			X		X	
Data Set 252	6,124	Non-Interstate	Rigid	>=1975 and <=2006			X			X
Data Set 253	4,339	Non-Interstate	Rigid	>=1975 and <=2006				X	X	
Data Set 254	2,646	Non-Interstate	Rigid	>=1975 and <=2006				X		X

In table 12, the number of records corresponds to the total number of recorded CRS conditions for pavement sections in that family. The number of records does not directly correlate with the number of pavement sections as each pavement section may have many records associated with it. Therefore, pavement families with less than 100 records are very scarcely populated and results from those sets should be considered cautiously. In addition to those that are scarcely populated, there are 23 of the 254 pavement families that had no data to populate the data set and, hence, could not be analyzed. Those data sets that could not be analyzed include:

- **Dataset 49**: Interstate, underlying flexible pavement with SMART overlays constructed from 1975 to 1980.
- **Dataset 50**: Interstate, underlying flexible pavement with SMART overlays constructed from 1981 to 1987.
- **Dataset 53**: Interstate, underlying rigid pavement with SMART overlays constructed from 1975 to 1980.
- **Dataset 54**: Interstate, underlying rigid pavement with SMART overlays constructed from 1981 to 1987.
- **Dataset 57**: Non-Interstate, underlying flexible pavement with SMART overlays constructed from 1975 to 1980.
- **Dataset 58**: Non-Interstate, underlying flexible pavement with SMART overlays constructed from 1981 to 1988.
- **Dataset 65**: Interstate, underlying flexible pavement with 3P overlay constructed from 1975 to 1980.
- **Dataset 66**: Interstate, underlying flexible pavement with 3P overlay constructed from 1981 to 1987.
- **Dataset 68**: Interstate, underlying flexible pavement with 3P overlay constructed from 2001 to 2006.
- **Dataset 69**: Interstate, underlying rigid pavement with 3P overlay constructed from 1975 to 1980.
- **Dataset 73**: Non-Interstate, underlying flexible pavement with 3P overlay constructed from 1975 to 1980.
- **Dataset 81**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 1980 on pavements with a CRS condition between 9.0 and 7.6.
- **Dataset 83**: Interstate, underlying flexible pavement with overlay constructed from 1988 to 2000 on pavements with a CRS condition between 9.0 and 7.6.
- **Dataset 97**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 1980 on pavements with a CRS condition between 7.5 and 6.1.
- **Dataset 98**: Interstate, underlying flexible pavement with overlay constructed from 1981 to 1987 on pavements with a CRS condition between 7.5 and 6.1.
- **Dataset 113**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 1980 on pavements with a CRS condition between 6.0 and 4.6.
- **Dataset 145**: Interstate, underlying rigid pavement with overlay constructed from 1975 to 1980 on pavements with D-cracking present.
- **Dataset 146**: Interstate, underlying rigid pavement with overlay constructed from 1981 to 1987 on pavements with D-cracking present.
- **Dataset 149**: Non-Interstate, underlying rigid pavement with overlay constructed from 1975 to 1980 on pavements with D-cracking present.

- **Dataset 150**: Non-Interstate, underlying rigid pavement with overlay constructed from 1981 to 1987 on pavements with D-cracking present.
- **Dataset 225**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 2006 on second generation SMART overlay.
- **Dataset 229**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 2006 on greater than third generation SMART overlay.
- **Dataset 230**: Interstate, underlying flexible pavement with overlay constructed from 1975 to 2006 on greater than third generation 3P overlay.

In most cases, the datasets that were unable to be populated are logical. For example, SMART overlays were not used on pavements in Illinois until 1986 so data sets for this overlay type could not be populated prior to that date.

The 231 datasets that had data populated were analyzed to provide a comparison of the various characteristics noted. The details of the data analysis methods are described in the next section.

DATA ANALYSIS METHODS

Three methods for analysis were utilized to assess the service life associated with the various HMA overlay pavement families. The first method involves the use of a survival analysis to determine when the age and/or traffic level of the pavement sections reach a 50 percent survival rate. This approach is viable as long as a sufficiently large number of pavement sections are included in each of the pavement subgroups and that a significant number of pavement sections have reached the failure criteria. In some cases, however, the available data sets were not large enough or had not achieved significant enough failure rates to populate the survival curve. Therefore, the other two analysis methods—namely the regression analysis and the CRS slope analysis—were used to determine a time to reach the backlog condition state. The details and results of each of these analysis methods are described in the following sections.

Survival Analysis

A survival analysis provides a statistical representation of the life expectancy of the tested item or subject. The life expectancy is determined from an examination of the distribution of lives and is based upon the use of a mean life or a 50 percent probability of failure. To conduct a survival analysis, a sufficient number of pavement sections must reach the failure criteria in order to obtain meaningful results.

For the analysis of the performance of overlays, the time until failure is defined as the time between overlay placements. Over time, IDOT has used overlays as a rehabilitation method when pavements have reached an undesirable condition due to distress levels and/or roughness issues. Therefore, it seems appropriate to use the placement of an overlay to signify the end of the life of a pavement section, thereby providing a clear definition of pavement life. The only issue with using the placement of an overlay as a representation of the life of the pavement is that the placement can be affected by the highway program funding levels and priorities. For example, reduced funding levels can result in predicted pavement life expectancies that are inflated because money was not available to immediately address the poor condition of the pavement.

Funding issues aside, the life expectancy of pavement sections is affected by a variety of factors and is often assessed as a function of factors such as age and traffic loading. Age provides a representation of the variety of factors that affect pavement performance including environmental effects, load variables, construction variables, and maintenance considerations. The characterization of traffic loadings into a form such as ESAL applications provides a second way to examine the performance period of pavement sections.

In conducting the survival analysis, the Kaplan-Meier method was used to determine the 50 percent probability of failure for each pavement family based upon age and traffic applications. The Kaplan-Meier method is a statistical method for predicting the probability of failure at any time by studying a set of data with different survival periods, and allows sections of different ages to be compared without bias. For example, if a data set including a pavement that failed at 15 years and a pavement that has only been in place for 5 years are compared, the analysis can proceed without assuming that the newer pavement failed at 5 years or that the newer pavement will survive for a full 15 years. Each data point is simply "censored" at the appropriate time, and any later probabilities are based on the number of pavements that are still within the period of study.

Survival curves were created for each of the 231 pavement families. The majority of the pavement sections had a sufficient number of failed pavement sections in order to use the survival analysis to estimate the life expectancy of the pavement sections. The plotted results from the analysis are provided in Appendix A and are discussed in detail in the Data Analysis section of the report. Example survival curves for dataset 5 (Overlays on interstates with underlying concrete pavement constructed between 1975 and 1980) are provided in figures 4 and 5 based upon age and traffic loadings, respectively. Based upon figures 4 and 5, the 50 percent probability of failure for dataset 5 is at age 15.5 and a traffic loading of approximately 21 million ESALs.

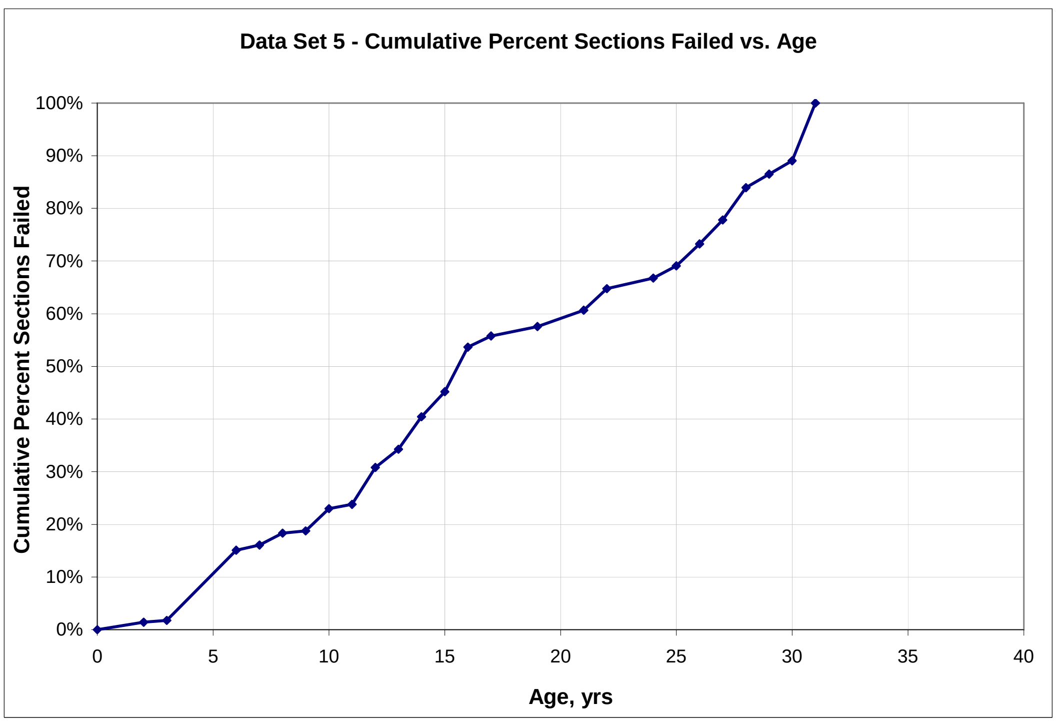

Figure 4. Survival curve based upon age for dataset 5.

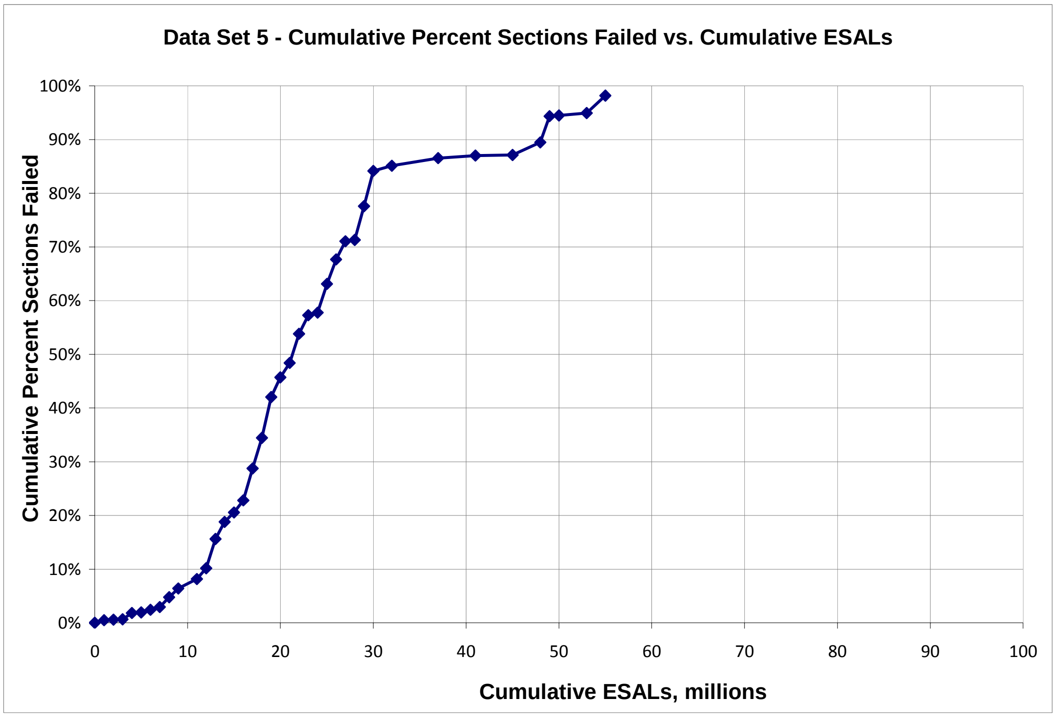

Figure 5. Survival curve based upon traffic loadings for dataset 5.

While a survival analysis provides a general representation of the performance period of a group of pavement sections, there are several factors that are not accounted for when examining the life of a pavement section as a function of the time between overlays. As mentioned previously, the time and ESAL applications between overlays may also be a function of the funding levels available to meet the overlay project needs. When funding levels are insufficient to meet all the needs, the survival life of pavement sections may show an increase in pavement life. Therefore, in addition to examining the survival life of the pavement sections, a regression analysis is used to examine the time and traffic levels associated with meeting a "backlog" and "critical backlog" condition state.

Regression Analysis

Using the 231 pavement families that were created, regression analysis was used to determine a time or traffic level associated with reaching a backlog and critical backlog condition. A pavement in backlog condition is one whose condition has deteriorated to the level where an improvement is recommended now. A regression analysis can be used to represent the average time or traffic level to meet a specific condition state.

The first step in the analysis focused on the development of a linear regression of the all data over all time for each pavement family. Linear least squares regression is a commonly used modeling method. In a linear regression model, the behavior of the independent variable is used to explain the behavior of a dependent variable. The general form of the equation is shown in equation 1.

$$y = b_0 + b_1x_1 \tag{1}$$

where:

y = dependent variable

x_1= independent variables
b_0 and b_1 = coefficients

The linear least squares regression involves estimating coefficients by minimizing the sum of the squared deviations between the observed and predicted values to determine the model with the best fit to the data. The results of the analysis are summarized in Appendix B.

CRS Slope Analysis

In addition to examining linear regression models for the entire data set, the CRS slopes of the pavement sections were examined. A recent study by Heckel and Ouyang (2007) conducted for IDOT showed that the CRS values are best predicted using the analysis of slopes. The CRS slope analysis creates a two-piece slope to describe the behavior of the pavement performance. This was used instead of a single slope as past analysis has shown that there is a discernable difference in the deterioration rates for pavements with high versus low CRS values.

For this analysis, slopes for age and traffic loadings were examined for CRS values above and below the backlog CRS condition level. This examination was completed for each pavement section separately. This analysis was defined as a “within-section slope” analysis. A second slope analysis was examined that defined the slope between each data point for every section in the dataset. This analysis was defined as a “line-to-line section slope” analysis. Example plots of from the “line-to-line section slope” analysis to reach the backlog condition are shown in Figures 6 and 7 for the age and traffic loading plots, respectively. The plots for each data set are provided in Appendix C.

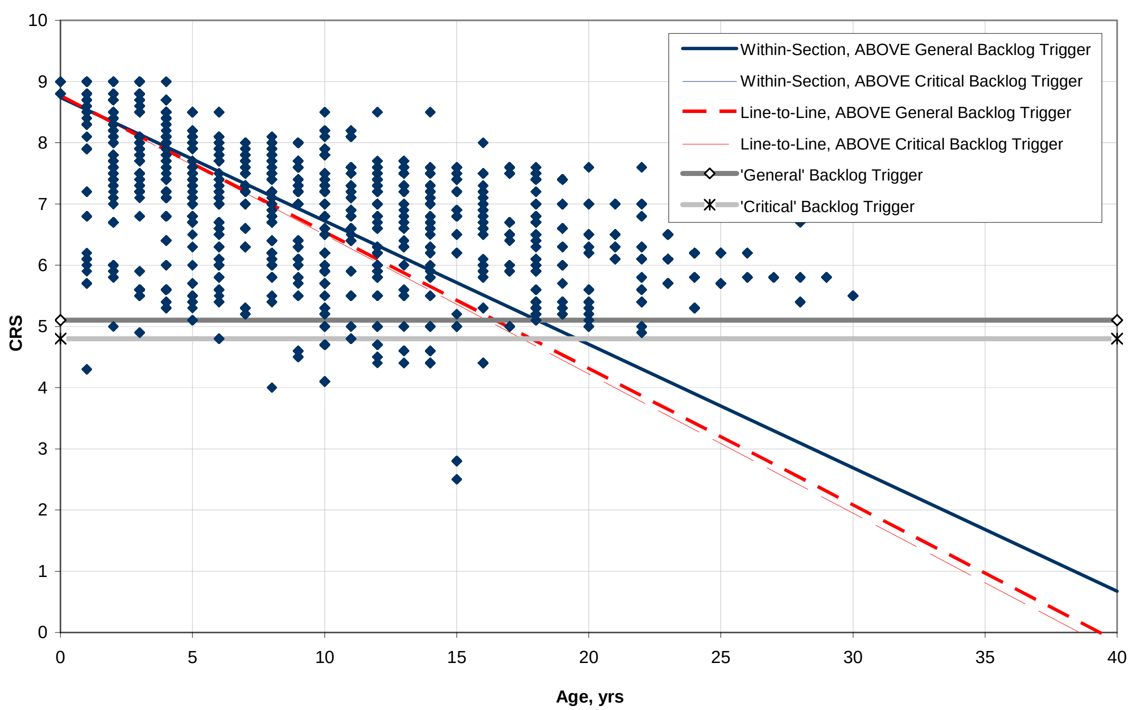

Figure 6. CRS versus age trends using the average predicted values at backlog trigger levels.

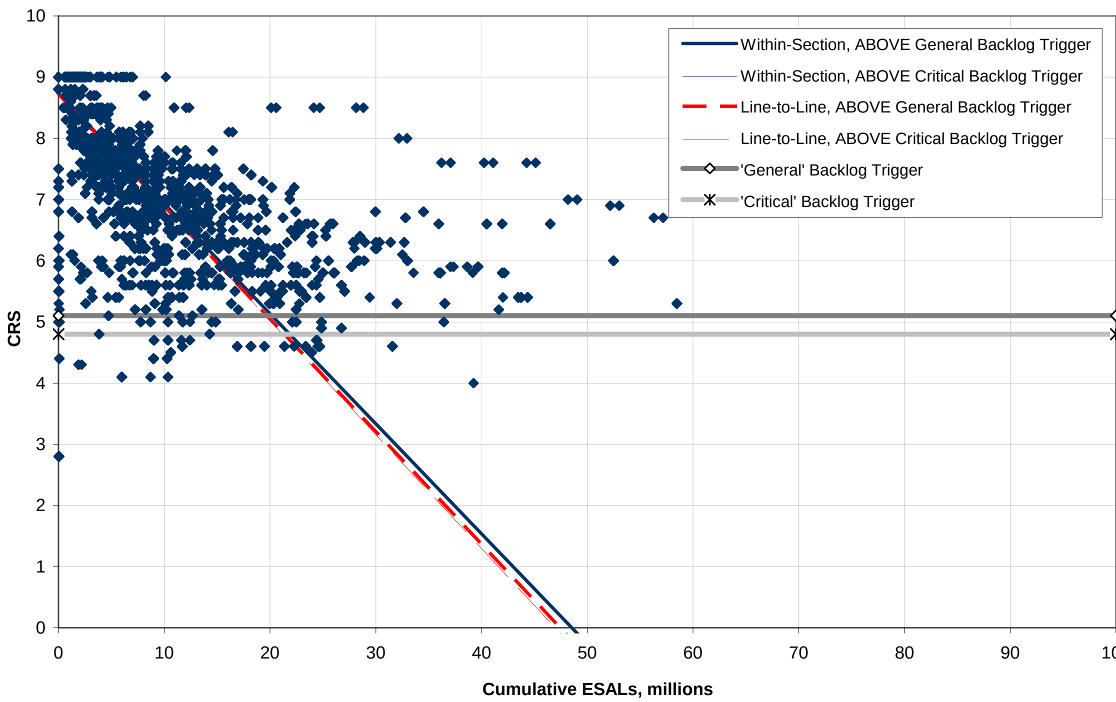

Figure 7. CRS versus cumulative ESALs trends using the average predicted values at backlog trigger levels.

For both analyses, the values of 5.1 and 5.0 were used to describe the typical CRS backlog condition for the interstate and non-interstate pavements, respectively. With backlog CRS values for non-interstate pavements varying based upon attributes such as functional class, ADT, and roadway width, the 5.0 value was used as a representation of the high end of the backlog condition. In addition to using the backlog condition, the piecewise slope analysis was used to analyze the difference between the slope of data above and below the critical backlog condition. The critical backlog condition values used to describe the interstate and non-interstate pavements were 4.8 and 4.5. Again, the 4.5 value for the critical backlog represents the high end of the critical backlog condition. The results of the piecewise CRS slope analysis for the backlog and critical conditions are summarized in Appendix D and E, respectively, for the "within-section slope" analysis. Appendix F and G provide the summaries of the "line-to-line section slope" analysis for the backlog and critical conditions, respectively.

DATA ANALYSIS RESULTS

The data analysis methods resulted in a substantial amount of data for comparison. In this section of the report, the results from the survival and slope analysis are used to examine the performance trends of the HMA overlays. The effects of various attributes are linked to the overall performance of the pavement sections. The following attributes are examined and detailed further in this section.

- Construction year period
- Location
- Condition before overlay placement

- Presence of D-cracking in rigid pavement sections before overlay
- Underlying concrete type
- Estimated overlay number
- Overlay type

The time and traffic loadings associated with the 50 percent probability of failure and time to reach the backlog condition state are used in the following discussions as indicators of the service life of the pavement family and are referred to as such throughout the discussion. Also throughout this discussion, the four main pavement families are referred to extensively:

- Interstate, underlying flexible pavement constructed between 1975 and 2006.
- Interstate, underlying rigid pavement constructed between 1975 and 2006.
- Non-Interstate, underlying flexible pavement constructed between 1975 and 2006.
- Non-Interstate, underlying rigid pavement constructed between 1975 and 2006.

Construction Year Period

A comparison of the construction year period for each of the four combinations of facility type and pavement type (datasets 1 through 16) provides the details needed to assess the contribution of policy changes to the performance of overlays in Illinois. As mentioned before, the construction period from *1975 to 1980* represents the time period when overlays were structurally designed. In the early 1980s, IDOT began the use of policy overlays and, in 1988, an increase was made in the in the policy overlay thicknesses. By 2001, all overlays were being constructed with SUPERPAVE mixtures. Each of these major changes in construction practices led to the creation of the four construction year periods as detailed below:

- 1975 to 1980 – Construction year period when overlays were structurally designed.
- 1981 to 1987 – Construction year period when policy overlays were implemented. The 3P overlays used were 3.0- and 2.0-inches for the interstate and non-interstate systems, respectively.
- 1988 to 2000 – Construction year period when the thickness of the standard policy overlay was increased to 3.25- and 2.25-inches. This was also the approximate time of the introduction of the SMART overlay.
- 2001 to 2006 – Construction year period when IDOT converted to SUPERPAVE. During this time, interstate policy overlay thickness was also increased to 3.75 inches.

The results of the survival and slope analysis for these sections are summarized in table 13 and discussed below.

Interstate, underlying flexible pavement family (Datasets 1 through 4)

Based upon the slope analysis, the slopes associated with the initial construction time period indicate that the introduction of the policy overlay had a negative effect on the time it took for the condition of the pavement family to reach the backlog CRS state. However, this pavement family shows that the increase in policy overlay thicknesses associated with the 1988 to 2000 construction period resulted in an increased life and traffic loadings on interstate pavements with an underlying flexible pavement structure when compared to the standard policy overlay thickness used between 1981 and 1987. This trend was also shown in the slope analysis. The results of the slope analysis also indicate that the time to reach the backlog condition state is longer for the pavement sections constructed between 2001 and 2006 as compared to the sections constructed between 1988 and 2000. This may indicate an increase in service life for the overlays that were constructed using improved construction techniques such as SUPERPAVE mixes.

Table 13. Summary of Analysis of Service Life Results for the Various Overlay Construction Periods

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis		Slope Analysis	
			50% Probability of Failure		Time or traffic loadings to reach backlog condition	
			Age, years	ESALs, millions	Age, years	ESALs, millions
1	Interstate, Flexible	1975 to 1980	N/A	N/A	15.3*	0.2*
2		1981 to 1987	6.0	4.5	6.3	3.1
3		1988 to 2000	10.5	10.2	12.9	11.4
4		2001 to 2006	N/A	N/A	15.5	10.8
5	Interstate, Rigid	1975 to 1980	15.5	21.0	16.5	19.7
6		1981 to 1987	11.5	18.5	12.4	20.8
7		1988 to 2000	13.5	39	14.2	28.3
8		2001 to 2006	N/A	N/A	15.7	33.0
9	Non-Interstate, Flexible	1975 to 1980	14.0	0.27	9.1	0.2
10		1981 to 1987	18.0	0.65	11.7	0.3
11		1988 to 2000	N/A	1.7	16.2	1.3
12		2001 to 2006	N/A	N/A	24.3	1.5
13	Non-Interstate, Rigid	1975 to 1980	16.5	0.85	14.0	0.7
14		1981 to 1987	14.5	0.8	12.4	0.6
15		1988 to 2000	15.5	4.0	14.1	1.7
16		2001 to 2006	N/A	0.6	13.2	1.9

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Interstate, underlying rigid pavement family (Datasets 5 through 8)

The introduction of the policy overlay decreased the overlay life in terms of age and traffic loadings by 25 and 12 percent, respectively, as shown by the survival analysis for this pavement family (i.e., data set 5 to data set 6). The results of the slope analysis also show that the time to reach the backlog condition was reduced with the introduction of the policy overlay. Even though the traffic levels associated with the 1988 to 2000 and 2001 to 2006 data set increased, the pavement sections saw increased service lives. The trends seen for this data set are similar to those seen for datasets 1 through 4 that the introduction of an increased thickness to the policy overlays and the adoption of SUPERPAVE both resulted in increased average service life of the pavement family.

Non-Interstate, underlying rigid pavement family (Datasets 9 through 12)

This data set shows a different trend than the interstate, flexible and interstate, rigid pavement families. For this data set the introduction of the policy overlays increased the life of the pavement sections. It should be noted that the trend for this data set is based upon a very small set of data. This data set does, however, show the same trends of increased service life in terms of age and traffic loadings to reach the backlog condition state with the increase in policy overlay thickness and the use of SUPERPAVE mixes.

Non-Interstate, underlying rigid pavement family (Datasets 13 through 16)

The non-interstate, underlying rigid pavement family is showing the same general trends at the interstate datasets 1 though 8. The use of policy overlays decreased the service life of the pavement sections but an increase in pavement life was observed in the 1988 to 2000 and 2001 and 2006 as compared to the 1981 to 1987 time period.

Location

A comparison of the performance of the overlays based upon location within the State was examined. In the past study by Heckel and Ouyang (2007), it was determined that for asphalt-surfaced pavements, a grouping of Districts 1 through 4 and Districts 5 through 9 was the optimal division of the state to reflect the environmental effects on performance of the north and south portions of Illinois, respectively. Therefore, this division was used to assess the difference in performance of the locations in the state. The results of the analysis of the comparison of HMA overlays in the northern and southern portions of the states are shown in table 14.

Table 14. Summary of Service Life Analysis Results Based upon Pavement Location for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			Age, years		ESALs, millions		Age, years		ESALs, millions	
			North	South	North	South	North	South	North	South
17/33	Interstate, Flexible	1975 to 1980	4*	N/A	0.01*	N/A	19.5*	14.5*	N/A	0.2*
18/34		1981 to 1987	6*	N/A	4.3*	N/A	6.8*	3.4*	3.6*	0.1*
19/35		1988 to 2000	10*	13	5.5*	N/A	11.6*	13.3	5.7*	13.1
20/36		2001 to 2006	N/A	N/A	N/A	N/A	18.1	14.0	22.4	4.8
21/37	Interstate, Rigid	1975 to 1980	13	22	18	23	11.7	20.0	21.1	18.6
22/38		1981 to 1987	11.5	11.5	19	17	11.2	13.7	22.0	19.5
23/39		1988 to 2000	13.5	14	50	24	13.5	14.7	30.5	26.3
24/40		2001 to 2006	N/A	N/A	N/A	N/A	16.5	15.2	32.9	33.1
25/41	Non-Interstate, Flexible	1975 to 1980	14	N/A	0.27	N/A	8.8	10.3*	0.2	0.2*
26/42		1981 to 1987	13	18	0.9	0.7	7.4	12.7	0.9	0.3
27/43		1988 to 2000	15	N/A	1.3	1.7	14.3	17.2	1.2	1.3
28/44		2001 to 2006	N/A	N/A	N/A	N/A	12.7	29.5	1.0	1.6
29/45	Non-Interstate, Rigid	1975 to 1980	15	17	0.75	0.8	10.3	16.9	0.5	0.8
30/46		1981 to 1987	13	17	0.85	0.8	10.3	14.5	0.6	0.6
31/47		1988 to 2000	15	16	6	2.1	13.4	14.7	2.5	1.1
32/48		2001 to 2006	N/A	N/A	0.3	0.75	12.8	13.6	2.6	1.2

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Based on the survival analysis, for those pavement sections with available data, the pavement sections in the southern portion of the state have equal or extended service lives compared to those in the northern portion of the state. The slope analysis included in table 14 shows that approximately 80 percent of the time, the pavement sections in the southern portion of the state have an extended service life according to age but 70 percent of the time they are receiving a reduced application of ESALs at that service life.

A summary analysis (see table 15) that combined the overlay construction periods for the north and south datasets reiterated the fact that the HMA overlays in the south were performing better than those in the north in terms of age of the service life; however, the overlays in the south were not carrying as many loads as those in the north. This trend was shown by all datasets except the interstate, flexible family, which was a much smaller dataset compared to the other pavement families. A comparison of the service life from the slope analysis in Table 15 shows that on average the pavements in the south have service lives that are 20 percent longer but they receive approximately 19 percent less traffic than the pavements in the north.

Table 15. Summary of Service Life Analysis Results Based upon Pavement Location

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			Age, years		ESALs, millions		Age, years		ESALs, millions	
			North	South	North	South	North	South	North	South
187/ 191	Interstate, Flexible	1975 to 2006	10.0	N/A	6.0	N/A	13.6	13.4	12.7	8.5
188/ 192	Interstate, Rigid	1975 to 2006	13.0	13.5	33.0	24.0	13.3	15.0	28.3	25.8
189/ 193	Non-Interstate, Flexible	1975 to 2006	14.0	18.0	1.0	N/A	13.0	19.3	1.0	1.2
190/ 194	Non-Interstate, Rigid	1975 to 2006	14.5	16.5	6.0	1.5	12.2	14.8	2.1	1.0

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Condition Before Overlay Placement

The condition before the placement of the overlay is also a contributing factor to the performance of the overlay after construction. Initially it may be expected that the overlays placed on pavements in excellent condition (9.0 to 7.6) will potentially have lives that are greater than those overlays placed on a pavement section in poor condition (4.5 to 1.0). However, results of the survival and slope analysis as shown in tables 16 and 17 reveal that there is not a consistent behavior predicted service life of the pavements related to the CRS condition before placement. There are several possible reasons for this, one of which is that the CRS may not necessarily reflect the conditions under which a pavement may be a good candidate for an overlay; that is, two existing pavements with the same CRS values may exhibit different distresses and it would be expected that overlays placed on them would perform differently.

Table 16. Summary of Service Life Age Analysis Results Based Upon Condition of Pavement Before Overlay Placement for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis: 50% Probability of Failure; Age, years; CRS before placement: 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0	Slope Analysis: Time to reach backlog condition; Age, years; CRS before placement: 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0
81/97/113/129	Interstate, Flexible	1975 to 1980	-	-	-	2.4*	-	-	-	N/A
82/98/114/130		1981 to 1987	N/A	-	7*	4.0*	3.0*	-	6.6*	7.3*
83/99/115/131		1988 to 2000	-	N/A	7	11*	-	15.2*	13.8	12.0*
84/100/116/132		2001 to 2006	N/A	N/A	N/A	N/A	6.3*	7.8*	16.6	2.6*
85/101/117/133	Interstate, Rigid	1975 to 1980	11*	5	13	13	10.9*	6.0	13.6	13.7
86/102/118/134		1981 to 1987	11	13	9.5	12.5	8.5	12.8	10.2	11.3
87/103/119/135		1988 to 2000	12	14.5	13	10	11.5	18.3	12.8	12.9
88/104/120/136		2001 to 2006	N/A	N/A	N/A	N/A	10.8	15.9	16.7	10.6
89/105/121/137	Non-Interstate, Flexible	1975 to 1980	N/A	N/A	N/A	13.5*	N/A	N/A	3.4*	13.0*
90/106/122/138		1981 to 1987	N/A	13	18	16	12.8*	13.0	12.2	12.0
91/107/123/139		1988 to 2000	13	N/A	N/A	N/A	15.1	15.2	16.1	14.3
92/108/124/140		2001 to 2006	N/A	N/A	N/A	N/A	37.8	35.0	24.0	29.2
93/109/125/141	Non-Interstate, Rigid	1975 to 1980	N/A	18	14	17	19.0	16.7	13.2	13.6
94/110/126/142		1981 to 1987	13.5	14	15	15	13.0	12.6	12.5	12.4
95/111/127/143		1988 to 2000	N/A	15	16	15	15.4	15.5	13.8	13.8
96/112/128/144		2001 to 2006	N/A	N/A	N/A	N/A	12.2	12.0	14.2	11.2

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated
“-“= Data not available

Table 17. Summary of Service Life Traffic Loading Analysis Results Based Upon Condition of Pavement before Overlay Placement for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			ESALs, millions				ESALs, millions			
			CRS before placement:				CRS before placement			
			9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0	9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0
81/97/ 113/129	Interstate, Flexible	1975 to 1980	-	-	-	0.012*	-	-	-	N/A
82/98/ 114/130		1981 to 1987	N/A	-	4*	3.2*	0.01*	-	2.9*	5.4*
83/99/ 115/131		1988 to 2000	-	N/A	10	N/A	-	27.1*	7.4	0.9*
84/100/ 116/132		2001 to 2006	-	N/A	N/A	N/A	-	15.3*	10.5	.001*
85/101/ 117/133	Interstate, Rigid	1975 to 1980	14*	18.5	18	19	16.0*	13.1	20.0	32.3
86/102/ 118/134		1981 to 1987	13	28	17	19	12.9	22.5	16.7	20.9
87/103/ 119/135		1988 to 2000	N/A	22	24	50	31.1	38.0	25.3	24.2
88/104/ 120/136		2001 to 2006	N/A	N/A	N/A	N/A	39.6	32.9	32.4	13.8
89/105/ 121/137	Non-Interstate, Flexible	1975 to 1980	-	N/A	-	0.27*	-	N/A	-	0.3*
90/106/ 122/138		1981 to 1987	N/A	0.3	0.8	0.4	0.4*	0.6	0.4	0.2
91/107/ 123/139		1988 to 2000	N/A	1.4	1.6	N/A	1.2	1.4	1.0	1.2
92/108/ 124/140		2001 to 2006	N/A	N/A	N/A	N/A	3.2	1.9	1.6	1.2
93/109/ 125/141	Non-Interstate, Rigid	1975 to 1980	1	0.8	0.9	0.85	1.1	0.9	0.8	0.6
94/110/ 126/142		1981 to 1987	0.6	0.8	0.9	0.8	0.6	0.9	0.7	0.6
95/111/ 127/143		1988 to 2000	2.5	2.3	2	N/A	2.3	2.2	1.4	1.8
96/112/ 128/144		2001 to 2006	0.4	3.3	N/A	0.7	2.9	1.8	2.3	0.4

* - Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated
“-“= Data not available

A summary analysis that combined the overlay construction periods for each of the CRS condition families that indicate condition before placement also showed an inconsistency in the trends of the service lives of the overlays. On average for each of the datasets highlighted in tables 18 and 19, the performance of the overlays for pavements in poor (4.5 to 1.0) condition had the shortest service life, whereas the service lives of the overlays over pavement in excellent (9.0 to 7.6) and fair (6.0 to 4.6) condition were very close to that of the pavements in poor condition before overlay. Therefore, on average the overlays placed on pavements in satisfactory condition (7.5 to 6.1) had the best performance. Nevertheless, the overall services lives were very similar to one another.

Table 18. Summary of Service Life Age Analysis Results Based Upon Condition of Pavement Before Overlay Placement

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis: 50% Probability of Failure, Age, years, CRS before placement: 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0	Slope Analysis: Time to reach backlog condition, Age, years, CRS before placement 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0
203/207/ 211/215	Interstate, Flexible	1975 to 2006	N/A	N/A	10.0	6.5	4.8*	13.5	14.8	9.9*
204/208/ 212/216	Interstate, Rigid	1975 to 2006	10.5	13.5	12.0	14.0	10.8	16.3	13.1	12.2
205/209/ 213/217	Non-Interstate, Flexible	1975 to 2006	14.0	13.5	18.0	17.0	19.3	20.9	17.2	16.6
206/210/ 214/218	Non-Interstate, Rigid	1975 to 2006	15.5	15.0	16.0	15.5	14.4	14.1	13.6	13.0

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Table 19. Summary of Service Life Traffic Loading Analysis Results Based Upon Condition of Pavement Before Overlay Placement

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis: 50% Probability of Failure, ESALS, millions, CRS before placement: 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0	Slope Analysis: Time to reach backlog condition, ESALS, millions, CRS before placement 9 to 7.6	7.5 to 6.1	6.0 to 4.6	4.5 to 1.0
203/207/ 211/215	Interstate, Flexible	1975 to 2006	N/A	N/A	8.0	3.0	0.003*	24.4	8.9	2.4*
204/208/ 212/216	Interstate, Rigid	1975 to 2006	24.0	27.0	23.0	42.0	31.6	33.4	24.9	23.0
205/209/ 213/217	Non-Interstate, Flexible	1975 to 2006	N/A	N/A	0.9	N/A	1.6	1.5	1.1	0.98
206/210/ 214/218	Non-Interstate, Rigid	1975 to 2006	N/A	N/A	2.2	1.7	2.2	1.9	1.5	1.1

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Presence of D-cracking on Rigid Pavement Sections before Overlay

The presence of D-cracking on a rigid pavement section before overlay placement has a significant effect on the performance of an overlay, as shown by the results in table 20. Where applicable, the comparison of load-carrying capacity for each of the detailed construction periods shows that the pavements without D-cracking can provide up to 30 percent more load carrying capacity than those with D-cracking. The summarized results across all construction time periods is provided in table 21. It should be noted that the data extracted from IRIS and processed for this analysis did not appear to provide a full summary of sections with D-cracking. Therefore, these results should be used with caution.

Table 20. Summary of Service Life Analysis Results Based Upon Presence Of D-Cracking Before Overlay Placement for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			Age, years		ESALs, Million		Age, years		ESALs, Millions	
			D-crack	No D-crack	D-crack	No D-crack	D-crack	No D-crack	D-crack	No D-crack
145/ 153	Interstate, Rigid	1975 to 1980	-	15.5	-	21	-	16.5	-	19.7
146/ 154		1981 to 1987	-	11.5	-	18.5	-	12.4	-	20.8
147/ 155		1988 to 2000	N/A	13.5	N/A	35	18.0	13.8	24.0	28.7
148/ 156		2001 to 2006	N/A	N/A	N/A	8.5	13.3	16.5	24.9	35.7
149/ 157	Non-Interstate, Rigid	1975 to 1980	-	16.5	-	0.8	-	14.0	-	0.7
150/ 158		1981 to 1987	-	15	-	0.8	-	12.4	-	0.6
151/ 159		1988 to 2000	12	15.5	2.4	4.0	14.2	14.1	2.1	1.7
152/ 160		2001 to 2006	N/A	N/A	0.6	0.65	13.0	13.2	1.4	1.9

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated
"-"= Data not available

Table 21. Summary of Service Life Analysis Results Based Upon Presence Of D-Cracking Before Overlay Placement for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			Age, years		ESALs, Million		Age, years		ESALs, Millions	
			D-crack	No D-crack	D-crack	No D-crack	D-crack	No D-crack	D-crack	No D-crack
219/ 221	Interstate, Rigid	1975 to 2006	N/A	13.5	N/A	28.0	15.8	14.0	24.4	27.2
220/ 222	Non-Interstate, Rigid	1975 to 2006	11.5	**	N/A	**	13.9	**	1.9	**

N/A = value was not able to be calculated
** = Dataset too large for analysis with Excel

Past study results by Gharaibeh and Darter (2002) showed more significant reductions in the load-carrying capacity of the interstate pavements as compared to the results of the current study. The reductions in load-carrying capacity ranged from 30 to 50 percent as shown previously in table 1. However, that study also evaluated the performance of the overlays over D-cracked concrete pavements according to overlay thicknesses, which may have allowed a better assessment of the difference in performance due specifically to D-cracking.

Underlying Concrete Type

The performance of the overlays was also reviewed based upon the underlying concrete type. The service life in terms of age and traffic loadings is summarized in table 22, in which slight differences in the results are noted for the survival analysis and slope analysis. When evaluated using the slope analysis, the overlays on underlying CRCP pavements have the longest life for both the interstate and non-interstate pavements, but otherwise the lives and ESALs for each concrete pavement type are similar.

Table 22. Summary of Service Life Analysis Results Based Upon Underlying Concrete Pavement Type Before Overlay Placement

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis			Slope Analysis		
			50% Probability of Failure			Time or traffic loadings to reach backlog condition		
			Age, years			Age, years		
			Underlying concrete type:			Underlying concrete type:		
			JPCP	JRCP	CRCP	JPCP	JRCP	CRCP
177-179	Interstate, Rigid	1975 to 2006	13.5	13.0	12.0	11.8	13.6	13.9
180-182	Non-Interstate, Rigid	1975 to 2006	16.0	14.0	15.5	13.6	12.1	16.3
			ESALs, millions			ESALs, millions		
177-179	Interstate, Rigid	1975 to 2006	31	34	33	24.8	29.2	28.9
180-182	Non-Interstate, Rigid	1975 to 2006	2.4	2	1.3	1.3	1.6	2.7

Estimated Overlay Number

The analysis of the performance of the HMA overlays based upon the estimated of overlay number shows some unexpected performance trends for age and traffic loadings in tables 23 and 24. Specifically, a decrease in service life was expected with each increase in overlay number. However, that trend did not hold true. Instead, the service lives have varied trends for each pavement family. The unexpected varied performance of the pavement families based upon overlay number is likely due to the inclusion of various overlay thicknesses in the analysis of each overlay number type. It is also possible in some cases that the progressive build-up of overlay thicknesses, perhaps in conjunction with milling or repair of distresses areas, may be contributing to increased performance of the third generation or later overlays.

The use of the division of overlay type and overlay number is assessed in the next section to determine if a standard performance can be defined.

Table 23. Summary of Service Life Age Analysis Results Based Upon Estimated Overlay Number

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis			Slope Analysis		
			50% Probability of Failure			Time to reach backlog condition		
			Age, years			Age, years		
			Estimated overlay number:			Estimated overlay number:		
			1	2	3	1	2	3
161-164	Interstate, Flexible	1975 to 2006	11.5	10.5	N/A	12.7	11.3	21.6*
165-168	Interstate, Rigid	1975 to 2006	14	13	17.5	13.5	14.9	17.8
169-172	Non-Interstate, Flexible	1975 to 2006	16	18	16.5	14.8	19.5	22.4
173-176	Non-Interstate, Rigid	1975 to 2006	15	15.5	16.5	14.0	13.3	13.2

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

Table 24. Summary of Service Life Traffic Loading Analysis Results Based Upon Estimated Overlay Number

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis			Slope Analysis		
			50% Probability of Failure			Traffic loadings to reach backlog condition		
			ESALs, millions			ESALs, millions		
			Estimated overlay number:			Estimated overlay number:		
			1	2	3	1	2	3
161-164	Interstate, Flexible	1975 to 2006	6	7.5	N/A	8.1	6.5	31.7*
165-168	Interstate, Rigid	1975 to 2006	25	37	48	21.3	31.9	50.6
169-172	Non-Interstate, Flexible	1975 to 2006	1	1.1	0.5	1.3	1.2	1.2
173-176	Non-Interstate, Rigid	1975 to 2006	2	1.8	1.7	1.9	1.2	1.0

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

The estimated overlay number, as explained in the data compilation section of the report, was determined based upon changes of CRS to 8.8 or greater. During the life of each pavement section there are other jumps in condition caused by activities such as maintenance that are not directly incorporated into the overlay count number. These types of work occurrences may be contributing to the unexpected trends in service life associated with each estimated overlay number family.

Overlay Type

The comparison of performance of the SMART and 3P overlays is summarized in table 25. As depicted in the table, there are many data sets where the thickness data needed to characterize the overlay type were not available to provide details of performance. Nevertheless, for the datasets with data, the trend is consistent with expected performance that the 3P overlays performed better than the SMART overlays in terms of both service life age and loadings.

Table 25. Summary of Service Life Analysis Results Based Upon Overlay Type for Each Construction Period

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis				Slope Analysis			
			50% Probability of Failure				Time or traffic loadings to reach backlog condition			
			Age, years		ESALs, Million		Age, years		ESALs, Millions	
			SMART	3P	SMART	3P	SMART	3P	SMART	3P
49/65	Interstate, Flexible	1975 to 1980	-	-	-	-	-	-	-	-
50/66		1981 to 1987	-	-	-	-	-	-	-	-
51/67		1988 to 2000	12*	N/A	N/A	N/A	8.8*	13.6	0.005*	19.9
52/68		2001 to 2006	N/A	-	N/A	-	7.8*	-	15.3*	-
53/69	Interstate, Rigid	1975 to 1980	-	-	-	-	-	-	-	-
54/70		1981 to 1987	-	5	-	19	-	7.5	-	14.4
55/71		1988 to 2000	11	14	17.5	23	12.2	14.1	15.4	27.7
56/72		2001 to 2006	5	N/A	4.2	N/A	11.6	12.3	15.6	21.2
57/73	Non-Interstate, Flexible	1975 to 1980	-	-	-	-	-	-	-	-
58/74		1981 to 1987	-	8*	-	0.3*	-	17.5*	-	0.6*
59/75		1988 to 2000	N/A	N/A	N/A	N/A	16.6	16.6	0.7	1.3
60/76		2001 to 2006	N/A	N/A	N/A	N/A	11.3	29.4	0.5	2.3
61/77	Non-Interstate, Rigid	1975 to 1980	N/A	13	N/A	0.26	5.8*	10.5	N/A	0.2
62/78		1981 to 1987	N/A	13	N/A	1.0	7.8*	9.4	0.1*	0.6
63/79		1988 to 2000	14.5	N/A	2.1	3.3	13.3	14.4	1.3	1.6
64/80		2001 to 2006	N/A	N/A	N/A	0.6	12.4	13.2	2.1	1.1

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated
"-"= Data not available

The results of a summary analysis that combined the overlay construction periods for the SMART and 3P overlays are shown in table 26. On average, the results of the slope analysis show that the 3P overlays have a 40 percent longer life while carrying nearly twice the traffic as the SMART overlays.

Table 26. Summary of Service Life Analysis Results Based Upon Overlay Type

Data Set	Facility and Pavement Type	Overlay Construction Period	Survival Analysis: 50% Probability of Failure — Age, years — SMART	Survival Analysis: 50% Probability of Failure — Age, years — 3P	Survival Analysis: 50% Probability of Failure — ESALs, millions — SMART	Survival Analysis: 50% Probability of Failure — ESALs, millions — 3P	Slope Analysis: Time or traffic loadings to reach backlog condition — Age, years — SMART	Slope Analysis: Time or traffic loadings to reach backlog condition — Age, years — 3P	Slope Analysis: Time or traffic loadings to reach backlog condition — ESALs, millions — SMART	Slope Analysis: Time or traffic loadings to reach backlog condition — ESALs, millions — 3P
195/ 199	Interstate, Flexible	1975 to 2006	12.0*	N/A	N/A	N/A	8.4*	13.6	8.4*	20.7
196/ 200	Interstate, Rigid	1975 to 2006	10.5	14.0	17.5	N/A	12.0	13.7	15.4	26.2
197/ 201	Non-Interstate, Flexible	1975 to 2006	N/A	16.0	N/A	N/A	15.2	22.3	0.6	1.7
198/ 202	Non-Interstate, Rigid	1975 to 2006	14.0	15.0	N/A	N/A	13.1	14.0	1.5	1.4

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
N/A = Value was not able to be calculated

In addition to the analysis of the performance of the SMART and 3P pavement sections, a slope analysis of the age and traffic loadings associated with reaching a CRS backlog condition state was also conducted. The results of that analysis are provided in tables 27 and 28. The performance trends show that for the SMART overlays the service life decreased as the estimated overlay number increased. Likewise, the traffic loadings decreased with the reached service lives of each subsequent overlay. The trends for the 3P overlays, specifically on the non-interstate flexible pavements, did not show the same trend as the SMART overlays. In fact, the second and third generation 3P overlays were extremely high in comparison to all other predicted overlay performances. A detailed review of the data analysis sets shows that each data set has a significant number of pavement sections that were early in the life of the overlay and were showing CRS changes of 0.1 over the 2-year data collection cycle. The weight of these sections to the average life of the 3P overlay resulted in the inflated service lives shown in table 27. This data also contributed to some elevated time to backlog condition of 29.4 years and 22.3 years from the slope analysis for the 3P non-interstate, flexible pavement sections as shown in tables 25 and 26, respectively.

The results of the service life of the 3P overlays are compared to the results of the study by Schutzbach (1995) in table 29. The summarized average service lives from the current study are based upon an average of all lives from the four main pavement families. Overall, there was an observed increase in the projected service lives for all policy overlay sections associated with the current study as compared to those determined in the 1995 study. It is likely that some of the observed increase in the average service life is again due to the occurrence of a large number of sections with a 0.05 CRS deterioration rate.

Table 27. Summary of Service Life Age Analysis Results Based Upon Overlay Type and Estimated Overlay Number

Data Set	Facility and Pavement Type	Overlay Construction Period	Slope Analysis: Time or traffic loadings to reach backlog condition — Age, years					
			SMART			3P		
			Estimated overlay number:			Estimated overlay number:		
			1	2	3	1	2	3
223/225/227/224/226/ 228	Interstate, Flexible	1975 to 2006	8.8*	-	7.8*	14.1*	12.4*	12.4*
231/233/235/232/234/ 236	Interstate, Rigid	1975 to 2006	12.4	12.5	8.5	13.7	13.8	16.0
239/241/243/240/242/244	Non-Interstate, Flexible	1975 to 2006	14.5	14.2	12.1	14.3	27.1#	36.7#
247/249/251/248/250/ 252	Non-Interstate, Rigid	1975 to 2006	14.6	12.5	11.2	14.1	14.0	14.6

* = Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
"-"= Data not available
\# = Inflated service lives

Table 28. Summary of Service Life Traffic Loading Analysis Results Based Upon Overlay Type and Estimated Overlay Number

Data Set	Facility and Pavement Type	Overlay Construction Period	Slope Analysis: Time or traffic loadings to reach backlog condition — ESALs, millions					
			SMART			3P		
			Estimated overlay number:			Estimated overlay number:		
			1	2	3	1	2	3
223/225/227/224/226/ 228	Interstate, Flexible	1975 to 2006	0.005*	-	15.3*	28.8*	0.9*	1.3*
231/233/235/232/234/ 236	Interstate, Rigid	1975 to 2006	15.0	14.9	14.4	22.0	28.3	35.9
239/241/243/240/242/ 244	Non-Interstate, Flexible	1975 to 2006	1.0	0.4	0.5	1.1	2.5	1.9
247/249/251/248/250/ 252	Non-Interstate, Rigid	1975 to 2006	2.5	1.1	0.8	1.8	1.2	1.2

* - Less than 100 data records; analysis of data for the dataset may be skewed due to small sampling
"-"= Data not available

Table 29. Comparison of Average Service Life of HMA 3P Overlays

Pavement Families	**Average Service Life (years)**	
	IDOT Study (Schutzbach 1995)	**Current Study (Survival Analysis/ Slope Analysis)**
All Policy Overlay Sections (Dataset 199 to 202)	12.2	15.0 / 16.6
Rigid Pavement, First Overlay	13.9	13.5 / 13.9
Flexible Pavement	11.3	16.0 / 18.0

CHAPTER 5 CONCLUSIONS

The purpose of this study was to examine the performance of HMA overlays in Illinois. The service life of the overlays is affected by a variety of factors that were examined in this study. Specifically, the following attributes were examined:

- Construction year period
- Location
- Condition before overlay placement
- Presence of D-cracking on rigid pavement sections before overlay
- Underlying concrete type
- Estimated overlay number
- Overlay type

The analysis of these attributes allowed for a determination of relative services lives for a variety of pavement families. A summary of all of the pavement service lives and associated traffic loadings is provided in the *Data Analysis* portion of the report. The determination of the services lives also allows for some generalities regarding the affect of these attributes on the performance of HMA overlays in Illinois.

IMPACTS OF CONSTRUCTION YEAR PERIOD

The analysis of datasets 1 through 16 allowed for a comparison of the performance of overlays over various construction year periods. Based upon the general service life findings, the majority of the pavement sections showed a reduced service life between the 1975 to 1980 and the 1981 to 1987 time periods. While a number of factors could be contributing to this trend, the initiation in the early 1980s of the use of a standard overlay thickness instead of designing the structural overlay is expected to have contributed to this trend. Although this trend is suspected, the thickness data from IRIS was a field that was not fully populated. Therefore, the average thickness of all the overlays contributing to the performance could not be reviewed to assess this factor. In addition, these pavement sections were seeing an increased number of loadings that could be causing some of the decreased service life.

The comparison of the 1981 to 1987 dataset to the 1988 to 2000 dataset shows an average 42 percent increase in the service life of the overlay along with a more than doubled number of loadings based upon the slope analysis for the four pavement families. This trend indicates a change in policy or construction practice that caused a substantial improvement in the long term performance of the pavement sections. A contributing factor to this may have been the incorporation of increased thicknesses for the policy overlays. However, this substantial change in condition is also likely to be caused by a combination of several factors.

In 2001, all HMA overlays constructed in the state were constructed using SUPERPAVE mix designs. The overlays constructed from 2001 to 2006 showed an average service life increase of 19 percent as compared to the overlays constructed between 1988 and 2000 when examining the four main pavement families. This increase in service life may be associated with the improved construction method occurring during this time period. Graphical representations of these trends for the slope and survival analysis are provided in Figures 8 through 11.

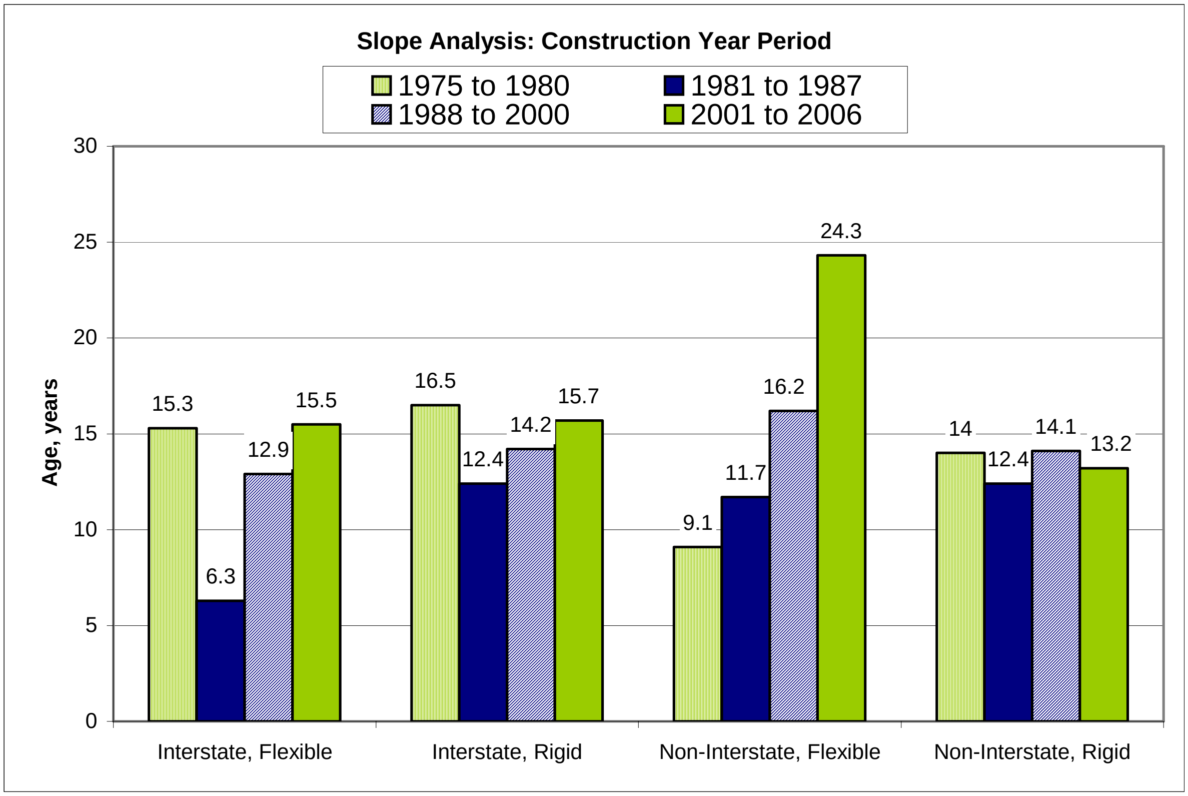

Figure 8. Slope analysis of service life age based upon construction year period.

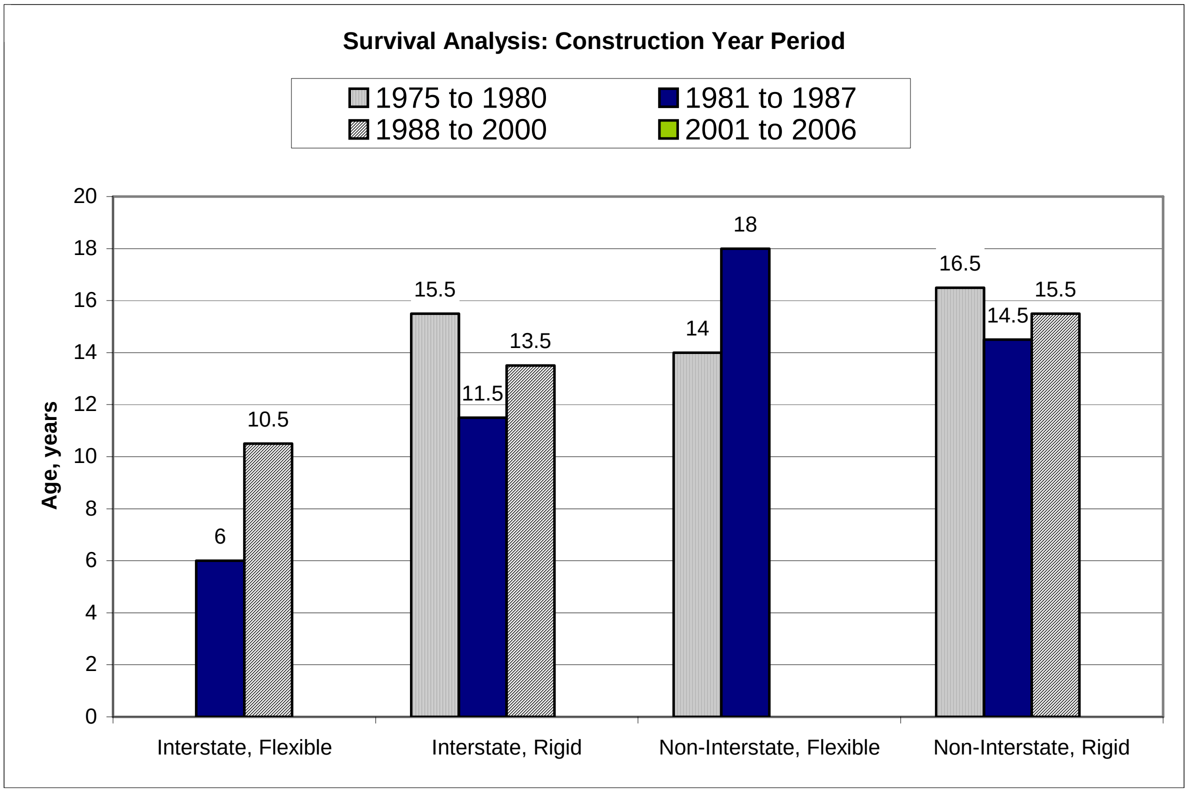

Figure 9. Survival analysis of service life age based upon construction year period.

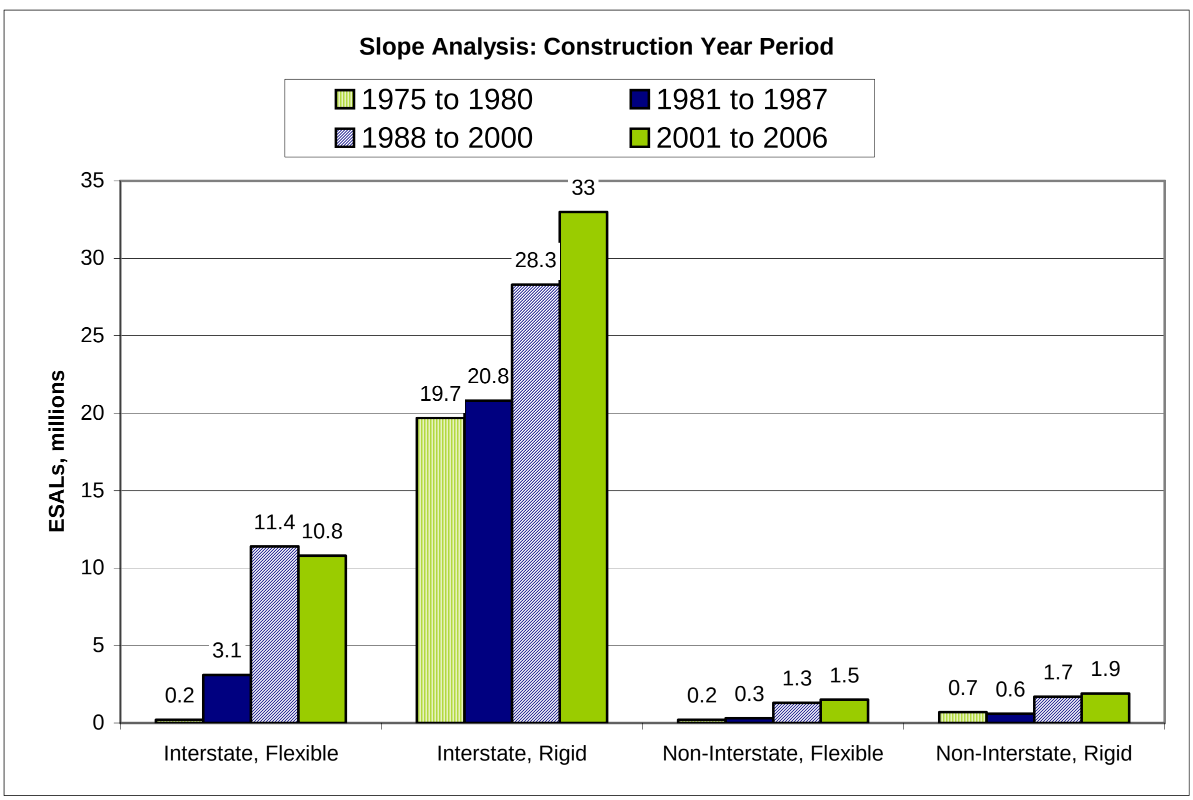

Figure 10. Slope analysis of service life ESALs based upon construction year period.

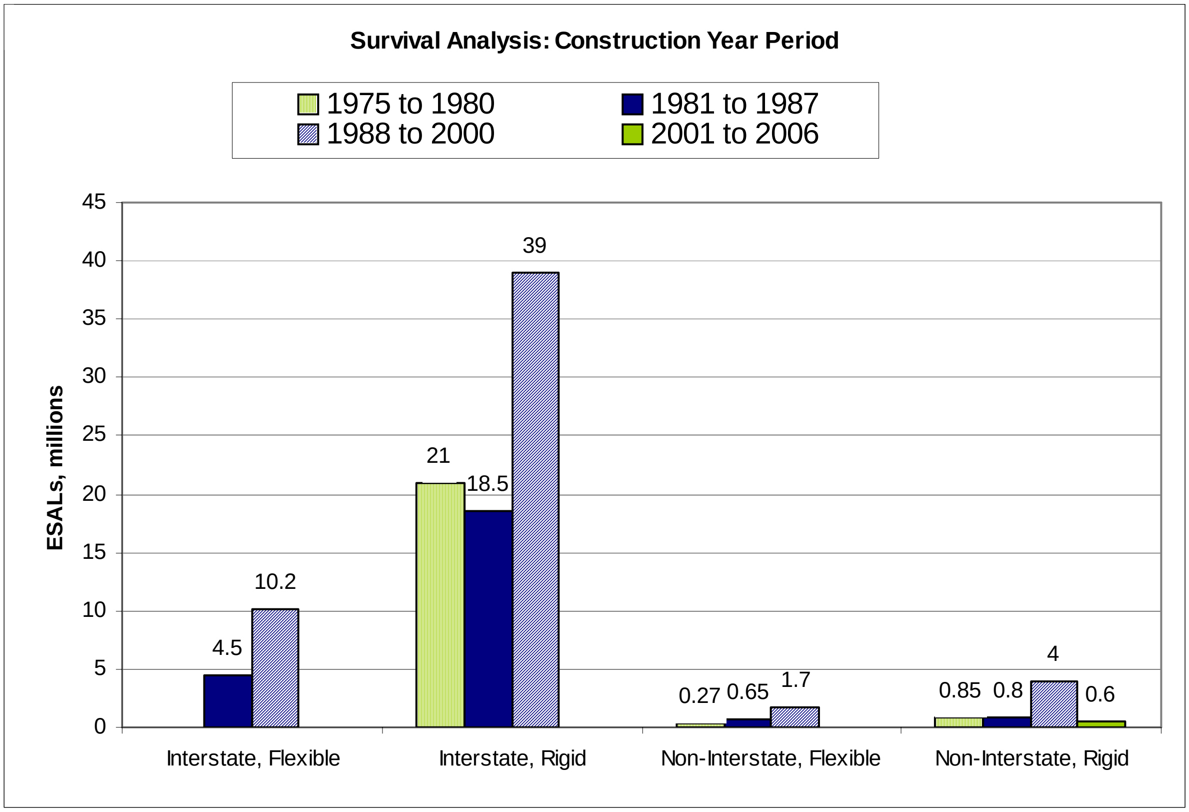

Figure 11. Survival analysis of service life ESALs based upon construction year period.

IMPACTS OF LOCATION

The location of the HMA overlay proved to have an impact on the performance of the pavement section. Specifically, the comparison of the service life from the slope analysis on the four main pavement families shows that on average the pavements in the south have service lives that are 20 percent longer, although they experience approximately 19 percent less traffic than the pavements in the north as shown in Figures 12 and 13.

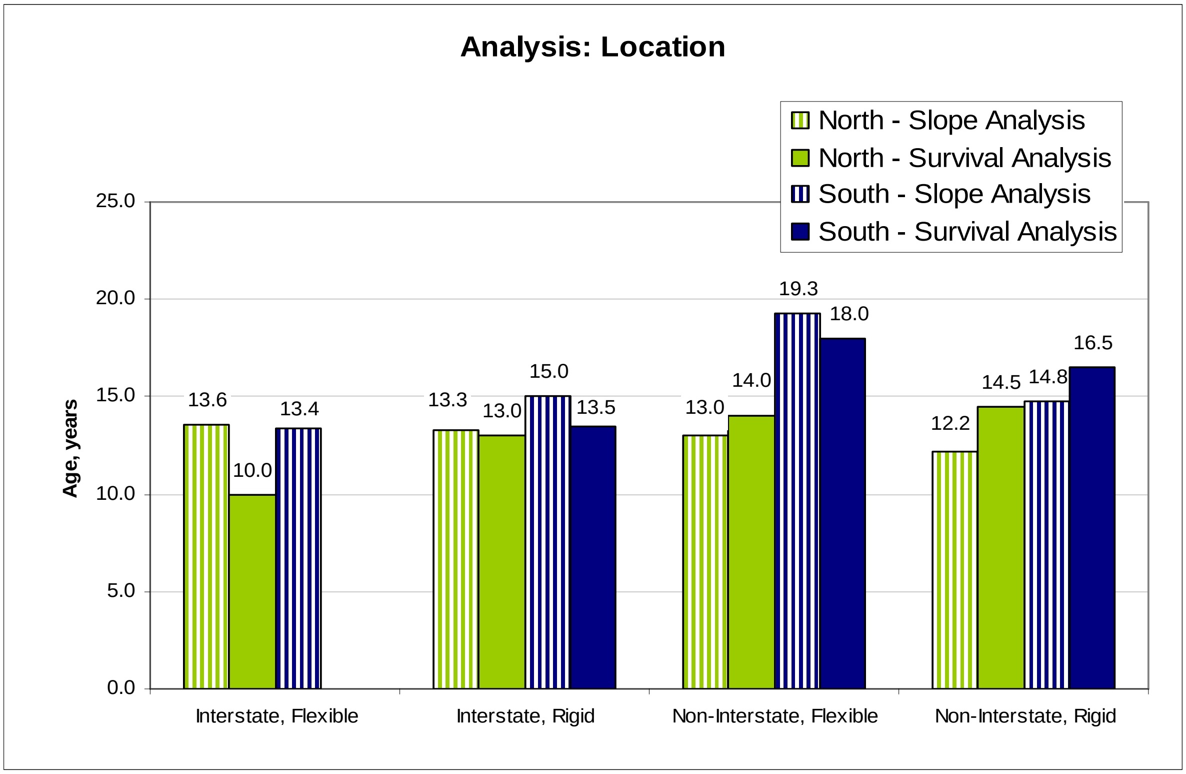

Figure 12. Analysis of service life age based upon location.

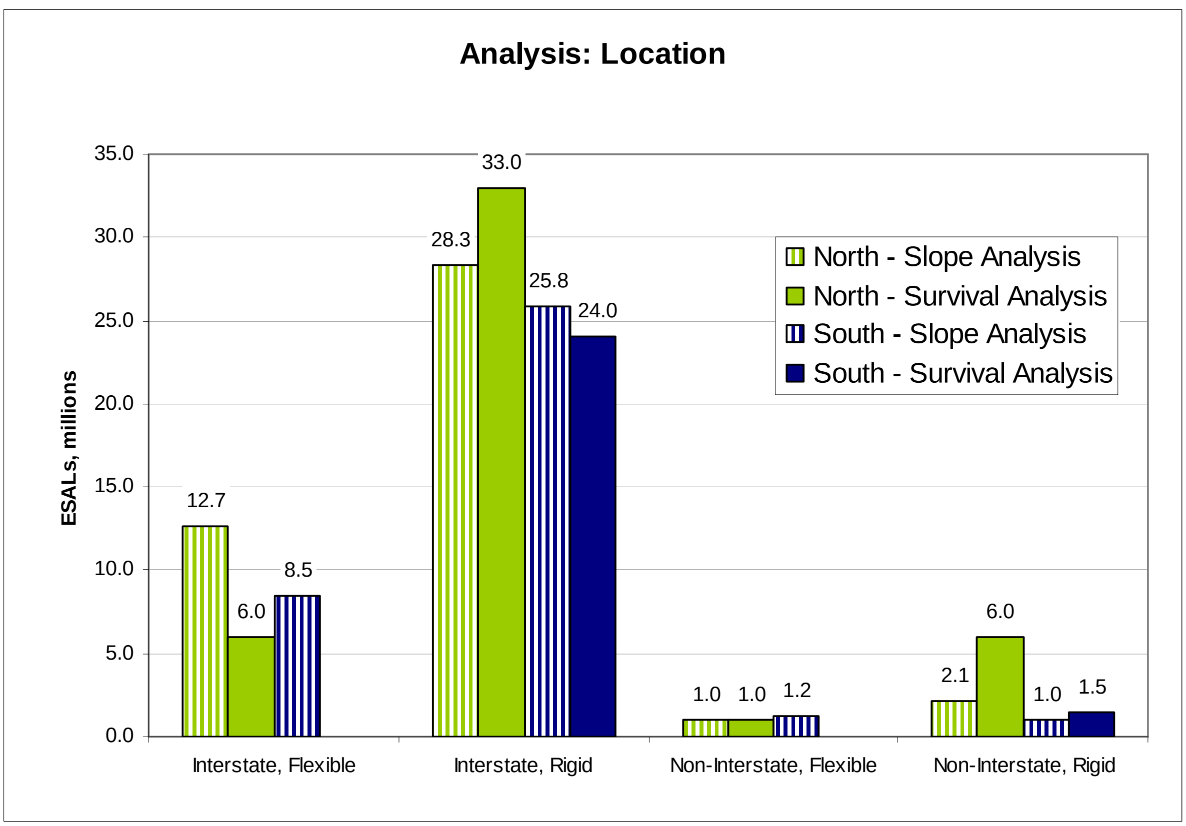

Figure 13. Analysis of service life ESALs based upon location.

IMPACTS OF CONDITION BEFORE OVERLAY PLACEMENT

The similarity of service life across the condition states is likely to be a factor of a different variable such as overlay thickness. The condition of the roadway before overlay placement will often dictate the selection of the thickness of the overlay placement. Therefore, those pavements in fair and poor condition are likely to receive more pre-repairs and a thicker overlay. Those in good condition will receive fewer pre-repairs and a SMART or 3P overlay without additional thickness. These changes in thickness across the pre-overlay condition state resulted in similar performance for all condition states. Figures 14 through 17 provide plots depicting these various trends.

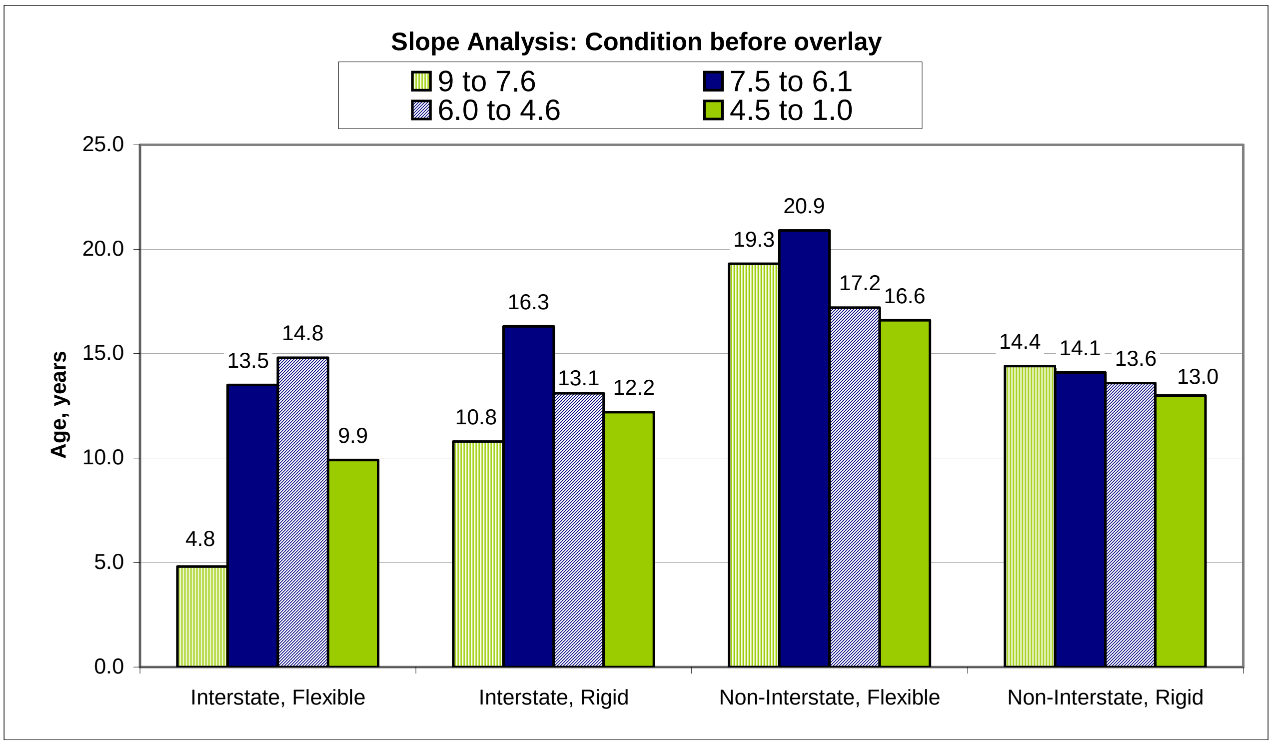

Figure 14. Slope analysis of service life age based upon condition before overlay.

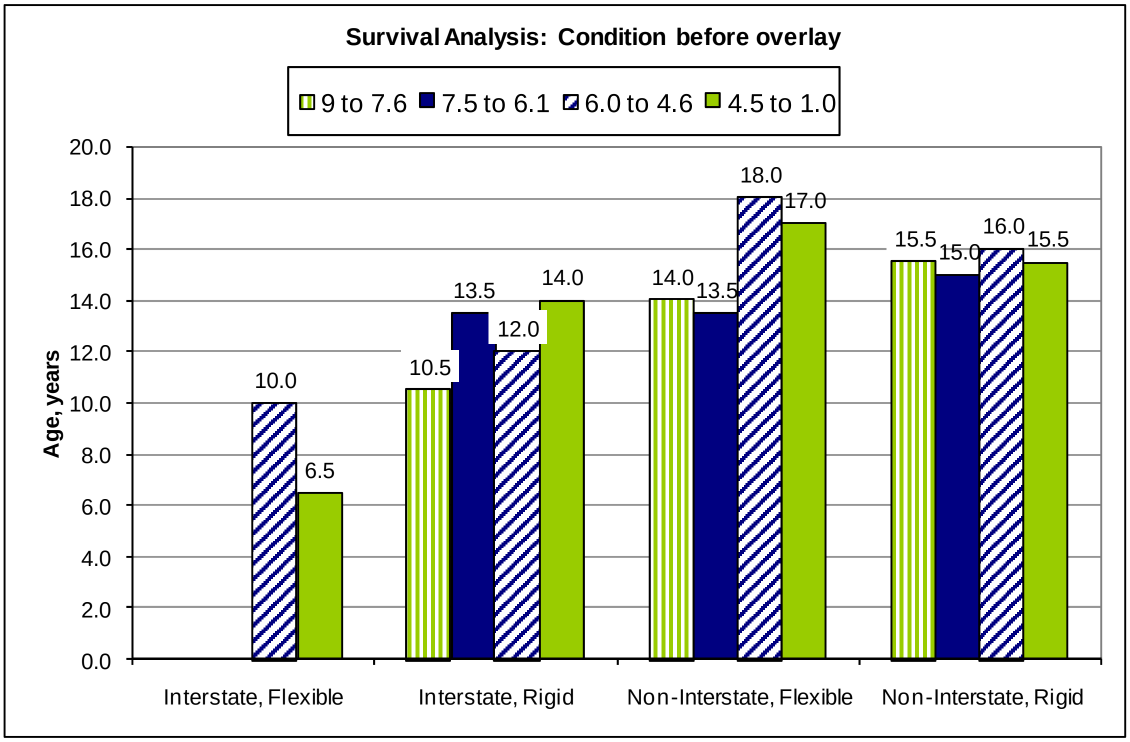

Figure 15. Survival analysis of service life age based upon condition before overlay.

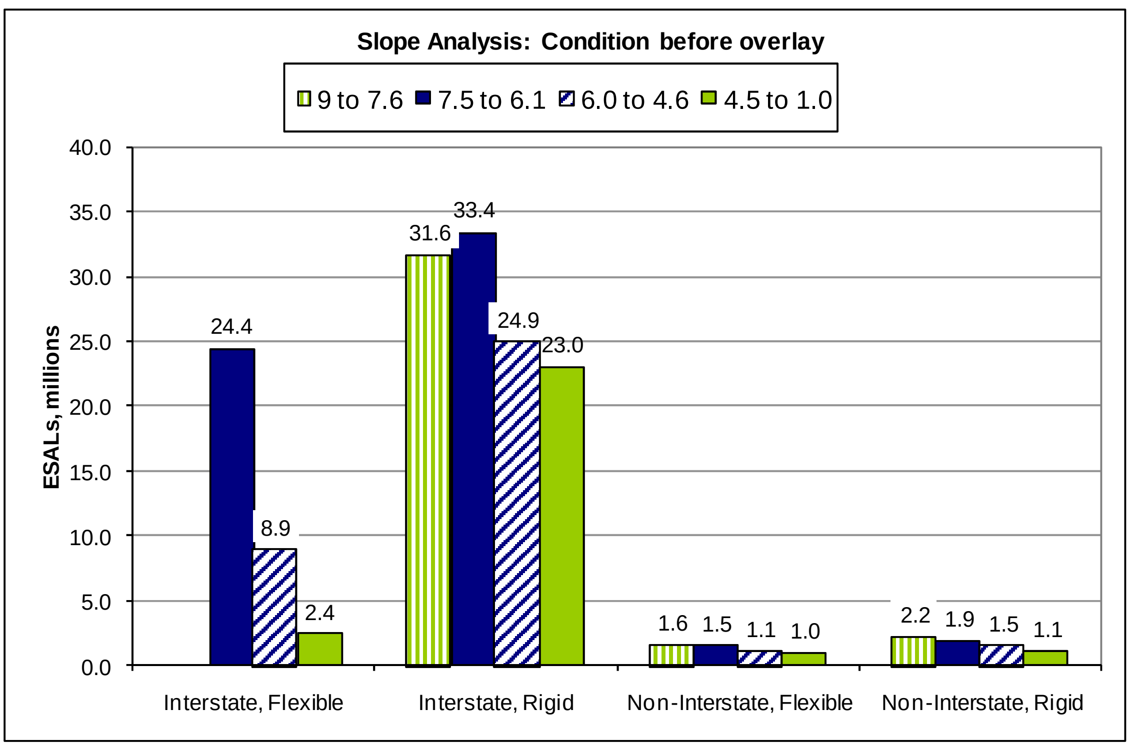

Figure 16. Slope analysis of service life ESALs based upon condition before overlay.

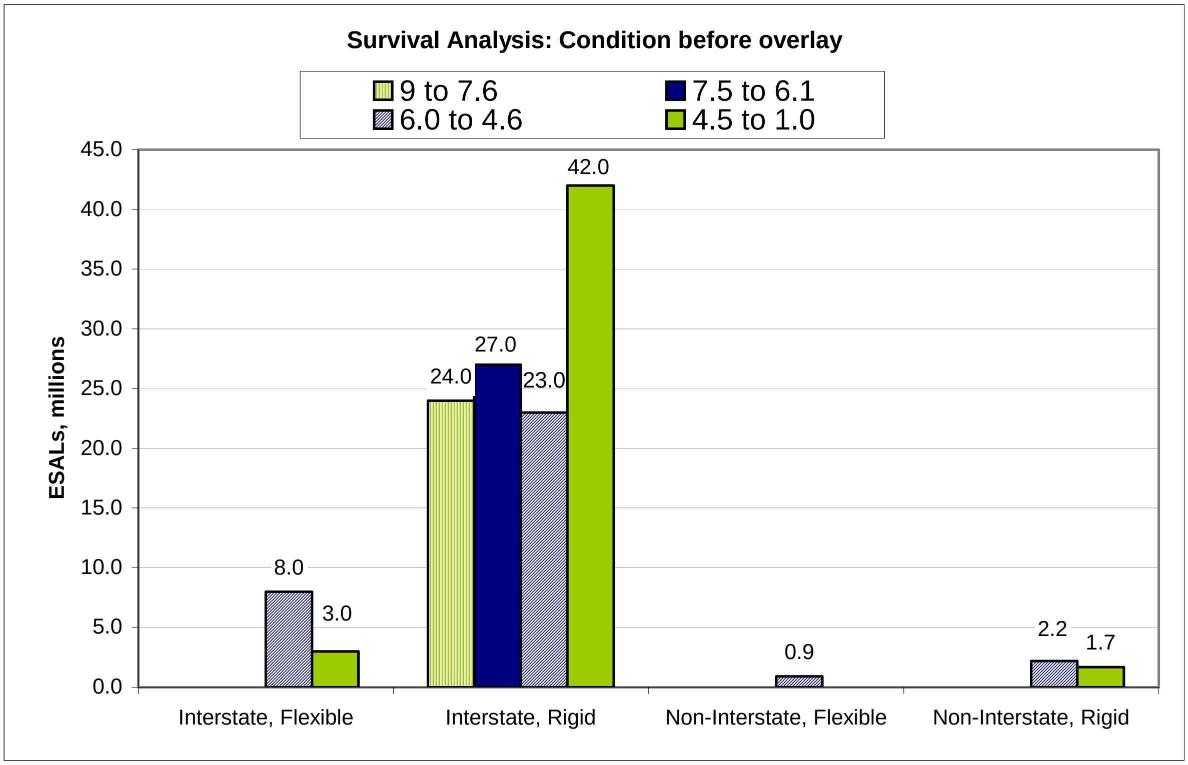

Figure 17. Survival analysis of service life ESALs based upon condition before overlay.

IMPACTS OF PRESENCE OF D-CRACKING

No reduction in service life was noted for the HMA overlays that were placed on pavement sections with D-cracking as compared to those overlays placed on pavements with no D-cracking. However, the comparison of load-carrying capacity for each of the detailed construction periods shows that the pavements without D-cracking provided up to 30 percent more load-carrying capacity than those with D-cracking as shown in Figure 18. The impacts of the presence of D-cracking may be better depicted with the examination of the service life of overlays with the same overlay thickness instead of having a family that incorporates a wide range of overlay thicknesses.

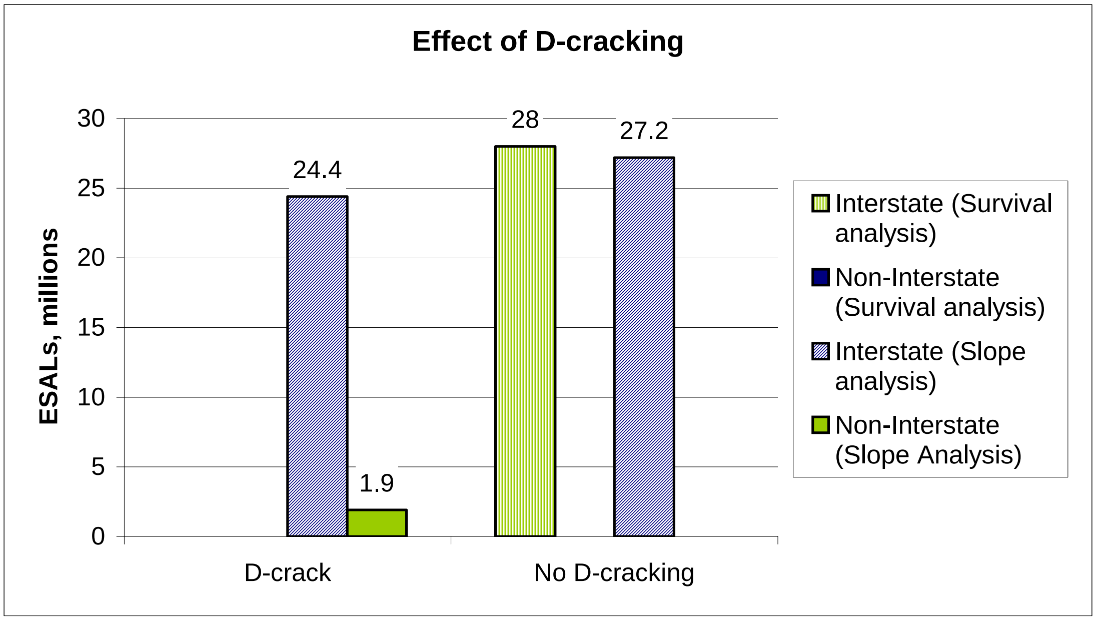

Figure 18. Analysis of service life ESALs based upon presence of D-cracking.

IMPACTS OF UNDERLYING CONCRETE TYPE

The type of underlying concrete pavement that exists below an HMA overlay proved to have little effect on the performance of the overlay. The overlays placed on CRCP pavements showed some improved performance compared to the overlays placed on JRCP and JPCP pavements but this was neither significant nor consistent (see Figure 19). The traffic loadings carried by all of the pavement sections were relatively consistent as shown in Figure 20 indicating that HMA overlay performance was not strongly dependent upon the underlying concrete pavement type.

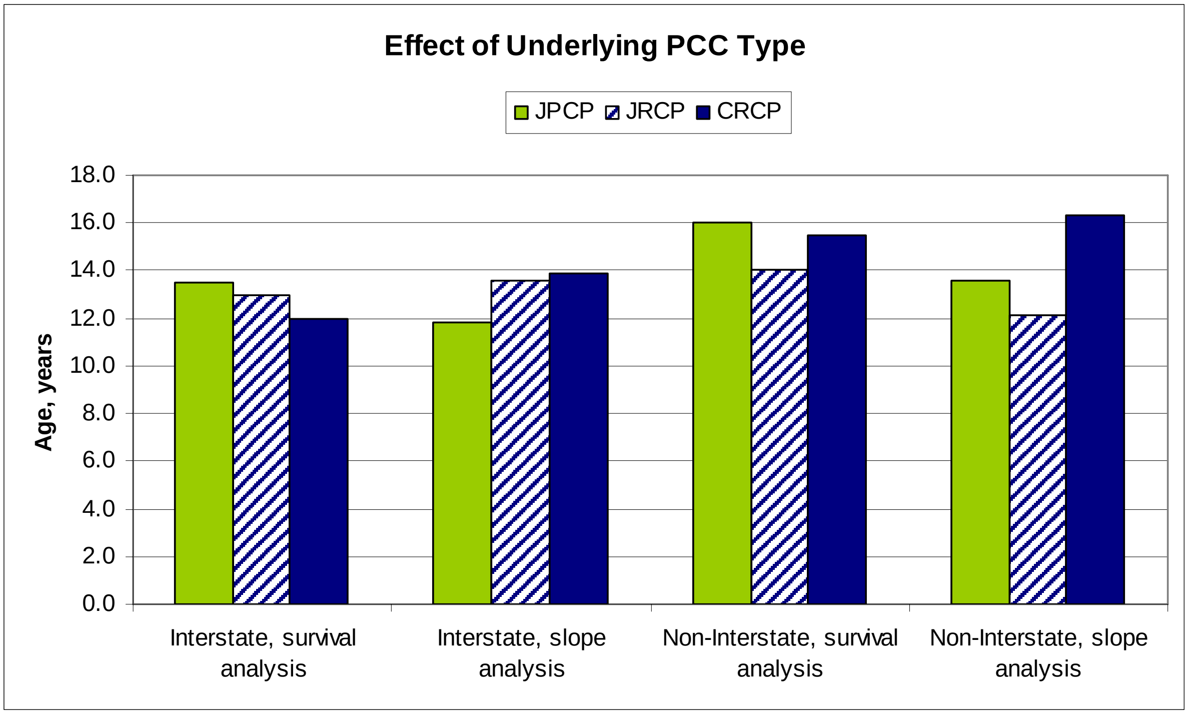

Figure 19. Analysis of service life age based upon underlying concrete type.

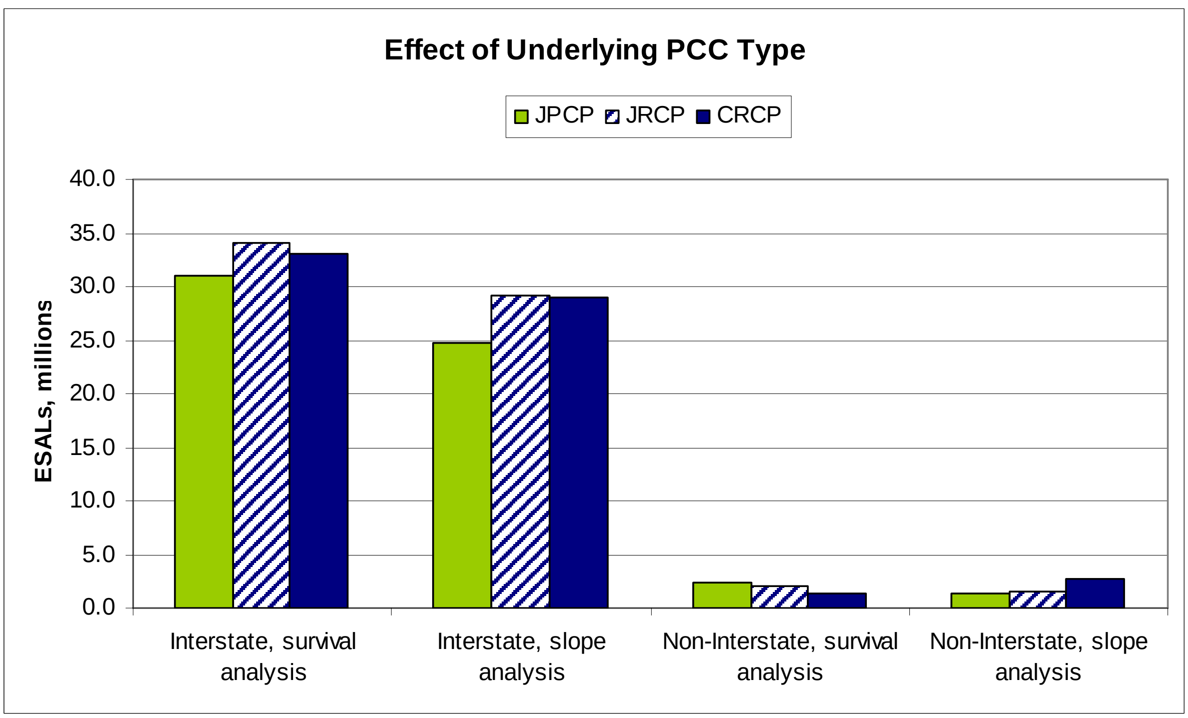

Figure 20. Analysis of service life ESALs based upon underlying concrete type.

IMPACTS OF ESTIMATED OVERLAY NUMBER

Given the variety of assumptions that were part of the analysis to define overlay number from the beginning IRIS data, the use of estimated overlay number as a predictor of performance was done so with some reservation. Nevertheless, it was expected that as overlay number increased, the resulting service life would show a decrease. However, the opposite trend was observed, and as the estimated overlay number increased there was a corresponding increase on the performance of the HMA overlays. Therefore estimated overlay data was examined in combination with the overlay type information to determine if a more realistic trend could be discerned from the data as discussed in the following section.

IMPACTS OF OVERLAY TYPE

As expected, the use of thicker 3P overlays provides a longer service life and available traffic loadings as compared to the SMART overlays. In addition to examining the service lives of the SMART and 3P overlays, an analysis of the combination of overlay type and estimated overlay number was used to examine the performance trends. The performance trends were as expected for the SMART overlays as the service lives decreased as the estimated overlay number increased. Likewise, the traffic loadings decreased with the reached service lives of each subsequent overlay. The trends for the 3P overlays showed the opposite of what was expected. The service lives for the second and third generation 3P overlays were extremely high because of some very low rates of deterioration of 0.05 CRS points per year for several pavement sections early in the pavement life.

SUMMARY

The study examined the performance of HMA overlays in the State of Illinois using data from IRIS. IRIS data was mined before to examine the performance of interstate and non-interstate pavements using both performance data and construction information. The data compilation portion of the project was a significant endeavor. Prior to the initiation of this study, it was unknown whether adequate data would exist to provide enough information for the analysis of the HMA overlay performance. The database of linked condition and work history information can be used to provide additional analysis of pavement section attributes. It should be noted, however, that there are some attributes that are incomplete as described in the report. Therefore, further supplements of the collected data could be made using additional resources prior to any additional analysis. Future linkage of condition and work history would provide a more streamlined process for data analysis.

Results of the data compilation provided sufficient data for most pavement families and the data analysis portion of the project continued. The service life trends observed in the 231 examined datasets were as expected for the majority of the datasets. However, there were some inconsistencies or unexpected trends in the results for several data sets. For those cases, the data were reviewed and the reasons for the inconsistent or unexpected trends were often obvious. The data causing the unexpected trends were not removed from the datasets as the data was true CRS data. Based upon the service life results, the impact of the evaluated variables on the performance of the HMA overlays was examined and documented in the report. The database of information developed as part of the study contains a wealth of information that can be used to further analyze the effects of various attributes on the performance of HMA overlays.

REFERENCES

Dwiggins, M. E., J. P. Hall, M. I. Darter, C. L. Flowers, and J. B. DuBose. Pavement Performance Analysis of the Illinois Interstate Highways System. FHWA-IL-UI-220, 1989.

Gharaibeh, N. G. and M. I. Darter. Longevity of Highway Pavements in Illinois – 2000 Update, IHR-R24, 2002.

Gharaibeh, N. G., M. I. Darter, F. LaTorre, J. W. Vespa, and D. L. Lippert. Performance of Original and Resurfaced Pavements on the Illinois Freeway System, FHWA-IL-UI-244, 1993.

Hall, K. T., M. I. Darter, and W. M. Rexroad. Performance of Bare and Resurfaced JRCP and CRCP on the Illinois Interstate Highway System – 1991 Update, FHWA-IL-UI-244, 1993.

Heckel, L. B. and Y. Ouyang. Phase III: CRS Prediction Model Development, ICT R27-13, Illinois Center for Transportation, 2007.

Illinois Department of Transportation (IDOT). Bureau of Design and Environment Manual. 2002.

Reed, C. M. The Performance Evaluation of Single Pass Thin Lift Bituminous Overlays. IHR-523, Illinois Department of Transportation, 1992.

Schutzbach, A. M. Bituminous Overlay Policy – A Performance Evaluation. IHR-530, Illinois Department of Transportation, 1995.