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EXECUTIVE SUMMARY

With increasing customer expectations and limited funding, VDOT must ensure that the most cost-effective, smooth, and long-lasting pavements are constructed on Virginia's highways. With the volume of traffic using Virginia's highways, the public will no longer tolerate excessive work-zone disruptions because of emergency or unplanned maintenance on a roadway. Additionally, VDOT cannot afford to rehabilitate these pavements prematurely. Both the public and VDOT want VDOT to "Get In, Get Out, and Stay Out." To fulfill this expectation, VDOT is designing pavements using new approaches and enhanced state-of-the-art materials.

VDOT like many other agencies utilizes life cycle cost analysis (LCCA) procedure into the process of selecting pavement type. This analysis incorporates proven national methodologies customized to Virginia's unique circumstances. VDOT looks beyond initial construction costs by considering the future maintenance and rehabilitation needs associated with a particular type of pavement. This approach, then, improves the decision-making process by enabling the selection of the most cost-effective type of pavement based on an estimation of *costs incurred* throughout a suitable analysis period, or "life cycle." For the LCCA procedure, a 50-year analysis period is considered sufficiently long to capture the maintenance and rehabilitation costs that span at least one full series of treatment activities with the exception of major rehab type projects where the analysis period is taken as the design life for the competing pavement options.

The procedure herein was derived largely from the Federal Highway Administration Technical Bulletin, *Life Cycle Cost Analysis in Pavement Design*, discussion with various stakeholders and both asphalt and concrete industries. Geared toward state highway agency personnel responsible for designing highway pavements, the FHWA bulletin provides technical guidance and recommendations on "good practice" in conducting LCCA in pavement design. It was authored by representatives of various state transportation departments, the Federal Highway Administration (FHWA), the National Asphalt Pavement Association, and the American Concrete Pavement Association. Additionally, VDOT's LCCA Guidelines draw upon the experience and expertise of its own workforce, particularly in areas related to pavement performance prediction and maintenance effectiveness as well as practices by other agencies. Where records are available, historic performance data were used to support planned maintenance/rehabilitation intervals for certain activities.

LCCA will enhance VDOT's ability to make sound engineering and cost-effective economic decisions pertaining to the construction/reconstruction and major rehabilitations of Virginia's major highways. However, it is important to remember that the LCCA process is based on the premise that the pavements are properly designed and will be reasonably maintained, that the quality of the construction and materials is consistently good, and that the pavement is not subject to adverse or unforeseen site conditions. Performance of the different pavement types and extent of specific rehabilitation treatment had been established based on available performance data, local practice and engineering judgments. Actual performance and the exact extent of the specific rehabilitation treatment of a particular project could be different. However, established parameters reflect the best possible realistic and practical assumptions that are needed to be made to perform LCCA computations.

I. INTRODUCTION

A major factor in selecting the type of pavement for use on new construction and major rehabilitation projects is cost. In many cases, the initial construction cost is the main consideration. Although a particular pavement type may have a low initial cost, the future maintenance and rehabilitation costs may be exorbitant and, therefore, must be considered in a fair and objective decision-making process. In order to account for the initial and future costs associated with the construction and maintenance of roadway infrastructure, a life cycle cost analysis (LCCA) should be performed. LCCA may not be necessary on all projects largely because of the nature and location of a particular project. LCCA is necessary for projects where multiple pavement types are feasible and considered. Materials Division's "Pavement Type Selection Procedures" document (section 606 of Chapter VI of MOI) outlines the situations where multiple pavement types should be considered and hence LCCA needs to be performed in order to select the most cost effective option.

Purpose

The purpose of this document is to provide technical guidance to VDOT engineers involved in selecting a pavement type for major construction and rehabilitation projects that provides the best cost effective solution. Separate tables have been generated and presented herein outlining the assumed performance and rehabilitation year and treatment for separate pavement type.

What is LCCA?

LCCA is an economic method to compare alternatives that satisfy a need in order to determine the lowest cost alternative. According to Chapter 3 of the *AASHTO Guide for Design of Pavement Structures*, life cycle costs "refer to all costs which are involved in the provision of a pavement during its complete life cycle." These costs borne by the agency include the costs associated with initial construction and future maintenance and rehabilitation. Additionally, costs are borne by the traveling public and overall economy in terms of user delay. The life cycle starts when the project is initiated and opened to traffic and ends when the initial pavement structure is no longer serviceable and reconstruction is necessary.

History of LCCA in VDOT

VDOT has used LCCA to evaluate and select pavement types on new Interstate and Primary Route projects for many years. Past LCCAs for pavements considered a 24-foot surface width and dealt with the cost for a lane mile. A 30-year analysis period was used, and only continuously reinforced concrete, jointed concrete, and flexible pavements were considered. In 2002, VDOT's LCCA was revised. One of the major changes was incorporation of 50 year analysis period and inclusion of the entire project cost as opposed to lane mile cost. The current revision (in 2011) reflects the updated performance of some materials and treatment, elimination of salvage value and inclusion of select major rehabilitation projects for LCCA process.

II. ECONOMIC ANALYSIS COMPONENTS

Analysis Period

To maintain consistency with the FHWA Technical Bulletin, *Life Cycle Cost Analysis in Pavement Design*, LCCA periods should be sufficiently long to reflect long-term differences associated with reasonable maintenance strategies. The analysis period should generally be longer than the pavement design period. As a rule of thumb, the analysis period should be long enough to incorporate at least one complete cycle of rehabilitation activity. The FHWA's September 1996 Final LCCA Policy Statement recommends an analysis period of at least 35 years for all pavement projects, including new or total reconstruction projects and rehabilitation, restoration, and resurfacing projects. For VDOT's LCCA procedure, a 50-year analysis period was selected for new construction and reconstruction type projects. This period is sufficiently long to reflect the service lives of several rehabilitation activities. For major rehab type projects where multiple pavement types are considered and LCCA is required, the analysis period is taken to be the design life of the rehab design.

Discount Rate

In order to account for the cost related to future activities, the time value of money must be considered. In LCCA, the discount rate is used. The *discount rate* is defined as the difference between interest and inflation rates. Historically, this value has ranged from 2% to 5%; for LCCA purposes, a value of 4% will be used. This value is consistent with the values recommended in the FHWA Interim Technical Bulletin and practices by many other state agencies. The discount rate accounts not only for the increased cost associated with performing an activity in the future but also for the economic benefit the agency would receive if those funds were instead invested in an interest-bearing account.

Evaluation Methods

Numerous economic analysis methods can be used to evaluate pavement alternatives. The two most common are the present worth (PW) method and the equivalent uniform annual cost (EUAC) method.

The EUAC method describes the average cost an agency will pay per year over the analysis period. All costs including initial construction and future maintenance are distributed evenly. Although this dollar value may not seem realistic in years when little pavement action is required, it can be used to evaluate and compare alternatives.

The PW method reports initial and future pavement costs as a lump sum amount in today's dollar value. For activities that occur in the initial year of the analysis period, the PW cost is the same as the actual cost, i.e., no adjustment for inflation and interest. For future maintenance and rehabilitation activities, the PW cost is less than the actual cost (based on today's unit prices) since total costs are discounted. Please note that for two identical actions that occur 30 years apart, the later action will cost much less. This is because of the number of years that are discounted. The PW method is the more widely used approach for pavement LCCA. It gives an indication of how much a pavement alternative will cost over the analysis period and can be used to clearly compare alternatives for lowest cost. The formula to compute both PW and EUAC are provided below.

$$PW = \text{Initial cost} + \sum_{k=1}^{n} \text{Re}\,habCost_k * \left[\frac{1}{(1+i)^n}\right]$$

Where: i = discount rate
k = year of activity
n = analysis period

$$EUAC = PW * \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

Where: i = discount rate
n = analysis period

Sensitivity Analysis

As with any analysis, it is important to understand what variables make the largest difference in the final results. For pavement design, the pavement subgrade strength and traffic loading have the largest impact on the design outcome. For LCCA, multiple variables can affect the final PW or EUAC for a pavement alternative. For example, the unit cost of a material alone can be significant enough to cause a particular alternative go from the lowest PW to the highest. Therefore, the engineer must ensure that the unit costs used are reasonable; likewise, it is important to understand how sensitive the cost of an alternative is to the input assumptions. This is accomplished by performing a limited sensitivity analysis whereby various combinations of inputs are selected to qualify their effect on the analysis results. Other factors that can influence the LCCA results are analysis period, and timing of activities.

III. COST FACTORS

Numerous costs are included in LCCA for pavements, ranging from initial costs associated with new construction to future maintenance costs associated with patching, sealing, and other activities.

Initial Costs

To conduct an LCCA for comparing pavement alternatives, the initial cost is a major percentage of the PW or EUAC over the analysis period. The initial cost is determined at Year 0 of the analysis period.

Although numerous activities are performed during the construction, reconstruction, or major rehabilitation of a pavement, only those activities that are specific to a pavement alternative should be included in the initial costs. By focusing on those activities, the engineer can concentrate on estimating the quantities and costs related to those activities. Actions dependent on pavement type include, but are not limited to the following:

- milling
- pavement removal
- asphalt concrete paving
- portland cement concrete paving
- fracturing portland cement concrete slabs

Rehabilitation Costs

For all pavement options, the initial pavement life is designed to support traffic for 30 years. At around the end of the 30-year period, the pavement must be rehabilitated. For flexible pavements, this rehabilitation generally includes removing AC surface and intermediate materials and replacing with new AC material. For rigid pavements, concrete pavement restoration (CPR) is generally conducted and an AC overlay may be placed. However, wherever feasible, concrete overlays could also be considered on both asphalt and concrete pavements. Rehabilitation activities may include but are not limited to the following:

- milling
- AC paving
- PCC and AC patching
- joint cleaning.

Structural/Functional Improvement Costs

Structural/functional improvement activities are performed during the life of a pavement in order to maintain a smooth, safe, durable pavement surface. Structural/functional improvements are designed to last 10 years (higher life for SMA mixes). Typical improvement activities include the following:

- milling
- AC and PCC patching
- AC paving
- PCC grinding
- joint cleaning and sealing

Maintenance Costs

All pavement types require preventive and corrective maintenance during their service life. The timing and extent of these activities vary from year to year. Routine reactive type maintenance cost data are normally not available except on a very general, area wide type cost per lane mile. Fortunately, routine reactive type maintenance costs are generally not very high due to the relatively high performance levels maintained on major highway facilities. Further, state highway agencies that do report routine reactive maintenance costs note little difference between most alternative pavement strategies. When discounted to the present, small reactive maintenance cost differences have negligible effect on PW and can generally be ignored. Therefore, they are not included in this LCCA procedure.

Salvage Value

At the end of the LCCA period, the pavement structure may be defined as having some remaining value to the managing agency, known as the salvage value. Different pavement types attain different condition at the end of the analysis period. If the condition of the pavement at the end of the analysis period is such that a complete removal and replacement is warranted, then the salvage value would have been the cost of any residual materials obtained from the pavement system (materialized by the agency). However, in most situations and depending on the timing and extent of the last maintenance treatment, the pavement either continues to remain in service or some kind of rehabilitation treatment is performed on the existing pavement (which may involve partial removal of the pavement materials or reclamation type treatment combined with overlays). So, pavements typically offer some sort of remaining life at the end of analysis period. In such cases, the residual value of the materials are not realized. Therefore, the remaining life essentially represents the salvage value of the pavement for practical purpose. Estimating a dollar figure for this component could be complex. Fortunately, the dollar figures for the 'salvage value' for the competing pavement types when discounted 50 years to PW are not expected to be significantly different. For simplicity, VDOT disregards the salvage value for the competing pavement types in its LCCA process.

IV. OVERVIEW OF LCCA PAVEMENT OPTIONS

In order to conduct a LCCA, different pavement options must be identified and compared for a project. The number and type of viable pavement options depend on the project's characteristics. After an examination of the pavement structures (flexible, rigid, and composite), six pavement options were created. The following table identifies these pavement options:

Construction/Major Rehabilitation Pavement Options
Asphalt Concrete Construction/Reconstruction
Jointed Plain Concrete Construction/Reconstruction with Tied PCC Shoulders
Jointed Plain Concrete Construction/Reconstruction with Wide Lane and AC Shoulders
Continuously Reinforced Concrete Pavement Construction/ Reconstruction with Tied PCC Shoulders
Continuously Reinforced Concrete Pavement Construction/ Reconstruction with Wide Lane and AC Shoulders
Major Rehabilitation

The pavement options, criteria and suppositions in the table were made to accommodate the consistent application of LCCA across the state. Without these guidelines, an infinite number of pavement options could be developed. For some pavement options, specific criteria and suppositions were made. The general criteria and suppositions made are summarized below. It should be noted that the actual rehabilitation treatment on a particular pavement may be different from these assumptions. The assumptions made in this LCCA document reflect the prevailing VDOT practice and does not necessarily put a binding requirement on the pavement engineers while rehabilitating pavements. For example, unbonded or bonded PCC overlay could be considered to rehab a PCC section if such treatment provides the best solution to the specific circumstance even though it is not programmed in the LCCA process for PCC pavements.

The general criteria and suppositions made are:

- No reconstruction is planned during the analysis period beyond the original rehabilitation/reconstruction.
- Flexible pavements remain flexible throughout the analysis period, i.e., no white-topping.
- Rigid pavements are overlaid with AC during the analysis period. No unbonded or bonded concrete overlays are programmed.
- Subsurface drainage systems are independent of pavement type. If a site needs drainage, then

all options call for drainage. Therefore, this cost is treated as fixed regardless of pavement type.

- Full-depth shoulders are designed to carry potential future traffic.
- The timing of functional improvements and major rehabilitation is fixed.
- The activities associated with new construction, reconstruction, major rehabilitation, and functional/structural improvements are a function of the project. The activities included in LCCA must be determined by the engineer and supported by documentation.
- Reconstruction is defined as the treatment that involves removal (partial or full depth) and/or manipulation of unbound materials for asphalt pavement. Removal and replacement of the concrete pavement (with or without manipulation of unbound materials) are considered reconstruction. Unbonded concrete overlays are considered reconstruction. Bonded concrete pavement is designed to improve structural capacity of the existing pavement and is not considered as reconstruction.

V. ASPHALT PAVEMENT CONSTRUCTION/RECONSTRUCTION

For most projects, asphalt pavement construction or reconstruction is a viable option. Asphalt pavement can be constructed on a new alignment or an existing alignment. For existing alignments, the in-situ pavement is removed completely. Asphalt pavement could be utilized to rehabilitate existing PCC pavement through fracturing the PCC pavement and overlaying with AC layers. Fracturing techniques includes break and seat, crack and seat, and rubblization. The type of fracturing performed is based on the existing rigid pavement type, e.g., jointed plain, jointed reinforced, or continuously reinforced concrete. Once the pavement has been fractured and overlaid, it is considered a flexible pavement structure. Such an option is considered to behave like a new asphalt structure and follow the same life cycle as new AC pavement.

Beginning early 2000, VDOT starts utilizing a premium asphalt mix known as Stone Matrix Asphalt or SMA. This mix provides better performance compared to conventional asphalt mixes. In order to differentiate between the performance of SMA and conventional mixes, two separate performance tables had been generated and presented in this section. The designer needs to use appropriate performance table based on the asphalt mixes to be used in the pavement section.

<u>Performance for Dense Graded Mixes</u>

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years. Because of functional mill and replace at Year 12 and 22, major rehabilitation is not scheduled until Year 32.
2. For the structural rehabilitation at Year 32, the pavement surface life is 12 years.
3. Functional mill and replace is a fixed activity at Years 12, 22, and 44 in order to provide 10 additional years of life to the pavement surface and structure. The 10-year period is the average life for an AC surface based on data in VDOT’s pavement management database.
4. For structural adequacy, the pavement overlay design life at Year 32 is 20 years. Pavement activities and required structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers) at the time of rehab.
5. Patching of AC pavements is based on area of pavement surface.
6. Preventive maintenance activities considered in the analysis include surface treatments (e.g., BSTs, thin overlays, slurrys, microsurfacing), crack sealing, and patching. Preventative maintenance is only specified in the analysis for the shoulders if a functional or structural improvement is performed on the mainline pavement. No preventative maintenance is programmed for the mainline pavement as part of the LCCA.

Pavement Activities Table

Year 0 – New Construction/Reconstruction	**Year 12 – Functional Mill and Replace**
Mainline* AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase Shoulders* AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase	Mainline Pre-overlay repair - Patch – 1% (up to the top of base layer) Mill – Surface Layer Replace with AC Wearing Course – one layer Shoulders Surface Treatment

*As appropriate

Year 22 – Functional Mill and Replace	**Year 32 – Major Rehabilitation**
Mainline Pre-overlay Repair - Patch – 1% (up to the top of base layer) Mill – Surface layer Replace with AC Surface Materials – one layer Shoulders Surface Treatment	Mainline Pre-overlay Repair - Patch – 5% (full depth) Deep Mill (All Surface and Intermediate Layers) Replace with AC Base Material AC Intermediate Material AC Wearing Course Shoulders Overlay with AC Wearing Course

Year 44 – Functional Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay repair - Patch – 1% (up to the top of base layer) Mill - Surface layer Replace with AC Wearing Course - one layer Shoulders Surface Treatment	None

<u>Performance for SMA surface</u>

The designer will consider this section if the pavement is to be built using SMA mixes. As with all pavement options, several criteria were established and assumptions made. It is assumed that the pavement system receives appropriate SMA mixes during all maintenance treatments.

1. The initial pavement design life is 30 years. The pavement system will undergo a functional mill and replace at Year 15 and major rehabilitation is scheduled at Year 28.
2. For the structural rehabilitation at Year 28, the pavement surface life is 15 years

(assuming SMA mixes to be used).

3. Functional mill and replace is a fixed activity at Years 15 and 43 in order to provide 13 additional years of life to the pavement surface and structure.
4. For structural adequacy, the pavement overlay design life at Year 28 is 20 years. Pavement activities and required structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers) at the time of the rehab.
5. Patching of AC pavements is based on area of pavement surface.
6. Preventive maintenance activities considered in the analysis include surface treatments (e.g., BSTs, thin overlays, slurrys, microsurfacing), crack sealing, and patching. Preventative maintenance is only specified in the analysis for the shoulders if a functional or structural improvement is performed on the mainline pavement. No preventative maintenance is programmed for the mainline pavement as part of the LCCA.

Pavement Activities Table

Year 0 – New Construction/Reconstruction	**Year 15 – Functional Mill and Replace**
Mainline* AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase Shoulders* AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase	Mainline Pre-overlay repair - Patch – 1% (up to the top of base layer) Mill - Surface layer Replace with AC Wearing Course - one layer Shoulders Surface Treatment

*As appropriate

Year 28 – Major Rehabilitation	**Year 43 – Functional mill and replace**
Mainline Pre-overlay Repair - Patch – 5% (full depth) Deep Mill (All Surface and Intermediate Layers) Replace with AC Base Material AC Intermediate Material AC Wearing Course Shoulders Overlay with AC Wearing Course	Mainline Pre-overlay repair - Patch – 1% (up to the top of base layer) Mill - Surface layer Replace with AC Wearing Course - one layer Shoulders Surface Treatment

Year 50 – Salvage Value	
None	

VI. JOINTED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH TIED PORTLAND CEMENT CONCRETE SHOULDERS

For most projects, a jointed concrete pavement with tied PCC shoulders is a viable construction or reconstruction option. Jointed concrete pavement can be constructed on a new alignment or on an existing alignment. If the existing pavement on an alignment is flexible, then the jointed concrete pavement can be constructed on top of it (if geometrically feasible). At the same time, unbonded jointed concrete pavement can be constructed on top of existing asphalt or concrete pavement. Such a treatment is typically comparable with reconstruction. Such pavement will follow the same maintenance cycles as that of a new jointed concrete pavement.

As with all pavement options, several criteria were established and assumptions made:

1. Initial pavement design life is 30 years.
2. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
3. The mill and replace is a fixed activity at Year 42 or at Year 45 (if SMA mix is utilized) in order to provide 10 or 13 (for SMA mixes) additional years of life to the pavement surface and structure.
4. The full-depth patching percentage for composite pavement is based on the pavement surface area.
5. The full-depth patching percentage for jointed concrete pavement is based on the pavement surface area.
6. PCC slab costs include the costs of tie bars, dowels, cut joints, and seal joints.

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline* Pavement Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Shoulders* Shoulder Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Soil Stabilization	Mainline Patching – 1.5% (of surface area) Clean and Seal Joint – 100%

*As appropriate

Year 20 – Concrete Pavement Restoration	**Year 30 – Concrete Pavement Restoration and AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 5% (of surface area) Clean and Seal Joints – 100% Grinding – 100%	Mainline Pre-overlay Repair: Patch – 5% (of surface area) AC Overlay (Minimum two lifts) with: AC Surface Material AC Intermediate Material AC Base Material Shoulders AC Overlay (Minimum two lifts) with: AC Wearing Course AC Intermediate Material AC Base Material

Year 42 or 45* –Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC overlay) - 2.5% (of surface area) Patching (PCC Base) – 2.5% (of surface area) Mill – Surface layer Replace with AC Intermediate Materials – one layer Overlay with AC Wearing Course – one layer Shoulders Overlay with AC Wearing Course – one layer	None

*If SMA mixes utilized at year 30

VII. JOINTED PLAIN CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH WIDE LANE (14 FEET) AND ASPHALT CONCRETE SHOULDERS

For most projects, a jointed concrete pavement with wide lanes and AC shoulders is a viable construction or reconstruction option. Jointed concrete pavement can be constructed on a new alignment or an existing alignment. If the existing pavement on an alignment is flexible, then the jointed concrete pavement can be constructed on top of it (if geometrically feasible). At the same time, unbonded jointed concrete pavement can be constructed on top of existing asphalt or concrete pavement. Such a treatment is typically comparable with reconstruction. Such pavement will follow the same maintenance cycles as that of a new jointed concrete pavement.

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years for the mainline. For the AC shoulders, the total thickness of the AC layers will be equal to the thickness of the mainline PCC slab.
2. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
3. The mill and replace is a fixed activity at Year 42 or at Year 45 (if SMA mixes are utilized) in order to provide 10 or 13 (for SMA mixes) additional years of life to the pavement surface and structure.
4. The full-depth patching percentage for composite pavement is based on the pavement surface area.
5. The full-depth patching percentage for jointed concrete pavement is based on the pavement surface area.
6. PCC slab costs include the costs of tie bars, dowels, cut joints, and seal joints..

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline with 14-Foot Lanes* – Inside and Outside Mainline Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Shoulders* Shoulder Removal (Reconstruction) AC Surface Material AC Intermediate Material AC Base Material CTA or DGA Subbase Soil Stabilization	Mainline Patching – 1.5% (of surface area) Clean and Seal Joint – 100% Shoulders Surface Treatment

*As appropriate

Year 20 – Concrete Pavement Restoration	**Year 30 – Concrete Pavement Restoration and AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 5% (of surface area) Clean and Seal Joints – 100% Grinding – 100% Shoulders Surface Treatment	Mainline Pre-overlay Repair: Patch – 5% (of surface area) AC Overlay (Minimum two lifts) with: AC Surface Material AC Intermediate Material AC Base Material Shoulders AC Overlay (Minimum two lifts) with: AC Wearing Course AC Intermediate Material AC Base Material

Year 42 or 45*– Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC overlay) - 2.5% (of surface area) Patching (PCC Base) – 2.5% (of surface area) Mill – Surface Course Replace with AC Intermediate Materials – one layer Overlay with AC Wearing Course – one layer Shoulders Overlay with AC Wearing Course – one layer	None

*If SMA mixes utilized at year 30

VIII. CONTINUOUSLY REINFORCED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH TIED PORTLAND CEMENT CONCRETE SHOULDERS

Continuously reinforced concrete pavement with tied PCC shoulders is a viable construction or reconstruction option. Continuously reinforced concrete pavement can be constructed on a new alignment or an existing alignment. If the existing pavement on an alignment is flexible, then the continuously reinforced concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. Initial pavement design life is 30 years.
2. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
3. The mill and replace is a fixed activity at Year 42 or at Year 45 (if SMA mix is utilized) in order to provide 10 or 13 (for SMA mixes) additional years of life to the pavement surface and structure.
4. The full-depth patching percentage for composite pavement is based on pavement surface area.
5. The full-depth patching percentage for continuously reinforced concrete pavement is based on surface area.

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline* Mainline Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Shoulders* Shoulder Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Soil Stabilization	Mainline Patching – 1% (of surface area) Clean and Seal Longitudinal Joint – 100%

*As appropriate

Year 20 – Concrete Pavement Restoration	**Year 30 – Concrete Pavement Restoration and AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 5% (of surface area) Clean and Seal Joints – 100% Grinding – 100%	Mainline Concrete Pavement Restoration: Patching – 5% (of surface area) AC Overlay with (typically two lifts): AC Wearing Course AC Intermediate or Base Material Shoulders AC Overlay (typically two lifts) with: AC Wearing Course AC Intermediate or Base Material

Year 42 or 45* –Mill and Replace	**Year 50 – Salvage Value**
Mainline Patching (AC Overlay) – 2.5% Patching (PCC Base) – 2.5% Mill - Surface Course Replace with AC Wearing Course – one layer Shoulders Surface Treatment	None

*If SMA mixes utilized at year 30

IX. CONTINUOUSLY REINFORCED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH WIDE LANES (14 FEET) AND AC SHOULDERS

Continuously reinforced concrete pavement with wide lanes and AC shoulders is a viable construction or reconstruction option. Continuously reinforced concrete pavement can be constructed on a new alignment or an existing alignment regardless of the existing pavement type. If the existing pavement on an alignment is flexible, then the continuously reinforced concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. Initial pavement design life is 30 years.
2. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
3. The mill and replace is a fixed activity at Year 42 or at Year 45 (if SMA mix is utilized) in order to provide 10 or 13 (for SMA mixes) additional years of life to the pavement surface and structure.
4. The full-depth patching percentage for composite pavement is based on pavement surface area.
5. The full-depth patching percentage for continuously reinforced concrete pavement is based on surface area.

Pavement Activities Table

Year 0 – New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline with 14-Foot Lanes* – Outside and Inside	Mainline
Pavement Removal (Reconstruction)	Patching – 1% (of surface area)
PCC Slab	Clean and Seal Joint – 100%
Stabilized Drainage Layer	Shoulders
CTA or DGA Base	Surface Treatment
Shoulders*	
Shoulder Removal (Reconstruction)	
AC Surface Material	
AC Intermediate Material	
AC Base Material	
CTA or DGA Subbase	
Soil Stabilization	

Year 20 – Concrete Pavement Restoration	**Year 30 – Concrete Pavement Restoration and AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 5% Clean and Seal Joints – 100% Grinding – 100% Shoulders Surface Treatment	Mainline Concrete Pavement Restoration: Patching – 5% AC Overlay (typically two lifts) with: AC Wearing Course AC Intermediate or Base Material Shoulders AC Overlay (typically two lifts) with: AC Wearing Course AC Intermediate or Base Material

*As appropriate

Year 42 or 45* – Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC Overlay) - 2.5% Patching (PCC Base) – 2.5% Mill - Surface course Replace with AC Surface Course – one layer Shoulders Surface Treatment	None

*For SMA mixes

X. LCCA FOR MAJOR REHABILITATION PROJECTS

As stated in the Pavement Type Selection Procedures document (also Section 606 of Chapter VI of the MOI), multiple pavement types should be considered for major rehabilitation projects that meet certain length and structural criteria as described in that document. The rehabilitation design life for such projects must be at least 20 year. Pavement at this stage is significantly old and projection of service life for another 50 years is not realistic. For performing LCCA on major rehab projects, analysis period will be considered same as design life. The maintenance activity will be the same as those for the respective surface type up to the design life (not including any treatment necessary at the end of design life). For example, if the design life for major rehabilitation project is 20 years, the analysis period will also be 20 years. For AC option, overlay activities will be considered at year 15 (SMA mixes) and 12 (Superpave mixes). For PCC surface, concrete pavement maintenance will be conducted at year 10. However, CPR activity scheduled at year 20 will not be considered for LCCA since 20 year marks the end of analysis period in this case. If the design life for the competing options are different, Equivalent Uniform Annual Cost (EUAC) approach shall be used instead of Present Worth (PW) approach to accommodate the difference in design life. EUAC distributes the PW of the each option (initial cost plus any treatment cost during the design life) equally over the analysis period. The formula to compute both PW and EUAC are provided in section II of this document.

XI. UNIT COSTS AND MEASURES

The life cycle cost for a pavement option is dependent on the corresponding activities required to construct and maintain the pavement. The cost for each activity is a function of unit cost and quantity measure. The following table provides units of measure. The measure is based on the Measurement and Payment Section in VDOT's *Road and Bridge Specifications* for each activity. The unit cost is based on historical and current costs to VDOT for similar or equivalent measures (i.e., quantities).

Activity	**Measure**
Milling/Planing	Square Yard – Inch
Fracturing PCC	Square Yard
AC Surface Material/Wearing Course	Tons
AC Intermediate Material	Tons
AC Base Material	Tons
Stabilized Drainage Layer	Tons
Pavement Demolition and Removal – Existing AC	Square Yard
Pavement Demolition and Removal – Existing PCC	Square Yard
Aggregate Subbase	Cubic Yard or Ton
Cement Treated Aggregate	Tons
Patching – CRCP	Square Yard
Patching – JPCP	Square Yard
Patching – AC	Tons
PCC Grinding	Square Yard
Joint Cleaning and Sealing	Linear Foot
CRCP	Square Yard
JPCP	Square Yard
Surface Treatment	Depends on Material Selected

XII. INTERPRETATION OF RESULTS

Once the LCCA is completed for a project, the PW cost results must be interpreted. For new construction (new alignment and reconstruction) projects, if the PW values differ by more than 10 percent, the pavement type with the lowest present worth shall be recommended for final selection. If the PW values are within 10 percent, the project is a suitable candidate for alternate bidding process and the final selection of the pavement type will be made based on the bids received on two different pavement types.

For major rehab projects, if the PW values (or EUAC if applicable) differ by more than 10 percent, the pavement type with the lowest present worth shall be recommended for final selection. However, ancillary costs (like maintenance of traffic, guard rail etc.) should be taken into consideration before making the final selection. If the PW values (or EUAC if applicable) are within 10 percent, the engineer should consider all pavement options as economically feasible. If more than one pavement option is determined to be economically feasible, then factors such as the following must be considered before making the final selection.

- initial constructability
- constructability of future improvements
- volume of traffic
- maintenance of traffic
- climate
- recycling
- adjacent existing pavement (if applicable)
- traffic safety
- incorporation of experimental feature
- participating local government preference