Proposed Performance-Prediction Equations and Threshold Triggers for Thin-Overlay Treatments Using the Long-Term Pavement Performance Database

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FOREWORD

This paper won the Challenge category of the 2015–2016 International Data Analysis Contest, which was sponsored by the Federal Highway Administration's Long-Term Pavement Performance (LTPP) program and the American Society of Civil Engineers. This paper, entitled *Proposed Performance-Prediction Equations and Threshold Triggers for Thin-Overlay Treatments Using the Long-Term Pavement Performance Database*, analyzes the use of thin overlays as a pavement-preservation treatment for prolonging the life of a pavement.

The research team proposes a methodology that analyzes survey data on pavement condition to determine the optimal time to apply a thin-overlay treatment to achieve a target pavement-life extension. Different climatic zones, traffic levels, and existing pavement conditions were considered to investigate the effectiveness of thin-overlay treatments.

The main objective of this study was to develop guidelines and/or parameters that highway agencies can use to determine the most appropriate time to apply thin-overlay treatments based on the condition of the existing pavement.

The results demonstrated that threshold triggers based on longitudinal cracking in the wheel path and rutting severity can be used to select the most appropriate time to apply a thin overlay. This report presents empirical equations to predict the life gain that can be achieved by a thin-overlay treatment based on the existing pavement conditions. The predicted life gain due to a thin-overlay treatment was found to be a function of the traffic level and the thickness of the existing asphalt-concrete layer.

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Director, Office of Infrastructure
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16. Abstract
The purpose of pavement-preservation treatments is to correct surface defects, improve ride quality, improve safety characteristics, and extend pavement life without increasing the structural capacity of the pavement. The application of a thin overlay is expected to extend the life of a pavement by 8–10 yr, although this range may vary depending on traffic, environmental conditions, quality of the materials, and workmanship. Thin overlays do not significantly increase the structural capacity of a pavement. Thus, the existing pavement condition should be evaluated carefully prior to the application of a thin overlay to ensure that structural rehabilitation is not necessary. A set of guidelines to determine the best time to apply thin-overlay treatments would help highway agencies optimize their budgets, thereby leading to potentially significant taxpayer savings.

The objective of this study was to develop guidelines, parameters, and performance-prediction equations to select the most appropriate time to apply a thin-overlay treatment based on the condition of the existing pavement. To arrive at the proposed guidelines, data from the Long-Term Pavement Performance (LTPP) Program Specific Pavement Studies 3 and 5 were used to evaluate the effects of climate, traffic, existing asphalt concrete (AC)–layer thickness, and overlay thickness on the life extension that results from the application of thin-overlay treatments.

The results demonstrate that threshold triggers based on longitudinal cracking in the wheel path and rutting severity can be used to select the best time to apply a thin overlay in order to achieve a target pavement-life extension. Analysis of the LTPP data shows that both the traffic level and existing AC-layer thickness significantly affect the life extension that results from the application of a thin overlay in terms of retarding rutting and longitudinal cracking, respectively. This paper presents empirical equations to predict the life gain that can be achieved from a thin-overlay treatment based on the existing pavement conditions.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS

AADT	annual average daily traffic
AADTT	annual average daily truck traffic
AC	asphalt concrete
CN	construction number
FWD	falling weight deflectometer
IRI	International Roughness Index
LTPP	Long-Term Pavement Performance
SPS	Specific Pavement Studies

CHAPTER 1. INTRODUCTION

The purpose of pavement-preservation treatments is to correct surface defects, improve ride quality, improve safety characteristics, and extend the life of pavements without increasing the structural capacity of pavements. Among commonly used pavement-preservation treatments, thin overlays can provide a quiet and smooth ride, improve surface friction, and seal the pavement from moisture infiltration at relatively low costs. Also, thin overlays can be applied relatively quickly, which minimizes traffic delays. A nationwide survey of highway agencies in North America reported that thin overlays can provide 2–10 yr of pavement-life extension, with a mode extension of 7–8 yr.(1) Hafez et al. conducted a similar survey and found that 29 out of 50 agencies estimated that the expected life of thin-overlay treatments applied to low-volume roads was between 6 and 10 yr.(2) The results of a survey conducted by Watson et al. indicated that climate region, traffic volume, existing pavement surface conditions, and construction quality are the primary factors that govern thin-overlay performance.(3) Thin overlays are commonly used in some States, but adoption of the practice has been slow in others.(2,3)

Thin overlays often are applied as part of mill-and-fill operations and are not designed to provide additional strength to the pavement structure. Because thin overlays do not increase the structural capacity of a pavement significantly, the condition of the existing pavement should be evaluated carefully prior to the application of a thin overlay to ensure that structural rehabilitation is not necessary. A distress survey should be performed to verify and measure distress types and to classify their severity. The common types of distress associated with asphalt pavements that may be candidates for thin overlays are as follows:

- Longitudinal cracking.
- Transverse cracking.
- Reflective cracking.
- Rutting that is not related to structural problems in the subgrade.

Rutting could indicate a structural problem if it is present in the subgrade. Alligator (interconnected) cracking, or fatigue cracking, may also indicate a structural problem. In these cases, a thin-overlay treatment would not be adequate, and structural rehabilitation would be required. However, if a thin overlay has been selected as a viable option for a given pavement, the surface preparation, materials, and thickness of the overlay are then determined based on the climate and anticipated traffic.

Regarding the materials and structures of thin overlays, significant variability, in terms of materials used and construction practices, has been found.(2,3) For example, the nominal maximum aggregate size of asphalt mixtures used for thin overlays can vary from 4.75 to 12.5 mm based on the thickness of the overlay.(3,4) Typically, a thin-overlay treatment consists of an asphalt-concrete (AC) layer with a thickness of 50 mm or less. (See references 1–3 and 9–11.) Recycled materials, including reclaimed asphalt pavement from mill-and-fill operations, reclaimed asphalt shingles, and ground tire rubber, may be incorporated into the mixture to reduce costs and improve environmental sustainability without compromising performance.(4–8)

The overall effectiveness of a pavement-preservation treatment can be measured in various ways to determine the optimal time to apply a given treatment. These methods must account for the service life and long-term effectiveness of the treatment. Threshold values represent the pavement conditions at which a pavement section can be considered to be at the end of its service life. Threshold values allow a condition-based evaluation of the service life rather than an age-based assessment. Pavement evaluation that is based on various performance indicators, such as the International Roughness Index (IRI), pavement-condition rating, and rut depth, can serve as an analytical tool to determine the service life of the treatment.(1) In addition, survivor curves can be used to predict the probable survival of a pavement and have been used to determine the life expectancy of pavement treatments.(11) Survivor curves also can be used to assess the traffic load–carrying capacity of newly treated pavements.(3)

CHAPTER 2. OBJECTIVES

This study proposes a methodology that analyzes survey data on pavement condition to determine the optimal time to apply a thin-overlay treatment in order to achieve a target pavement-life extension. Different climatic zones, traffic levels, and existing pavement conditions were considered in the investigation of the effectiveness of thin-overlay treatments. The main objectives of this research are summarized as follows:

- Develop guidelines and/or parameters that highway agencies can use to determine the optimal time to apply thin-overlay treatments.
- Develop equations that are based on the existing pavement conditions to predict the performance of thin-overlay treatments.
- Investigate the effects of climate, traffic, existing AC-layer thickness, and overlay thickness on the performance of thin-overlay treatments.

CHAPTER 3. DATA COLLECTION

The research team used data on pavement condition that was obtained from the Long-Term Pavement Performance (LTPP) Program database to develop performance-prediction equations and proposed trigger thresholds that are applicable for thin-overlay treatments in order to achieve the target extension of the pavement's service life. The LTPP data, retrieved from the Program website, contain detailed information, including construction, survey, monitoring, traffic, climate, performance data, etc.(12)

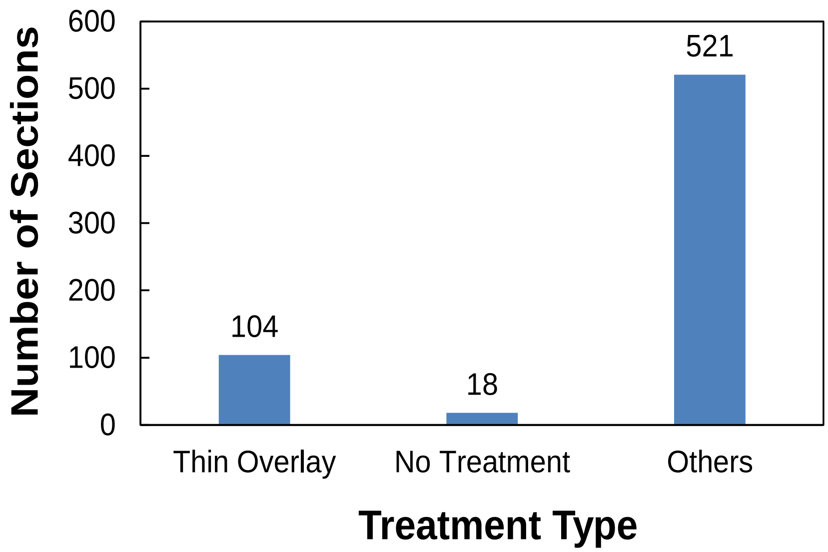
DATA-SELECTION CRITERIA

The criteria used to select the test sections from the LTPP database for this study include (a) experiment type, (b) treatment type, and (c) thickness of overlay. The LTPP Program includes 8 General Pavement Studies and 10 Specific Pavement Studies (SPS). For this study, SPS-3 (Preventive Maintenance Effectiveness of Flexible Pavements—445 test sections) and SPS-5 (Rehabilitation of Asphalt-Concrete Pavements—204 test sections) were considered. The overlays within these 649 test sections were identified by a construction number (CN) event code: 19 for AC overlays, 51 for mill-off AC and overlays with AC, 55 for mill existing pavement and overlays with hot-mix AC, and 56 for mill existing pavement and overlays with cold-mix AC.(13) The test sections used in this study were selected based on these CN codes and overlay thickness, for which the maximum was 55 mm. Each LTPP section was 152 m long with a total area of 556 m^2.(13,14)

DATA-COLLECTION RESULTS

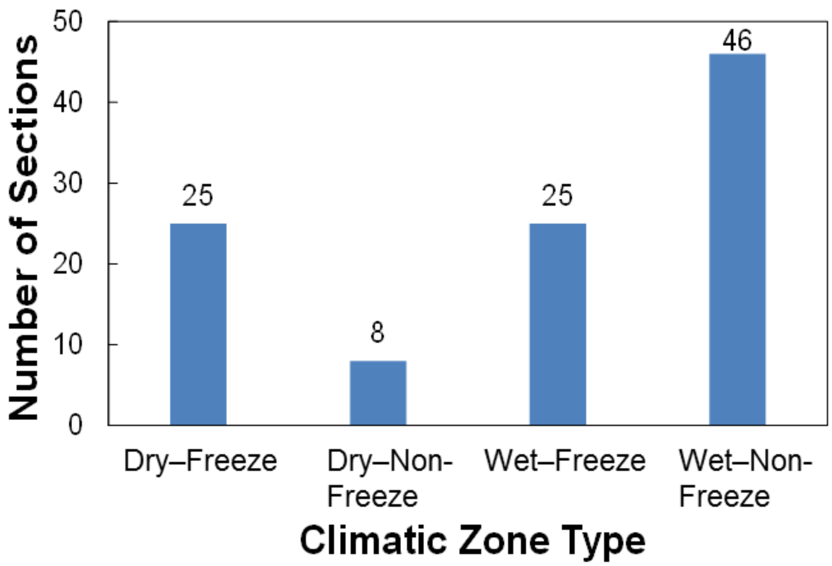
Figure 1 through figure 3 present the results of the investigation into the 649 SPS-3 and SPS-5 test sections, summarized as follows:

- Figure 1 shows 104 thin-overlay sections, 18 no-treatment sections, and 521 sections with other types of treatment.
- Figure 2 shows that, among the 104 thin-overlay sections, 25 (24 percent) are in dry–freeze climates, 8 (8 percent) are in dry–nonfreeze climates, 25 (24 percent) are in wet–freeze climates, and 46 (44 percent) are in wet–nonfreeze climates.
- Figure 3 shows that, among the 104 thin-overlay sections, 55 (53 percent) have overlay thicknesses less than 33 mm, and 49 (47 percent) have overlay thicknesses between 33 and 55 mm.



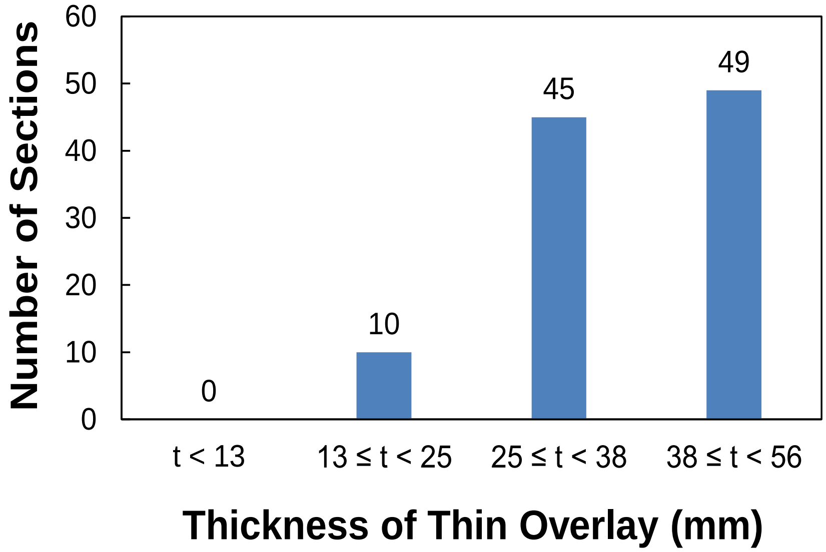
Source: FHWA.

Figure 1. Graph. Treatment types in LTPP experiments (SPS-3 and SPS-5).



Source: FHWA.

Figure 2. Graph. Climatic-zone distribution of thin-overlay sections in LTPP experiments (SPS-3 and SPS-5).



Source: FHWA.

Figure 3. Graph. Thin overlay–thickness distribution in LTPP experiments (SPS-3 and SPS-5).

CHAPTER 4. METHODOLOGY

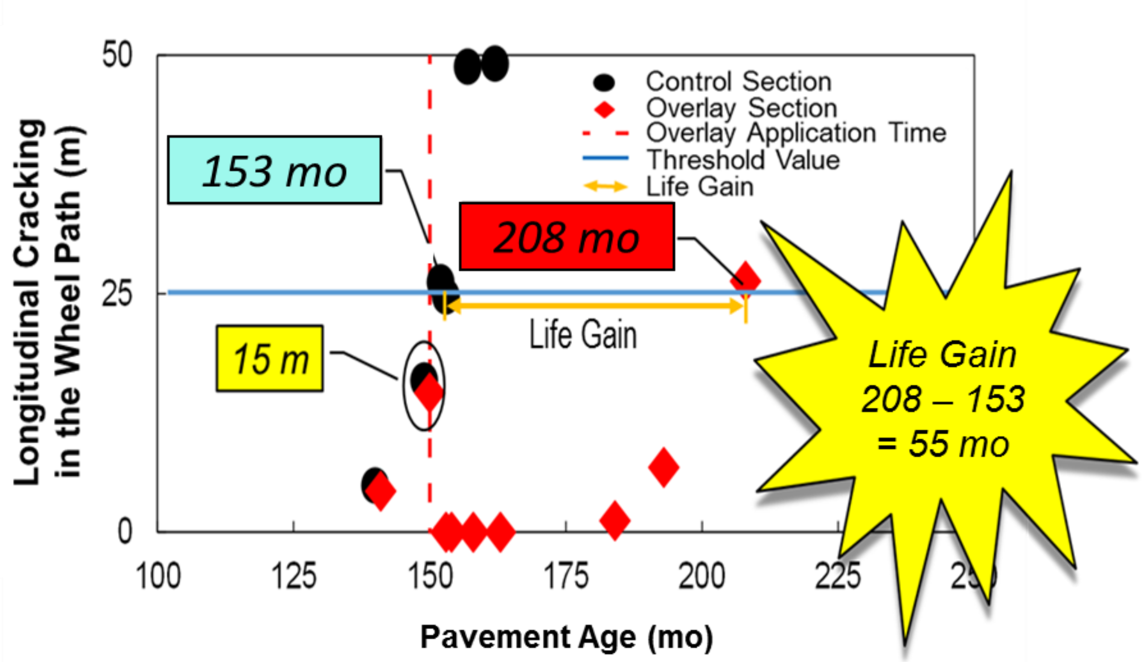
The effectiveness of pavement-preservation treatments can be measured in various ways, including consideration of the service life of the treatment, the increase in average pavement performance relative to the performance at the time of treatment, and the area bounded by the performance curve.[1] This study used the extension of pavement service life that results from the application of thin-overlay treatments to quantify the ability of the treatment to retard future deterioration. To this end, this study considered three distress types: fatigue cracking, longitudinal cracking in the wheel path, and rut depth. To quantify the extension of the pavement's service life, critical performance thresholds were employed to define the end-of-life gain. Table 1 presents the critical performance indicators that were used to quantify the pavement-life extension that resulted from the application of a thin-overlay treatment. Performance threshold values can vary depending on different agencies; however, in general, two methods are employed to select threshold values: (1) pavement failure and (2) treatment failure.[15] This study used pavement failure. The threshold value for fatigue cracking was determined as 35 percent failure of the total area of the section. The total area of each section included in this study is 556 m^2.[14] Therefore, the threshold value for fatigue cracking is 200 m^2. The threshold value for rutting was selected from an existing design manual.[1] The detailed procedures for determining the life gain that results from the treatment itself and from the time the treatment is applied are discussed in the following section.

Table 1. Performance indicators and threshold values for life-gain calculation.

Performance Indicator	Upper Limit Threshold Value for Life-Gain Calculation
Fatigue cracking	200 m^2 (total section area is 556 m^2)
Longitudinal cracking in wheel path	25 m (total section length is 152 m)
Rut depth	6.25 mm

ESTIMATION OF LIFE GAIN

Figure 4 presents the procedure used to quantify the life gain that is achieved by the application of a thin overlay for a section with longitudinal cracking. The first step to quantify this life extension is to plot the pavement condition–history values of the thin-overlay section (diamonds in figure 4) and a control section adjacent to the thin-overlay section where no treatment was applied (circles), the treatment application date (vertical line), and the upper-limit threshold (horizontal line). The pavement-life extension that results from the application of the thin overlay is calculated as the difference between the time at which the control and thin-overlay sections deteriorate to the critical performance threshold. The average pavement condition of the control and thin-overlay sections just prior to the thin-overlay application is also an important consideration (i.e., 15 m in figure 4) and was used in the analysis to determine the trigger threshold at which a thin overlay should be applied in order to reach the target extension of pavement life. In cases when the performance data available did not reach the critical performance threshold, an exponential function was fitted to the available data and the data were extrapolated to predict when the critical threshold would be reached.



Source: FHWA.

Figure 4. Chart. Example of life gain–calculation approach.

DETERMINING THE OPTIMAL TIME TO APPLY A THIN OVERLAY

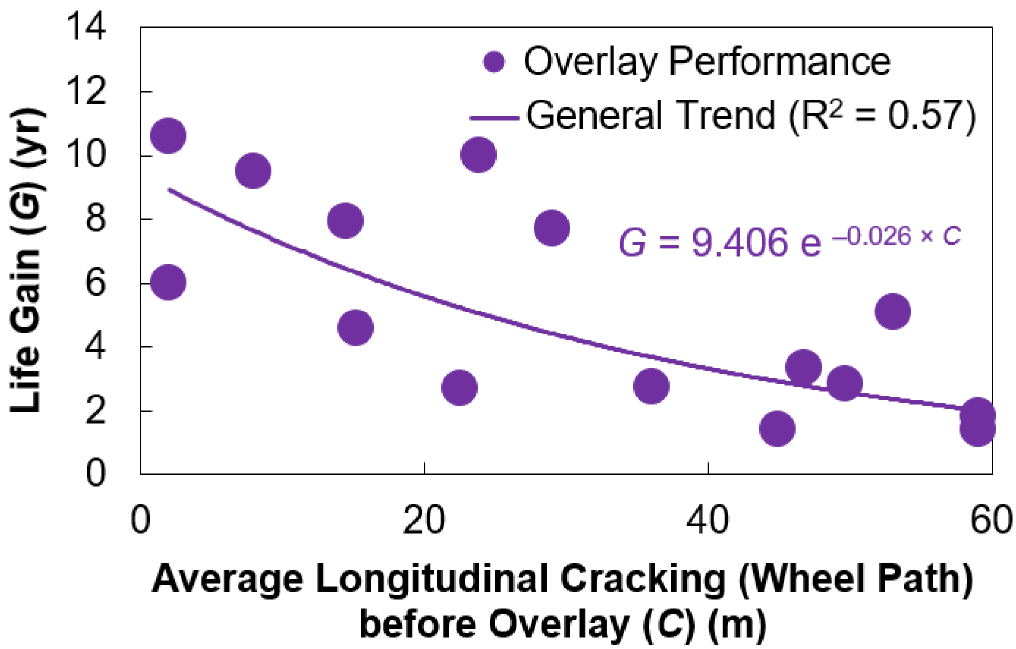
The relationship between the pavement-life extension that results from the application of a thin overlay and the average condition just prior to the application was investigated to establish critical pavement-condition thresholds that can be applied for thin-overlay treatments to achieve the desired life extension. The effects of climate, traffic level, and pavement structure on the relationship between life gain and the condition of the pavement at the time of the application of a thin overlay were investigated. Regression analysis of the longitudinal cracking and rutting data was undertaken to select threshold values that could help determine the optimal time to apply thin overlays to achieve a 5-yr extension of pavement life.

CHAPTER 5. RESULTS

The LTPP database provides survey data on pavement condition, including fatigue cracking, longitudinal cracking, rutting, IRI values, falling weight deflectometer (FWD) data, etc. This study evaluated three major distresses: (1) fatigue (alligator) cracking, (2) longitudinal cracking in the wheel path, and (3) rutting. Fatigue (alligator) cracking is assumed to be bottom–up cracking, whereas longitudinal cracking in the wheel path is assumed to initiate at the pavement surface and propagate downward.[16,17] FWD deflections were not included in this study because, generally, the application of a thin-overlay treatment is not expected to affect FWD deflections due to the fact that such treatments do not significantly increase the structural capacity of the existing pavement. Also, thin-overlay treatments typically do not affect the longitudinal profile of the highway, and thus, their effect on IRI data was assumed to be minor and was not investigated in this study.

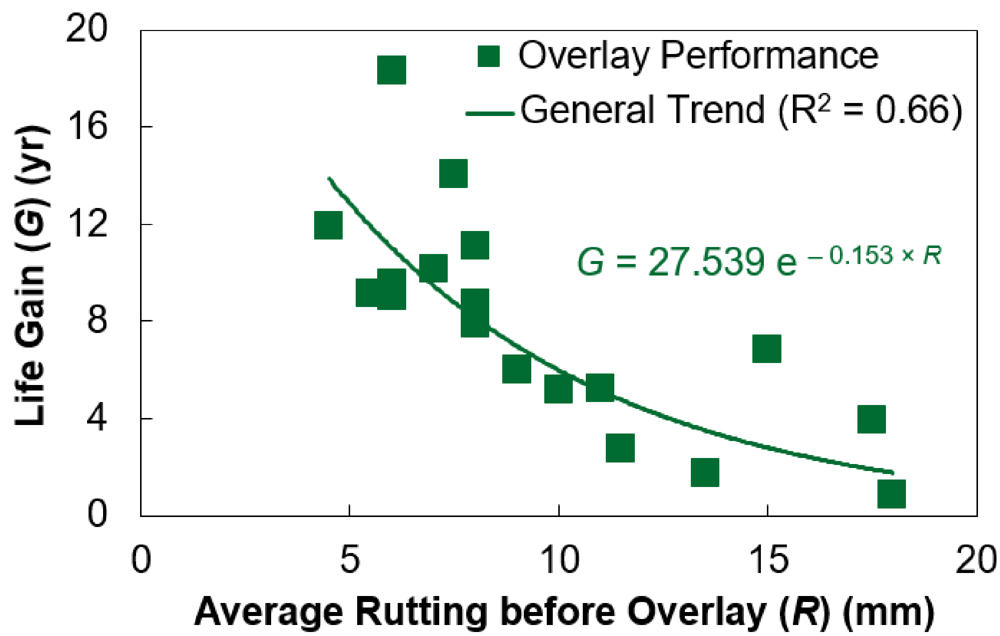
GENERAL OBSERVATIONS AND TRENDS

Figure 5 through figure 7 present the overall relationships between the pavement-life extension that results from the application of a thin overlay and the initial pavement condition in terms of longitudinal cracking, rutting, and fatigue cracking. The results presented in figure 5 and figure 6 demonstrate that the life gained by the application of a thin overlay generally decreases as the average pavement condition prior to the treatment application becomes worse for both rutting and fatigue. This finding implies that the best time to apply a thin overlay is early in a pavement's service life (i.e., while the pavement is in good condition). For example, the results suggest that a thin overlay must be applied before a longitudinal crack reaches approximately 25 m per a 152-m-long pavement section to extend the service life by 5 yr. Assuming that longitudinal cracks are top–down cracks, these results suggest that a thin overlay must be applied before the cracks reach the base layer to prevent moisture penetration.[16,17]



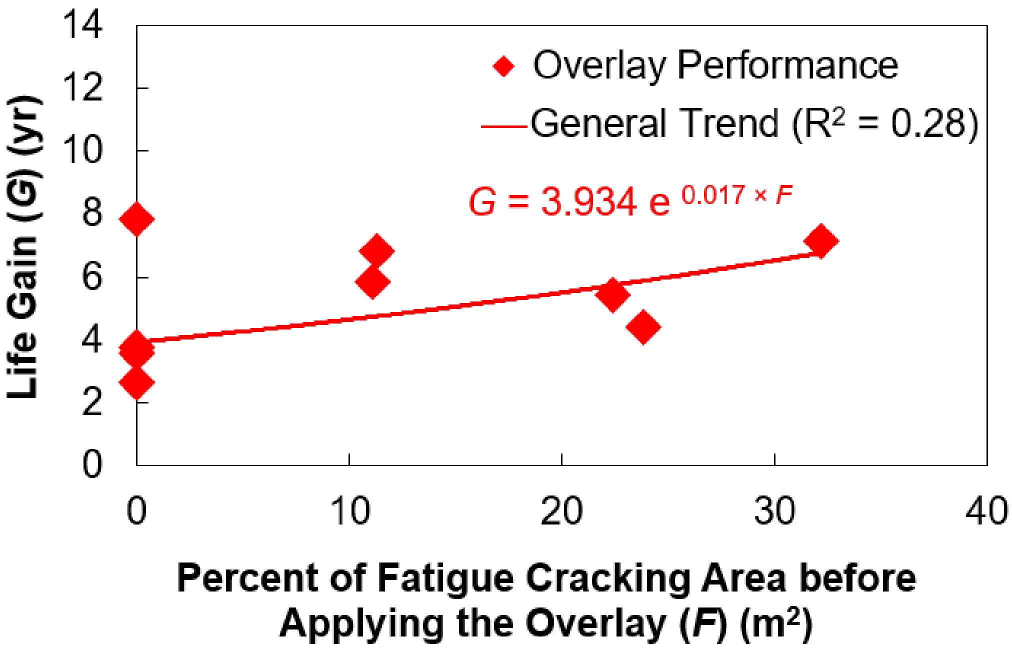
Source: FHWA.

Figure 5. Chart. General overlay performance in terms of life gain calculated based on longitudinal cracking in the wheel path as a function of the condition of the existing pavement prior to overlay.



Source: FHWA.

Figure 6. Chart. General overlay performance in terms of life gain calculated based on rut depth as a function of the condition of the existing pavement prior to overlay.



Source: FHWA.

Figure 7. Chart. General overlay performance in terms of life gain calculated based on fatigue cracking as a function of the condition of the existing pavement prior to overlay.

Rutting cannot be corrected by many pavement-preservation treatments, such as crack seals, chip seals, and slurry seals. However, the application of a thin overlay can help mitigate rutting in the AC layer if the rutting is not caused by a structural problem in the lower pavement layers. The LTPP database provides only the total pavement rut depth. Therefore, whether the observed rutting is confined to the surface layer cannot be determined. However, as shown in figure 6, the life gain achieved by the application of a thin overlay decreases as the trigger rut depth at which the overlay is applied increases. For example, the results suggest that a thin overlay must be applied before the rut depth exceeds 11 mm in order to extend the service life of the pavement by 5 yr.

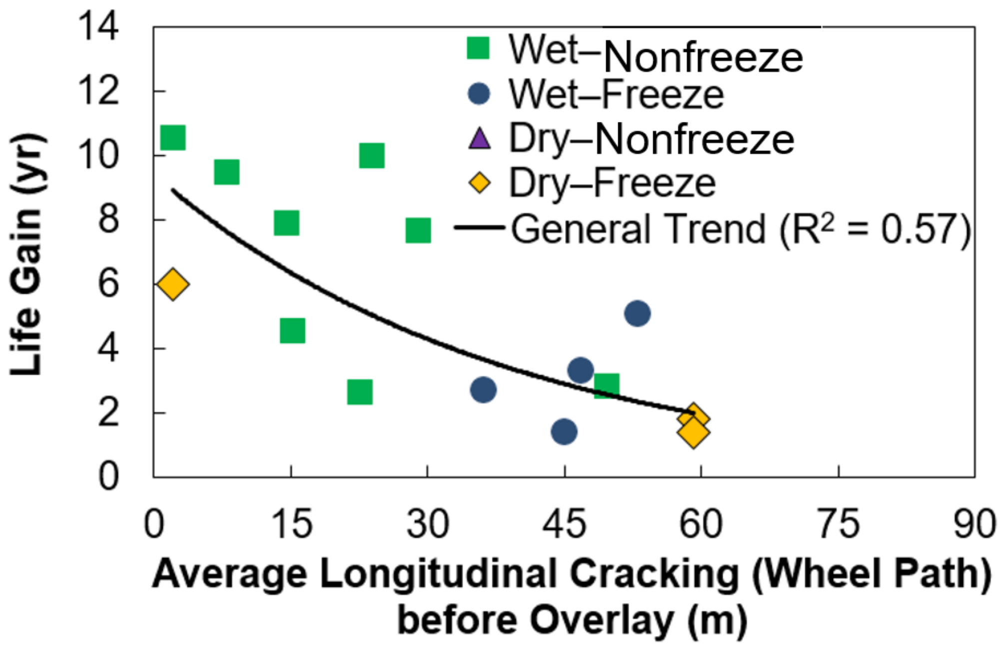
As shown in figure 7, unlike longitudinal cracking and rutting, the life gain for fatigue (alligator) cracking is weakly correlated with the pavement condition prior to the application of a thin overlay. In addition, the number of sections with alligator cracking prior to the application of a thin overlay that were identified within the LTPP database was relatively small compared to the number of sections with longitudinal cracking and rutting. Fatigue (alligator) cracking is generally assumed to initiate from the bottom of the AC within a pavement and propagate upward, which indicates a structural problem in the pavement. Thus, pavement preservation may not be an appropriate strategy to address fatigue cracking. Also, the results shown in figure 7 indicate that the maximum life gain that results from the application of a thin overlay in terms of fatigue-cracking resistance is significantly less than the life gain in terms of rutting or longitudinal-cracking resistance.

Although the results presented in figure 5 and figure 6 indicate that applying a thin overlay before any distress develops in the pavement would lead to the greatest life gain, this option may not be practical due to cost constraints. Therefore, lifecycle cost analysis and practical experience may be needed to evaluate the applicability and limitations of the performance predictions shown in these figures.

FACTORS THAT MAY AFFECT THE RELATIONSHIP BETWEEN LIFE GAIN AND AMOUNT OF LONGITUDINAL CRACKING BEFORE OVERLAY

Climatic Zone

In the LTPP database, locations are broadly classified by climatic region as follows: (a) wet–nonfreeze, (b) wet–freeze, (c) dry–nonfreeze, (d) dry–freeze. This study investigated the effect of climate on the ability of thin overlays to retard longitudinal cracking. Figure 8 presents the results and indicates that no significant relationship is found between life gain (based on longitudinal cracking) and climate.

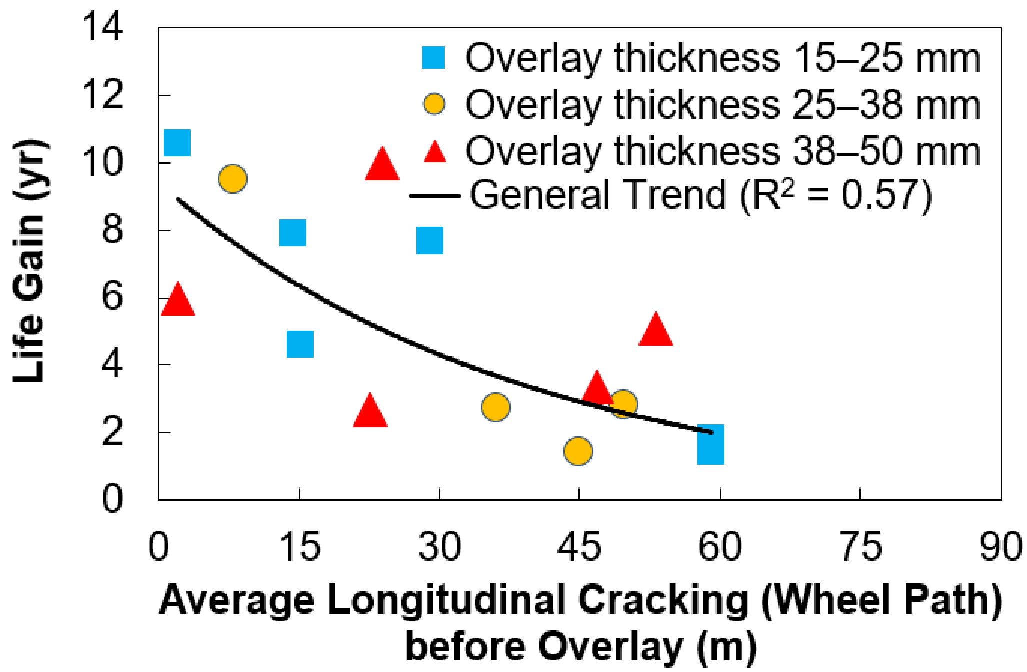


Source: FHWA.

Figure 8. Chart. Effects of climatic zone on general longitudinal-cracking trend.

Thin-Overlay Thickness

Figure 9 shows the relationship between the longitudinal cracking and pavement life gain that results from the application of a thin overlay and the initial pavement condition regarding overlay thickness as follows: (a) 15–25 mm, (b) 25–38 mm, and (c) 38–50 mm. The results suggest that the thickness of a thin overlay does not significantly impact its ability to retard longitudinal cracking.

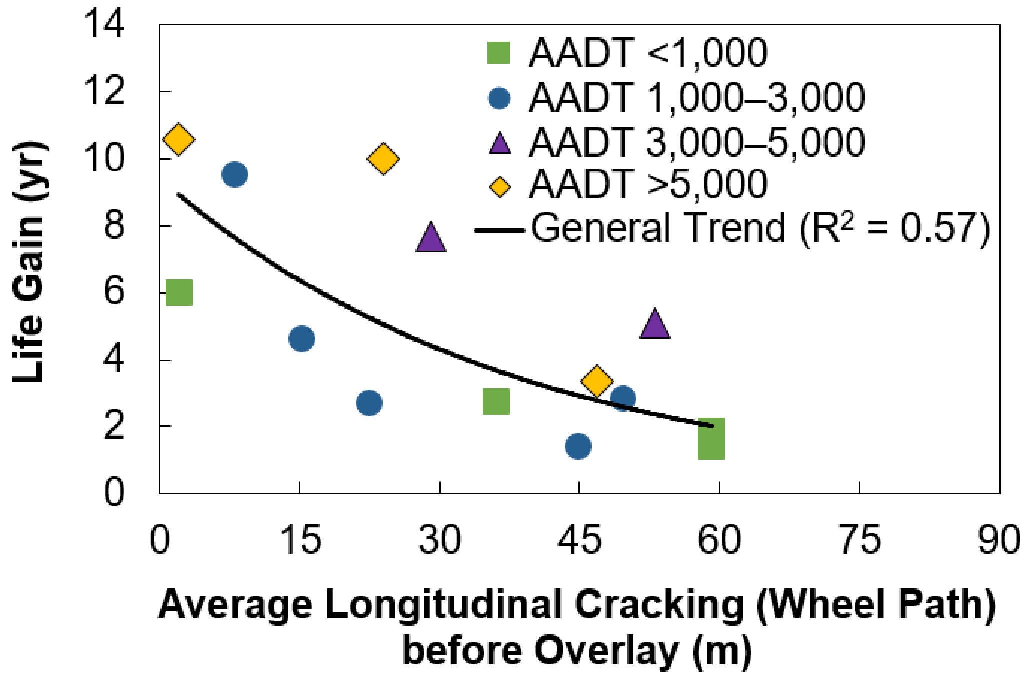


Source: FHWA.

Figure 9. Chart. Effects of overlay thickness on general longitudinal-cracking trend.

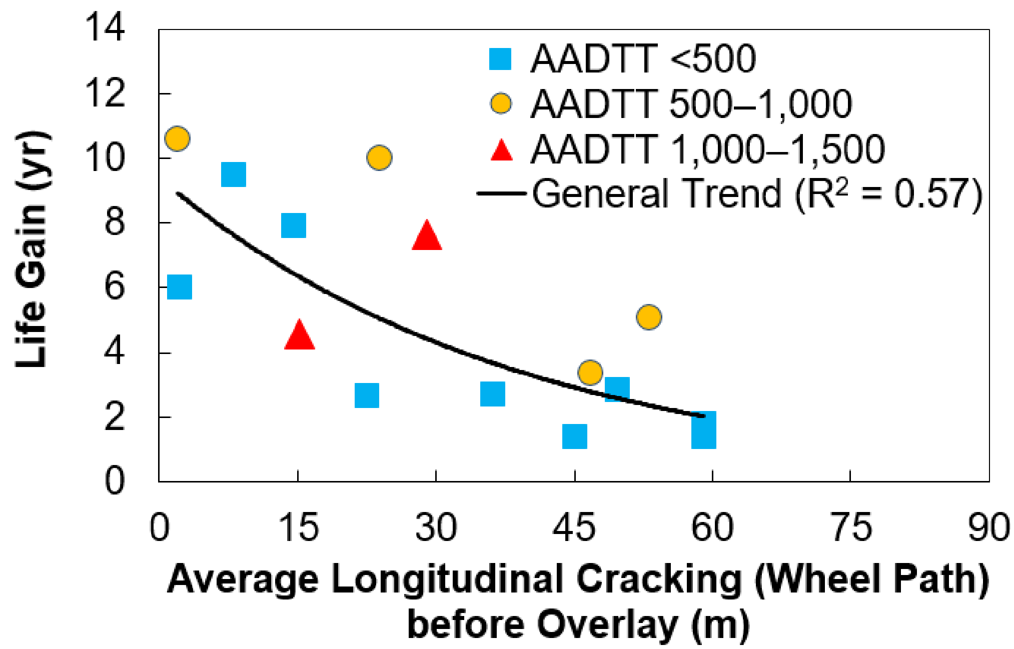
Total Traffic and Truck Traffic

The effects of traffic on the life gain that results from the application of a thin overlay were evaluated using two traffic metrics that are included in the LTPP database: (1) annual average daily traffic (AADT) and (2) annual average daily truck traffic (AADTT). The ranges of the AADT used in the analyses were as follows: (a) less than 1,000, (b) 1,000–3,000, (c) 3,000–5,000, and (d) more than 5,000. The ranges of AADTT were as follows: (a) less than 500, (b) 500–1,000, and (c) 1,000–1,500. Figure 10 and figure 11 show the effects of traffic on the relationship between the life gain and the amount of longitudinal cracking before overlay. Figure 10 shows that AADT has a significant effect on the life extension provided by thin-overlay treatments. The sections with AADT values less than 3,000 exhibited a smaller life gain for a given initial longitudinal-crack length compared to sections with higher AADT values. However, the effect of AADTT on the life gain that results from thin overlays is less clear in figure 11.



Source: FHWA.

Figure 10. Chart. Effects of AADT on general longitudinal-cracking trend.



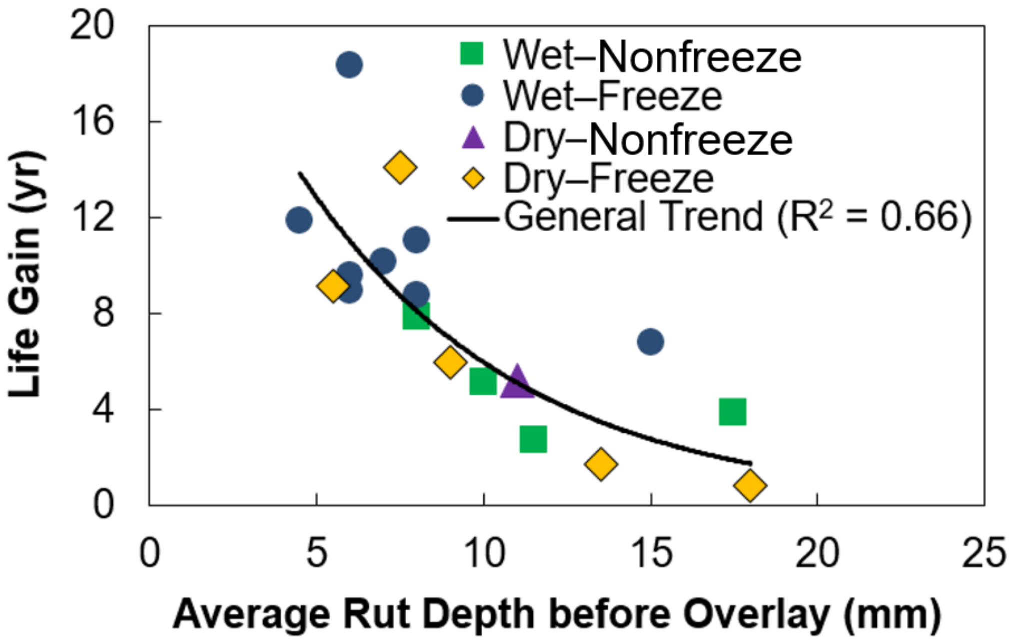
Source: FHWA.

Figure 11. Chart. Effects of AADTT on general longitudinal-cracking trend.

FACTORS THAT MAY AFFECT THE LIFE GAIN IN TERMS OF RUTTING

Climatic Zone

Figure 12 presents the relationship between the rutting life gain that results from the application of a thin overlay and the initial pavement condition in terms of climate zone. Similar to the longitudinal-cracking results, climate appears to have an insignificant effect on the life gain achieved by the application of thin overlays.

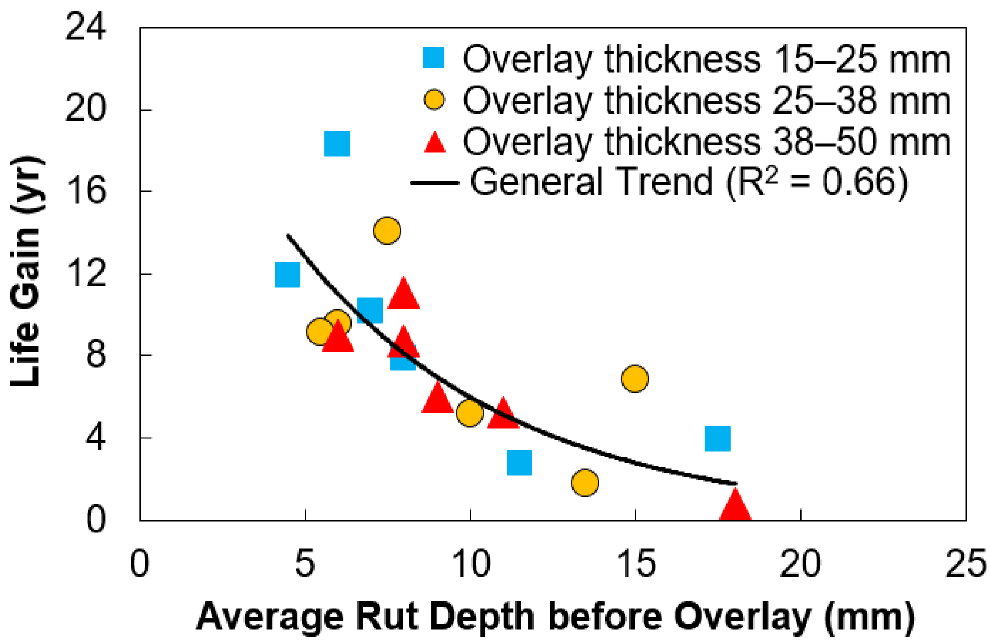


Source: FHWA.

Figure 12. Chart. Effects of climate zone on general rutting trend.

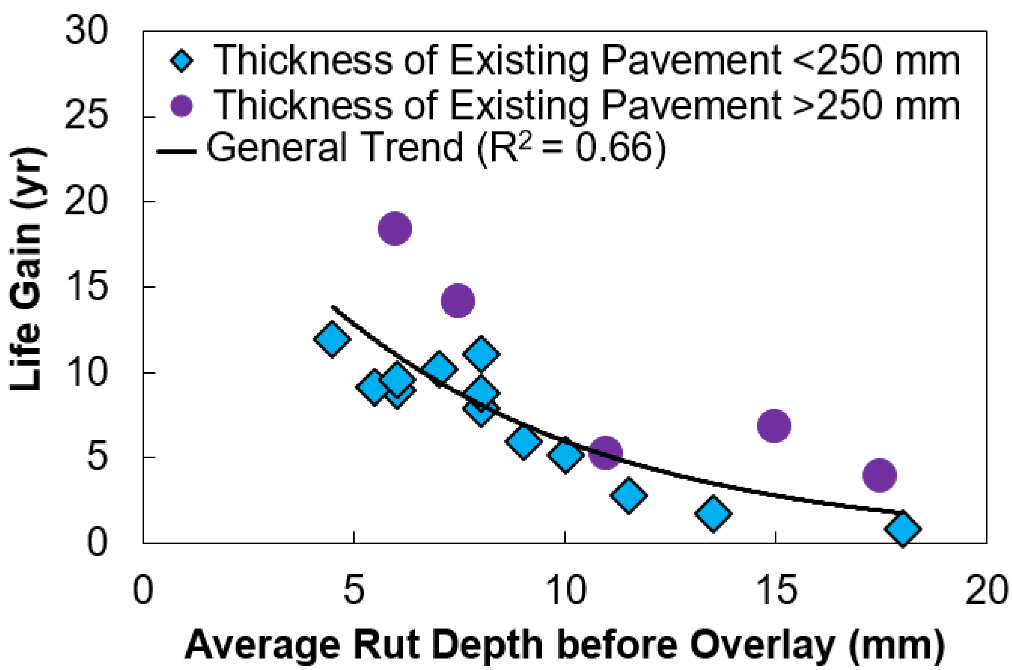
Thin-Overlay Thickness

Figure 13 and figure 14 present the relationship between the rutting life gain that results from the application of a thin overlay and the existing pavement condition in terms of overlay thickness and existing pavement thickness (i.e., total AC-layer thickness). Although overlay thickness appears to have an insignificant effect on the rutting life gain that results from the application of a thin overlay, the results demonstrate that a thin-overlay treatment provides a greater life extension when applied to thick, rather than thin, pavement structures.



Source: FHWA.

Figure 13. Chart. Effects of overlay thickness on general rutting trend.

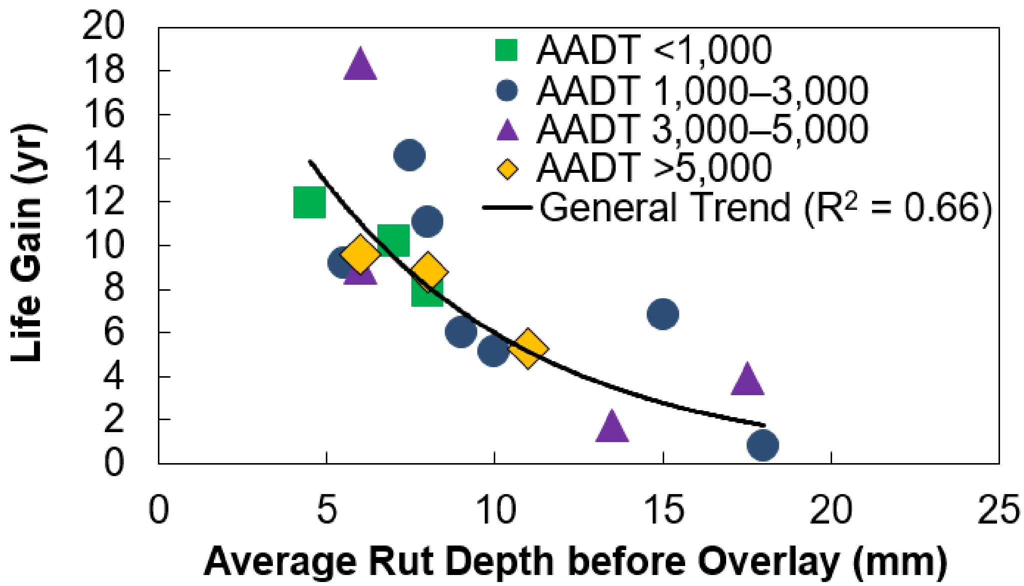


Source: FHWA.

Figure 14. Chart. Effects of thickness of existing pavement on general rutting trend.

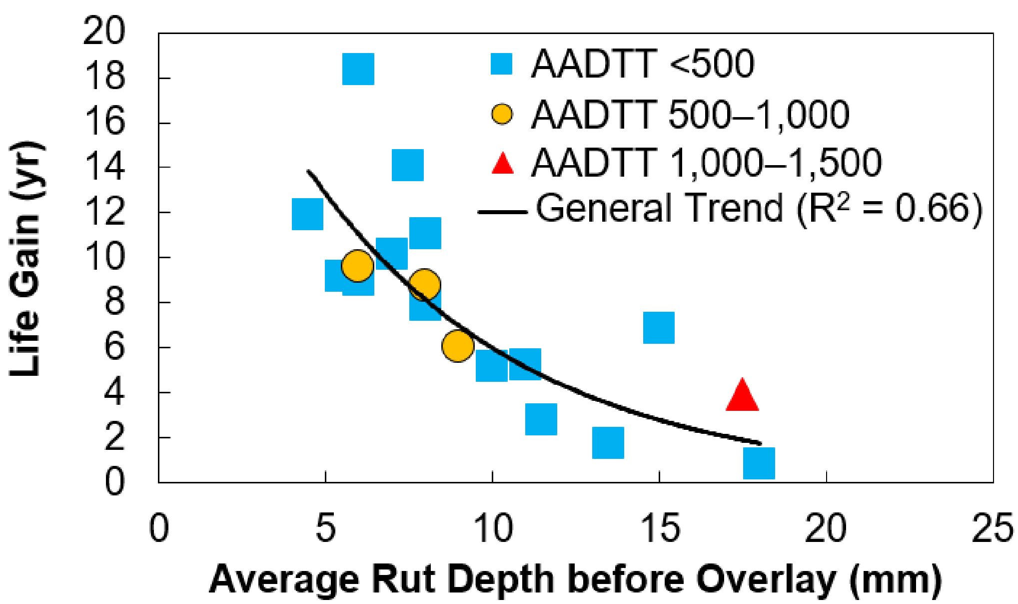
Total Traffic and Truck Traffic

Figure 15 and figure 16 present the relationship between the rutting life gain that results from the application of a thin overlay and the existing pavement condition in terms of AADT and AADTT. The results suggest that traffic does not significantly impact the ability of a thin overlay to retard rutting.



Source: FHWA.

Figure 15. Chart. Effects of AADT on general rutting trend.



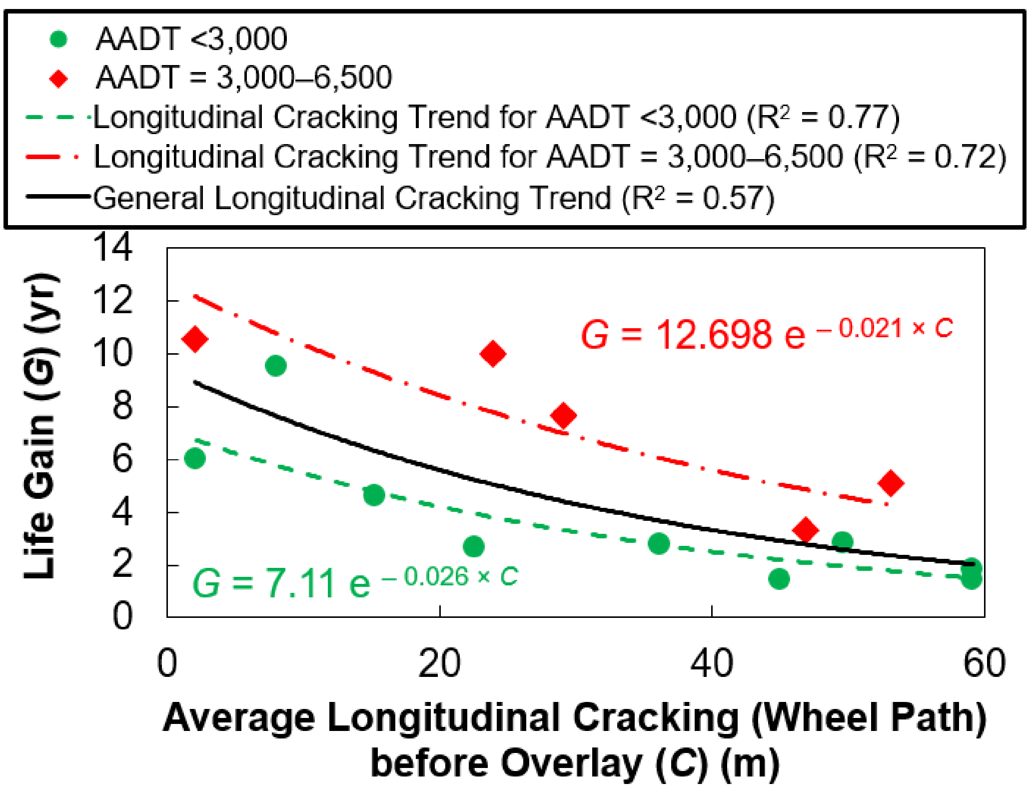
Source: FHWA.

Figure 16. Chart. Effects of AADTT on general rutting trend.

FINAL OBSERVATIONS

Data analysis of longitudinal cracking, based on various AADT categories, showed that the longitudinal-cracking thresholds that are required to trigger the application of a thin overlay should be AADT dependent. Similarly, based on the results presented, the rut-depth thresholds are dependent on the thickness of the existing pavement.

Figure 17 shows the relationship between the life gain and the existing pavement's longitudinal-cracking severity in terms of two traffic categories: (1) AADT less than 3,000 and (2) AADT 3,000–6,500. The trends for longitudinal cracking indicate that thin overlays can extend a pavement's service life further when the traffic exceeds 3,000 AADT compared to lower traffic levels. Although this trend might seem surprising, it is important to consider that sections with higher AADT counts generally will have significantly different structures (i.e., higher traffic roadways tend to have thicker total AC layers). In addition, the rate at which the control sections (against which the overlay sections are compared) deteriorate will affect the resultant life gain that is calculated. For roadways with higher traffic volume, the control sections may deteriorate much faster and result in a greater life gain from the overlay application. Equation 1 summarizes the predictive equations for life gain based on longitudinal cracking in the wheel path (m) as the performance indicator. Table 2 provides a summary of the proposed threshold trigger values for applying thin overlays based on the longitudinal-cracking results and a target life gain of 5 yr.



Source: FHWA.

Figure 17. Chart. Proposed fatigue (top–down) cracking performance-prediction equations for thin-overlay treatments.

$$\text{Life Gain } (G) = \begin{cases} 9.406\, e^{-0.026 \times C}, & \text{Overall Trend} \\ 7.11\, e^{-0.026 \times C}, & \text{AADT} < 3{,}000 \\ 12.698\, e^{-0.021 \times C}, & 3{,}000 \leq \text{AADT} < 6{,}500 \end{cases} \tag{1}$$

Where:

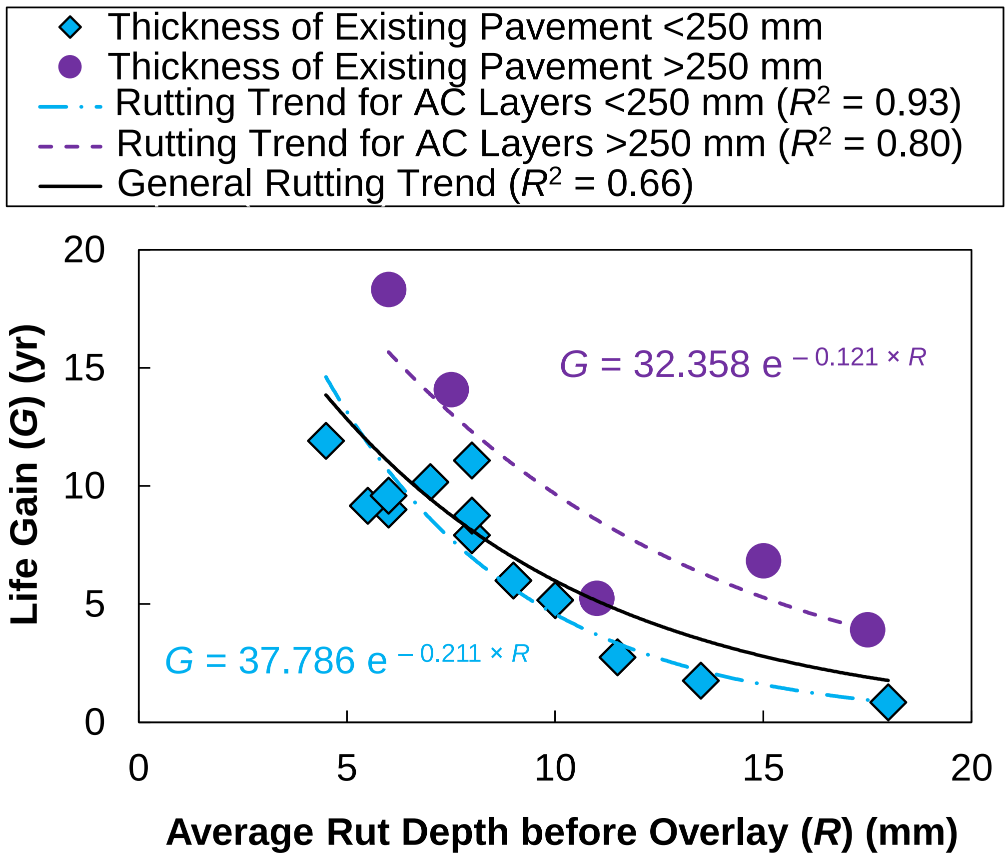
G = life gain (yr).

C = longitudinal cracking in the wheel path before overlay (m) for a section length of 152 m.

Table 2. Proposed threshold trigger values for thin-overlay treatments to achieve a minimum of 5 yr of life gain compared to control sections.

Performance Indicator	Condition	Threshold Trigger to Achieve a Minimum of 5 yr of Life Gain
Longitudinal cracking in the wheel path (m) (total section length 152 m)	Overall trend	24 m for a section length of 152 m
Longitudinal cracking in the wheel path (m) (total section length 152 m)	AADT < 3,000	13 m for a section length of 152 m
Longitudinal cracking in the wheel path (m) (total section length 152 m)	3,000 < AADT < 6,500	45 m for a section length of 152 m
Rut depth (mm)	Overall trend	11 mm
Rut depth (mm)	Existing AC layers < 250-mm thick	9 mm
Rut depth (mm)	Existing AC layers > 250-mm thick	15 mm

Figure 18 presents the relationship between the life extension that results from the application of a thin overlay and the existing pavement rut depth in terms of the existing pavement AC thickness as follows: (a) sections with a total thickness of AC layers less than 250 mm and (b) sections with a total thickness of AC layers more than 250 mm. As shown in figure 18, two distinct trends can be observed based on the total thickness of the AC layers in the existing pavement. The results suggest that thin overlays provide a greater life extension when applied to pavements with a total AC thickness that is greater than 250 mm. Based on the relationships presented in figure 18, rut-depth trigger thresholds that can be applied for a thin overlay in order to achieve a target life gain of 5 yr were derived and are listed in table 2. Equation 2 summarizes the predictive equations for life gain based on rut depth (mm) as a performance indicator.



Source: FHWA.

Figure 18. Chart. Proposed rutting-performance prediction equations for thin-overlay treatments.

$$\text{Life Gain } (G) = \begin{cases} 27.539\, e^{-0.153 \times R}, & \text{Overall Trend} \\ 37.786\, e^{-0.211 \times R}, & \text{Thickness of Existing AC Layers} < 250 \\ 32.358\, e^{-0.121 \times R}, & \text{Thickness of Existing AC Layers} > 250 \end{cases} \quad (2)$$

Where R is the average rut depth before overlay (mm).

It is noted that, as the thickness of the AC layers increases, the stresses experienced by the unbound layers would decrease. Low stresses on the unbound layers lead to less rutting in the unbound layers. In pavements with thick AC layers, permanent deformation in unbound layers would not be the main cause of the rutting due to low stresses in those layers, and the cause of rutting may be due to the quality of AC layers at the top of the pavement. This problem may be alleviated by adding a high-quality overlay on top of existing pavement. However, in pavements with thin AC layers, stresses in unbound layers are too large for an additional thin overlay to fix the rutting problem.(10)

CHAPTER 6. CONCLUSIONS

This paper presents a methodology that analyzes survey data on pavement condition to develop trigger thresholds in order to determine the best time to apply a thin overlay to achieve a desired (target) pavement-life extension. The analysis led to several promising results and conclusions that are summarized as follows:

- Thin overlays are an effective treatment for flexible pavement sections that contain existing rutting or longitudinal cracking in the wheel path.

- The performance of thin overlays is highly dependent on the condition of the existing pavement. Generally, a greater extension in pavement service life is achieved when the treatment is applied to a pavement that does not have significant distress.

- The level of AADT has a significant effect on the ability of thin overlays to retard longitudinal cracking.

- The thickness of the AC layers within the existing pavement has a significant effect on a thin overlay's ability to delay pavement rutting.

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