Life Cycle Cost Analysis

February 28, 2014

Executive Summary

Senate Bill 402, Section 34.25 requires NCDOT to report to the legislature on our life cycle cost analysis procedure by February 1, 2014. The four topics that are required in the legislation and a brief summary response are provided below:

1. Proportion of the Department's highway projects, by project category, for which the department has performed LCCA: 37% of Interstate Projects, 100% of Rest Area/Welcome Center projects, 43% of rural highway projects, and 36% of urban projects included life cycle cost analysis. Details of the projects and reasons for not conducting LCCA can be found on pages 8 and 9.
2. Federal or other statutory or regulatory impediments to the use of LCCA. No statutory or regulatory impediments are known.
3. A comparison between the Department's LCCA methodology and the LCCA methodology used by the U.S. Department of Transportation and by other states. A detailed comparison of NCDOT's methodology with 10 similar states is provided. This comparison shows that on most key components of LCCA, NCDOT uses similar values or approaches.
4. Information on the scope and nature of involvement of outside stakeholders in the Department's development and revision of its LCCA methodology. Details of the stakeholder involvement for the period of 2009 to 2013 are shown on pages 14 through 16. Between 1992 to 2009, the Pavement Management Unit has met regularly with industry representatives to discuss their interests and concerns, including LCCA

NCDOT's goal is to make the best possible economic and engineering decisions in selecting the pavement type for each project. Life cycle cost analysis (LCCA) is an important component of NCDOT's pavement type selection.

Introduction:

Life cycle cost analysis (LCCA) is a tool in making the pavement type selection. LCCA is a method of calculating the economic value of a pavement alternate considering its initial cost and the costs of future treatments over an analysis period (1). It combines economic analysis with engineering analysis. The economic analysis considers the time value of money in evaluating treatments over the analysis period of a pavement alternative. The engineering analysis involves the

Goal: Make the best business and engineering pavement type decision for each project.

identification of suitable pavement alternates and the type and timing of treatments that would occur for each alternate being considered.

Life cycle cost analysis is an important part of pavement type selection, but it is not the only consideration that an agency must evaluate. Urban projects require the agency to consider utility impacts and impacts to local businesses. Maintenance of traffic during construction and during future treatments is also an important factor.

Analysis Parameter	Value
Analysis Period	30 years
Discount Rate	4 percent
Economic Analysis Method	Present Worth
Included Initial Cost Elements	Full pavement structure Mainline pavement Paved shoulders
Flexible (Asphalt surfaced) Pavement	20-Year Structural Design
Rigid (Concrete) Pavement	30-Year Structural Design
Included Subsequent Costs	Rehabilitation at 10 and 20 years
Flexible Pavements	10-Year cost to mill and replace surface course
	20-Year cost to mill and replace surface course + Cost to provide any additional overlay thickness to meet structural requirements for 30-year analysis period.
Rigid Pavements	10-Year cost to clean and reseal joints
	20-Year cost to clean and reseal joints

Table 1: 2007 Life Cycle Cost Procedure

Note: to the extent they are available and there is a recognized difference between them, the following subsequent costs may also be included: user costs, annual maintenance costs, traffic control costs, and salvage value.

The pavement designer would typically develop pavement sections (layers of specific materials and their thicknesses) for three or more possible types: asphalt layers with asphalt base, asphalt layers with stone base, and jointed concrete pavement. For cases of widening adjacent to very stiff existing pavements, an alternate using cement treated aggregate base will be developed.

For each option, quantities are calculated for the mainline pavement and mainline shoulders. These quantities are sent to the Cost Estimating section which returns cost estimates to the pavement designer based on recent bid prices in the vicinity of the project. The unit costs are used to calculate the initial construction cost and the life cycle cost of each alternate pavement

design. A project description and life cycle cost figures for the project are sent to the Division in which the project is located as well as to the Pavement Review Committee. All options are discussed at the monthly Pavement Review Committee meeting.

LCCA Revision Process (2009 to present)

The North Carolina Turnpike Authority initiated discussions with NCDOT, North Carolina Aggregate Association, Carolina Asphalt Pavement Association, the southeast chapter of the American Concrete Pavement Association and the Association of General Contractors to reach consensus on a life cycle cost procedure to be used by the Turnpike Authority. The group met a total of ten times between December 2009 and March 2011. No consensus was reached.

In May, 2011, NCDOT contracted with David Peshkin, PE and Kelly Smith, PE of Applied Pavement Technology, Inc. to conduct a review of NCDOT's LCCA process. Mr. Peshkin is a nationally known expert in Pavement Management and LCCA. Their report (2) was finalized on January 6, 2012. Upon receipt of the final report, Pavement Management Unit engineers met to discuss the report and to recommend changes to our procedure.

NCDOT sought an additional external review beginning on July 11, 2012, aimed specifically at the timing of treatments for the major pavement types. This work was conducted by SAS using the Pavement Management System data and the final report (3) was received on August 21, 2012. Data provided to SAS included all sections and all historic data regarding construction and overlays. Data prior to 1980 has issues of quality and completeness. Inclusion of this data in the SAS analysis resulted in high standard deviations relative to the time to treatment.

Following receipt of the SAS report, minor modifications were made to the NCDOT proposed life cycle cost analysis procedure, and Applied Pavement Technology was contracted to conduct a review. That review was received on December 12, 2012 (4). The modified LCCA procedure is shown below. This modified version features use of equal design lives for flexible and rigid pavements, use of treatment times based on Pavement Management System history and a 45 year analysis period. Input from the asphalt industry led us to include a mill and replace treatment at year 12 instead of a more costly overlay treatment that requires guardrail and shoulder work. Minor patching of concrete pavements was included at 17 years to keep these pavements structurally sound. We continued to use Present Worth Analysis and a discount rate of 4 percent.

Time to Treatment (years)	Asphalt Pavements	Concrete Pavements
0	Initial Construction with 34-year design life	
12	Mill and replace 1.5 inches of surface and fog seal shoulders	
17		Saw and reseal joints and patch 1 percent of the area of the pavement's travel lanes. Fog seal shoulders if asphalt surfaced.
23	Mill and replace 1.5 inches of surface, including shoulders	
34	Mill 3 inches and add structure to achieve 20 more years of life. We assume this means milling and replacing with intermediate course in travel lanes only and overlaying with two lifts of surface course.	Unbonded jointed concrete overlay with a 30-year life.
45	Salvage (remaining life) value of 45 percent (9/20) of the year 34 treatment.	Salvage (remaining life) value of 63.3 percent (19/30) of year 34 treatment.

Table 2: 2012 Proposed life cycle cost procedure.

Mr. Peshkin concluded his review, "based on this review, NCDOT's proposed revised LCCA procedure is in line with the standard of practice associated with agencies with which NCDOT has the most in common." (4)

Significant interest in LCCA also existed in the NC House during 2012. The NC House Study Committee on Life Cycle Cost Analysis met on January 26, February 23, March 28 and April 19, 2012. Included in the report to the members of the Legislative Research Commission, dated April 2012, was the following recommendation: "Full and complete examination of Life Cycle Cost determinations."

On December 2, 2013, a meeting was convened by the Chief Engineer to discuss LCCA and the Federal Highway Administration technical guidance on alternate bidding. Pavement Management was tasked to review our LCCA recommendations, to meet with both the concrete industry and the asphalt industry to identify their ideas on how their product could/should be considered in LCCA. The meeting with the concrete industry representative was held on December 4, 2013 and with the asphalt industry representatives on December 6, 2013. NCDOT has received concerns from both industries that are detailed on pages 14-16.

Senate Bill 402, Sec. 34.25

This report is in response to Senate Bill 402, Section 34.25, page 316, which required NCDOT to report to the legislature on our life cycle cost procedure by February 1, 2014. Note that a two-week extension was requested and granted due to winter weather impacts on NCDOT. Specifically the legislation requires that NCDOT report on the following as a minimum:

1. "The proportion of the Department's highway projects, by project category, for which the Department has performed an LCCA
2. Federal and other statutory or regulatory impediments to the use of LCCA
3. A comparison between the Department's LCCA methodology and the LCCA methodology used by the U.S. Department of Transportation and by other states
4. Information on the scope and nature of involvement of outside stakeholders in the Department's development and revision of its LCCA methodology."

Summary Answers to the Four Questions

Question 1: When is Life Cycle Cost Analysis Conducted?

LCCA is done for the many of Transportation Improvement Projects (TIP) that are in the Interstate (I), Rural (R) and Urban (U) classes. "K" Projects are generally rest areas and weigh stations. LCCA is not done for bridge projects where the bridge construction costs dominate the project costs, nor is it done for projects that are designed and let by the Divisions. Similarly, it is not done for very short projects, where the tie-ins to existing pavement dictate the type of pavement that is feasible.

LCCA was conducted on 37% of the interstate projects, 100% of the K projects and 43% of the "R" projects. LCCA was conducted on about 36% of the "U" projects, where urban issues and widening are most common. The most common reason for not conducting LCCA was widening of existing asphalt pavement or variable widening. Four additional projects were not evaluated with LCCA because the average daily traffic (ADT) was below the threshold of 10,000 and three projects were less than 0.5 miles in length.

Question 2: Federal or Other Statutory or Regulatory Impediments

There are no known statutory or regulatory impediments to use of life cycle cost analysis. Use of life cycle cost analysis for NHS projects costing $25 million or more was mandated in the National Highway System (NHS) Designation Act of 1995. As part of the implementing guidance, no specific LCCA procedure was developed. Rather the guidance specified the use of good practice. The mandate on use of LCCA was lifted in the 1998 Transportation Equity Act for

the 21st Century (TEA-21), but FHWA has continued to provide training, materials and software to support the use of LCCA.

Question 3: Comparison of NCDOT's LCCA with that of Similar States

In the external report by David Peshkin, PE, and Kelly Smith (2), PE, NCDOTs life cycle procedure was compared to ten similar states. States used a variety of criteria for determining when to conduct LCCA, but most were related to project length, pavement thickness, or road class. None of the states used LCCA for all projects, for small projects, or for very short projects. Most states, including NC, use a discount rate of 4%, but the range is 1.1 to 4%. All of the states include initial construction costs and rehabilitation costs. Five also include engineering and administrative costs, two include mobilization. Four states, including NC, do not include user costs. Those that do include user cost consider it separately from LCCA. Seven of the states, including NC, include functional and structural rehabilitation and five states, including NC include pavement preservation. Eight states, including NC, used their Pavement Management System to determine treatment timing. None of the states have specific techniques for considering new technologies in LCCA.

Question 4: Scope and Nature of Stakeholder Involvement

The major stakeholder for whom NCDOT acts is the public. The goal of our pavement type selection process, and our life cycle cost analysis procedure is to make the best economic and engineering decision for each project, on behalf of the public.

Other external stakeholders are the three industries that supply the majority of paving materials: the Carolina Asphalt Pavement Association, the Southeast Chapter of the American Concrete Pavement Association, and the Aggregate Association. We interact regularly with all of these stakeholders through technical meetings and through email correspondence on a variety of issues, including life cycle cost analysis and alternate bidding. Another external stakeholder is Federal Highway Administration which contributes funding toward most of the projects for which LCCA is conducted.

Internal stakeholders include the Division in which a project is located, Roadway Design squad preparing the plans, Geotechnical Engineering who provides subgrade input, Work Zone Traffic Control Unit, and Project services. All of these stakeholders are part of the Pavement Review Committee which discusses each project, including life cycle cost analysis.

Proportion, by Project Category, for which LCCA is conducted

LCCA is done for the many of Transportation Improvement Projects (TIP) that are in the Interstate (I), Rural (R) and Urban (U) classes. These are centrally designed and centrally let

projects. "K" Projects are generally rest areas and weigh stations. LCCA is not done for bridge projects where the bridge construction costs dominate the project costs or where the length of paving on each side of the bridge is very short. LCCA is not done for projects that are designed and let by the Divisions. Similarly, it is not done for very short projects, where the tie-ins to existing pavement dictate the type of pavement that is feasible.

The table below demonstrates the wide variety of projects for which pavement designs are provided. LCCA was conducted on 37% of the interstate projects, 100% of the K projects and 43% of the "R" projects. LCCA was conducted on about 36% of the "U" projects, where urban issues and widening are most common. The most common reason for not conducting LCCA was widening of existing asphalt pavement or variable widening. Four additional projects were not evaluated with LCCA because the average daily traffic (ADT) was below the threshold of 10,000 vehicles per day and three projects were less than 0.5 miles in length.

Table 1 below lists projects other than bridge replacement projects that were designed by PMU in 2012 and 2013 and whether or not a LCCA was conducted as part of the pavement design process. For projects for which LCCA was not conducted, the reason is listed.

TIP #	**County**	**Route**	**Reason**	**LCCA (y or n)**
I-5338	Wake	I-40		yes
I-5311	Wake	I-440		yes
I-5501	Buncombe	I-26/NC 280	<0.5 mile; interchange	no
I-4733	Mecklenburg	I-77 at SR 5544	<0.5 mile and variable widening	no
I-4928	Gaston	I-85		yes
I-914BA	Vance and Warren	I-85	Corridor Consistency: Concrete	no
I-914BB	Warren	I-85	Corridor Consistency: Concrete	no
I-3802A	Cabarrus	I-85	Alternate Bid Design Build	no
K-4908	Iredell	I-77 Rest Area		yes
K-5002	Haywood	US 23 Rest Area		yes
R-2303D	Sampson	NC 24	SN<5	no
R-3421C	Richmond	US 220		yes
R-4047	Haywood	NC 209	Variable widening	no
R-2612B	Guilford	US 421	< 0.5 mile	no

R-4902	Mecklenburg	I-485	Widening existing asphalt	no
R-2246B	Cabarrus	George Liles Pkwy		yes
R-2707C	Cleveland	US 74		yes
R-2241A	Person	US 501		yes
R-3432	Brunswick	SR 1163	ADT<10000	no
R-2501C	Richmond	US 1	ADT<10000	no
R-2814C	Wake	US 401	Widening existing asphalt	no
R-3100A	Catawba	NC 16		yes
R-3100B	Catawba	NC 16		yes
R-2519B	Yancey	US 19E	Variable widening of existing asphalt	no
U-2810C	Cumberland	SR 1003	Widening existing asphalt	no
U-209B	Mecklenburg	US 74	Inside and outside widening	no
U-2809B	Cumberland	SR 1132	Widening existing asphalt	no
U-3321	Gaston	Garden Pkwy		yes
U-3315	Pitt	Stantonsburg Rd	Widening existing asphalt	no
U-2800	Forsyth	SR 2601	Widening	no
U-3459	Rowan	SR 2541	ADT < 10000	no
U-2925	Forsyth	Salem Creek Connector		yes
U-3465	Harnett	SR 1121		yes
U-4433	Wake	SR 1370		
U-4706	Cumberland	SR 1131	ADT<10000	no
U-2525B	Guilford	Greensboro Eastern Loop		yes

Table 3: Recent Pavement Design Projects and whether or not LCCA was used.

Federal and Other Statutory Impediments

The National Highway System (NHS) Designation Act of 1995 required use of life cycle cost analysis for NHS projects costing $25 million or more. However, no detailed life cycle cost analysis procedure was provided in the technical implementation guidance. The Federal Highway Administration (FHWA) told states to use "good practice." The Transportation Equity Act for the 21st Century (TEA-21) eliminated the mandate on use of LCCA in 1998, but FHWA has

continued to provide training, materials and software to support the use of LCCA. While lifting of the LCCA mandate may be viewed as an impediment, no change has been made in NCDOT's practice of conducting LCCA on projects for which pavement type selection is required.

There are no known impediments in North Carolina statute to impede use of LCCA analysis as part of the pavement type selection process.

Comparison of NCDOT's LCCA to Similar States (based on 2011 process)

FHWA has provided technical guidance, training and software to assist in conducting LCCA (6), but does not have a specific LCCA process. Using FHWA guidance, each state developed their process and typical values.

Component	Definition	NC value	How Chosen
Initial Cost	The cost of initial construction of an alternative.	Calculated for full cross section for 1 ft length	Based on cost estimates from project locale.
Analysis Period	The time over which various alternatives will be compared.	30 years; then 45 years proposed.	National trend is toward longer analysis period.
Discount Rate	The interest rate used to bring all expenses associated with each alternative to the time zero.	Was 4%. Would be 1.2% if OMB rate is used.	Value was specified in an early OIG audit. Now FHWA prefers use of OMB 30-year rate.
Design Life	The duration used in the design of the initial pavement thickness.	Was 20 years for asphalt and 30 years for concrete. Would be 34 years for both	Common practice in southeastern US. Best practice now is to use equal design life for all alternates.
Salvage Value	The remaining life value of the last treatment prior to the end of the analysis period.	None in early approach. Calculated in proposed approach.	Calculated
Treatment Type	Rehabilitation treatment usually done for that pavement type.	Example: asphalt overlay of asphalt pavement.	Pavement Management System
Treatment Timing	Time when a treatment will need to be applied.	Used to be 10 years for flexible; proposed is 11-12 years for flexible.	Used to be engineering judgment; now based on Pavement Management System.

Table 4: Common LCCA definitions and NC typical values

Element	NC	AL	CA	FL	GA	LA	OR	PA	TN	VA	WV
New/Reconstruction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rehabilitation			✓	✓	✓	✓	✓	✓	✓	✓	✓
Analysis Period (2011)	30	28	20-55	40	40	20	40-50	50	20-40	50	40-50
Discount Rate	4.0	4.0	4.0	3.5	3.0	4.0	4.0	4.0	4.0	4.0	OMB
Asphalt Design Life	20	12	20-40	20	20	20	20	20	20	20-30	10
Concrete Design Life	30	20	20-40	20	20	20	30	20	20	30	20
Salvage Value Tech.	Remaining Life		Remaining Life	Remaining Life	Remaining Life		Remaining Life	Remaining Life			
Other Features included	Shoulders& drainage	Shldrs, striping	Shldrs, drainage, earthwork	Shldrs	Shldrs	Shldrs. Ramps, striping	Shldrs, drainage, guardrail, temporary pavement	Shldrs, drainage, guiderail, approach slabs	Shldrs	Shldrs	Shldrs
Included agency costs	Construct., maint.., rehab, traffic control	construct. , maint., rehab	construct., maint., rehab, eng'g/ admin., traffic control, mobilization	construct. , maint., rehab	construct. , maint., rehab, eng'g/ admin.	construct. , maint., rehab	construct., maint., rehab, eng'g/ admin., bonuses	construct., maint., rehab, eng'g/ admin., mobilizat'n	construct. , maint., rehab	construct. , maint., rehab	construct ., maint., rehab, eng'g/ admin.
User cost Components	none	none	Work zone delay & operating costs	Work zone delay & operating costs + crash costs	Work zone delay and operating costs	Work zone delay and operating costs	Work zone delay and operating costs + crash costs	Work zone delay	none	none	Work zone delay and operating costs + crash costs
User costs considered separately ?			✓	✓	✓	✓	✓	✓			✓
Adjustments to improve cost estimates	Project size, location, price trends	Inflation, project size		Project location, Project size		Inflation	Project size, project location	Inflation, project size, project location, Inflation	Project location		Inflation, project location

% Difference to Consider LCC Equal	5 (use of 10 is proposed)	10	5	10		20-25	10	10	10	10	10
Input Variables subject to Sensitivity Testing				Future rehab periods, type of rehab and costs			Unit costs, discount rate, treatment timings for rehab.			Unit costs, analysis period, discount rate, treatment timing	Discount rate, material layer thickness, others

Table 5: LCCA elements and how they are defined by similar states. Source: Kelly and Peshkin (2).

Note: items in red will be discussed in the following report section.

Discussion of Comparison to Similar States

In the comparison to similar states, NCDOT and Alabama did not use LCCA for rehabilitation projects. NCDOT has historically "rehabbed in kind", meaning that concrete pavements had concrete rehabilitation while asphalt pavements had asphalt treatments. In the future, existing pavements consisting of asphalt over concrete or concrete over asphalt may be considered depending on the particular distresses in the existing pavement, restrictions on grade changes, and the existing pavement structure.

Most of the similar states, including NC, have used a discount rate of 4 percent. In the Federal Highway Administration Technical Advisory on Alternate Bidding (5), they stated that the figure in the Office of Management and Budget should be used in making comparisons of alternates. NCDOT proposed to use a 30-year rolling average of the OMB figure, but FHWA has stated that the 30-year figure (not a rolling average) should be used. This would change the discount rate from 4% to 1.2%.

The two rows of the table for Asphalt design life and Concrete design life are reddened. The FHWA Advisory on Alternate Bidding (5) also stated that the same design life should be used for all alternates. While NC was not an "outlier" (i.e. some other states were using different design lives for asphalt pavement than they were for concrete pavement), we propose to use an equal design life for both asphalt and concrete pavement in the future.

North Carolina generally includes two asphalt alternates; one with asphalt base and another with dense gravel base. Virginia does not include a dense gravel base alternate. Louisiana, Oregon and Tennessee do not include asphalt bases. Most of the states, including North Carolina, use jointed plain concrete with dowels, with either tied concrete shoulders or asphalt shoulders.

User costs are costs that are born by drivers and generally include delay costs and increased operating costs associated with work zones. Some agencies also include costs of accidents, but this is particularly challenging to collect. NCDOT has not historically included user costs because they are not costs to the agency. However, we are working with the Work Zone Traffic Control Unit to develop some typical cost tables for delay costs and operating costs caused by rehabilitation treatments to the roadway. Best practice is to consider user costs separate from the LCCA. That means that user costs are compared if the LCCA for two alternates is "equal". User costs of two alternates are considered equal if they are within 20%.

In our early version of LCCA, two alternates were considered to be economically equal if their LCCAs were within 5%. Based on the FHWA Advisory on Alternate Bidding (5) and on the common use of a 10% threshold among the similar states (2), we propose to consider two alternates equal if their LCCAs are within 10%.

LCCA is one component of the pavement type selection process. For a variety of reasons some states, including Texas, Oklahoma and Iowa, have NHS systems built primarily of concrete. Asphalt pavements have historically been dominant in the Southeastern states, as shown in Table 6 below. In comparison to other Southeastern states who responded with their system percentages, North Carolina's system has the second highest percentage of concrete interstate lane miles in the region. The comparison shows that NC is similar to other states for non-Interstate National Highway System roadways. The non-Interstate roads reflect the way the road system developed in North Carolina. Very low volume roads began as gravel roads, then were topped with surface treatments. Over time they were widened and paved with asphalt. These roads are frequently characterized by having many layers of pavement because they were constructed an asphalt layer at a time over many years.

		States					
		Miss.	Florida	Georgia	Virginia	N.C.	SC
Interstates	% Asphalt	79	91	85.6	88	75.6	71
	% Concrete	21	9	14.4	12	24.4	29
Other NHS	% Asphalt	97	99	96.5	99	98.8	99
	% Concrete	3	1	3.5	1	1.2	1

Table 6: Percentages of asphalt surfaced and concrete surfaced roadways in Southeastern states.

Stakeholders

As mentioned previously, NCDOT has many stakeholders in our Life Cycle Cost procedures. NCDOT represents the citizens in trying to make the best economic and engineering decision for each project. FHWA represents the citizens as a whole in trying to assure that our process meets the standard of "good practice" and to assure fiscal responsibility.

The two major stakeholders who have been involved in repeated discussions of life cycle cost analysis are the Southeast Chapter of the American Concrete Pavement Association (ACPA) and the Carolina Asphalt Pavement Association (CAPA). Detailed meetings were held with each industry in late 2013 to allow them to voice both their concerns and their thoughts on how their industry should be treated in LCCA. Both agreed with the general premise that treatment times should match agency experience, but both hoped for special consideration of improvements that should improve performance but that have not yet been demonstrated. These include use of 15 foot slabs which should reduce cracking in jointed concrete and increased asphalt content in Superpave mixes which should reduce alligator cracking in asphalt pavement. Both industries were assured that we would monitor the Pavement Management data and would modify the times to treatment once the improvements are apparent in the condition data.

In many cases, their concerns and desires are in direct opposition to each other. An example would be use of equal design lives for flexible and rigid pavement. The asphalt industry prefers to have a shorter design life for asphalt pavements because it significantly reduces the construction cost, which is the single largest element of the life cycle cost. The concrete industry prefers that both pavement types have equal design life. Use of equal design lives is specifically recommended in the FHWA Technical Advisory on Alternate Bidding (5) and we propose to move to equal design life of 30 years for both asphalt and concrete.

Both industries support the concept of using treatments in LCCA that are representative of field treatments. The asphalt industry noted, and was pleased, with use of mill and fill of the mainline pavement for the initial treatment instead of using a two lift overlay. NCDOT has realized significant savings using mill and fill due to reduction in cost of guardrail resetting and shoulder work. The concrete industry had previously noted that rather than an unbonded overlay at 30 years, use of an overlay with Ultra-Thin Bonded Wearing Course (UTBWC) is a more common treatment. We agreed and have proposed changing the treatment at 30 years, and repeating it at 40 years to UTBWC, combined with concrete patching. We are considering comments from CAPA that the 40 year treatment should be the unbonded overlay.

The use of the Office of Management and Budget discount rate has been discussed previously, but is mentioned again because it demonstrates the strong difference of opinion between the stakeholders. CAPA prefers the original 4% discount rate, while ACPA is in favor of the 30-year OMB discount rate.

CAPA was strongly in favor of including user costs in LCCA, believing that user costs for asphalt overlays will be significantly lower than treatments to concrete. FHWA has stated that best practice is to consider user cost separate from the LCCA. NCDOT proposes to develop user cost tables for delay cost and increased operating costs associated with work zones. It may take 6 months to a year to develop these tables. User costs will be considered separately, as recommended by FHWA.

The technical advisory on alternative bidding (5) says that only projects that have LCCA's within 10% should be considered for alternate bidding. This coincides with the threshold at which the agency costs are considered equal by most of the similar states. We propose to move our threshold from 5% to 10% to be consistent with FHWA guidance and practices in similar states.

The LCCA selection criterion needs to allow for consideration of specific project issues in addition to the economic analysis. These issues may include utilities in urban settings, and the number and frequency of driveways that require access during construction. The asphalt industry asked that the impact to the public of concrete construction's longer duration be included (note: this would be included in the user costs as previously described). The concrete

industry asked if it would be in the agency's best interest to consider the workloads of the respective industries during periods with very aggressive letting schedules.

Finally, the concrete industry asked that we consider using a lower cost typical section with aggregate base in lieu of permeable asphalt drainage layer for lower traffic volume roadways, including loop roads. This recommendation is under consideration, but is not part of the LCCA procedure.

The dialogue with industry representatives will not stop. An update on life cycle cost analysis is on the agenda for the CAPA DOT Joint meeting on February 27, 2014 and similar discussions will occur with ACPA. We have listened to industry input and have weighed it along with guidance from FHWA in developing a new LCCA procedure.

Next Steps

- Pavement Management Unit (PMU) will develop a draft LCCA. That draft will be discussed with both the asphalt industry and the concrete industry and with FHWA to assure that all parties have had additional input. Timeline, by April 30, 2014.
- As part of the preparation for the meeting with industry, PMU will compare 5 projects using both 1972 AASHTO design guide and the 2011 LCCA with mechanistic empirical design method pavement designs and the draft LCCA. These projects are intended to demonstrate the extent to which decisions may or may not change using the draft approach. This type of comparison was requested by the asphalt industry and NCDOT agrees that the comparison will assist in focusing the discussion of any proposed LCCA procedure. Timeline, by April 15, 2014.
- Based on the input from industry, a revised LCCA procedure, including details of time to treatment, treatment types, user costs, selection criteria, etc. will be sent for final comments from industry and FHWA. Timeline, by May 15, 2014. Note that final tables for user costs may not be available.
- The LCCA will be revised to consider comments received on the draft and the recommended LCCA will be presented to NCDOT leadership for approval. Timeline, by June 1, 2014 revised draft will be presented to NCDOT leadership.

Conclusions

NCDOT has used a process to review our LCCA procedure that includes gathering input from outside experts, other agencies, including FHWA, and our industry partners. We are continuing to dialogue with FHWA and industry in developing a revised LCCA procedure. Additional research is ongoing that will further improve the procedure by identifying the performance differences between full depth asphalt and asphalt over ABC.

If a data driven approach is selected, then there is a lag between the beginning of use of a new process (like Superpave asphalt or shortened slabs in concrete) and when you have enough data to change the time to treatment or treatment type in LCCA. This lag exists for both flexible pavements and rigid pavements.

The goal of the department is to select the most appropriate and cost effective pavement for each project. LCCA is a major tool in making this selection.

References

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2. Smith, Kelly L. and Peshkin, David, "North Carolina Department of Transportation Pavement Type Selection/ Life-Cycle Cost Analysis Process Evaluation", Applied Pavement Technology, Inc., Urbana, Illinois, December 2, 2011.
3. "North Carolina Department of Transportation Life Cycle Analysis", SAS Solutions On Demand, SAS Institute, Inc., Research Triangle Park, NC, August 12, 2012.
4. Peshkin, David, "Evaluation of North Carolina Department of Transportation Revised Life-Cycle Cost Analysis Procedure", memorandum report, Applied Pavement Technology, Inc., Urbana, Illinois, December 3, 2012.
5. "Technical Advisory: Use of Alternate Bidding for Pavement Type Selection", U.S. Department of Transportation, Federal Highway Administration, T 5040.39, December 20, 2012.
6. "Realcost 2.5" Life-Cycle Cost Analysis Software, Federal Highway Administration, Washington, DC, 10/23/2013.

Appendix A: Definitions

Initial cost: The cost of initial construction of an alternative. This cost includes the shoulder construction, pavement construction, subgrade stabilization, and all materials associated with the pavement and shoulders. The pavement costs do not include many other items that may be part of the contract, like utility relocations, bringing the project to final grade, bridge construction, installation of cross line pipes, pavement markings, guardrail adjustments, signing and engineering costs.

Time zero: The time associated with the initial cost. While the construction of a pavement project may extend over two or three years, the initial costs are assigned to a single point in time, usually the open-to-traffic date.

Analysis Period: The time over which various alternatives will be compared. The analysis period should be long enough to include one or more minor treatments and one rehabilitation treatment.

Design life: The duration used in the design of the initial pavement thickness. Best practice is to use equal design lives for all alternative pavement types.

Discount rate: The interest rate used to bring all expenses associated with each alternative to the time zero. The discount rate is based on the Office of Management and Budget long term rates and the rate is set on the first working day of the year for the entire year. NCDOT proposes to use a 30 year rolling average of the OMB long term rates.

Salvage Value: The value of remaining life in a particular treatment at the end of the analysis period.

Treatment type: The most common treatment for a particular pavement type.

Treatment timing and life: The most common time at which a treatment would be done for a particular pavement type and treatment type. The life is the period of time following treatment before a next treatment is required. The treatment timing and life should be based on the Pavement Management System.

User cost: The cost of delay due to construction activities that are experienced by the road user. This is considered separately from agency costs.

Cash flow: The series of expenditures and "income" associated with the initial construction, treatments, rehabilitation, and salvage value of a pavement alternate.

Present Worth: A single discounted value at a time considered to be time zero that is economically equivalent to the pavement alternative's cash flow.

Flexible Pavement: A pavement section with asphaltic material for the top surface. These are denoted as asphalt pavement in this report.

Rigid Pavement: A pavement section composed of concrete material as the top surface. These are denoted as concrete pavement in this report.

Structural Number: The result of the calculation of structural requirements from both the 1972 and the 1993 AASHTO Pavement Design Guide. The structural number is generally in the range of 1-10, with higher numbers for higher traffic volumes and higher truck traffic.

Fog Seal: A preventive maintenance emulsion applied to an asphalt pavement to retard aging and seal the surface.

Ultra Thin Bonded Wearing Course (UTBWC): A thin (5/8 inch typical), but very high quality layer consisting of a heavily polymerized emulsion applied using a spray paver followed immediately with high quality stone.