By Tom Kuennen, Contributing Editor

# Apples, Oranges and Pavements

**The value of life-cycle cost analysis lies in its ability to effectively compare a variety of different entities.**

When it comes to the long-term price of pavements, is it a good idea to compare apples to oranges? And if it is, can it be done?

The answer is "yes" if you use life-cycle cost analysis, or LCAA, prior to a project to compare design and material alternatives.

Life-cycle cost analysis (LCCA) helps government road agencies to better compare alternatives for proposed highway project design, based on the total – estimated or calculated – life-cycle cost for each alternative.

LCAA permits total cost comparison of the competing designs of a project. The Federal Highway Administration (FHWA) says in its *Life-Cycle Cost Analysis Primer* guide that all of the relevant costs that occur throughout the life of an alternative, not simply the original expenditures, are included.

That primer – and many other LCCA tools – may be downloaded from FHWA's Office of Asset Management at *www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm*.

What is the life cycle of a pavement? It is the totality of the pavement's journey, so to speak, including design, materials, construction, maintenance and preservation, all the way through the costs of potential demolition of the exhausted pavement and salvage value of the remaining materials.

Life cycle costing attempts to affix costs to each of the aspects of a pavement, such as initial materials and construction, to performance over years, to deterioration rates, to costs to an agency, and also user costs incurred any time motorists are interrupted or delayed as the result of agency activity involving the pavement.

One challenge to the agency is to make sure the analysis includes all cost variables that are meaningful, and excludes externalities (fringe costs) that have minimal to no bearing on the pavement life cycle.

LCCA delves into the financial side, an area in which civil engineers may not be acquainted. LCCA will compare present and future cost streams of the design options, taking into account including inflation and interest rates on project expenses during the complete

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life of a project. The analysis also has to figure in unpredictable variables that will maintain its accuracy even though unanticipated events rock the boat.

A number of software programs are available that will accept those cost inputs and permit comparison of total pavement worth or value over the period of the throughout the pavement's existence.

Life-cycle costing is not a new concept. The American Association of State Highway & Transportation Officials (AASHTO) – then the American Association of State Highway Officials (AASHO) – first introduced the concept of life-cycle cost analysis (or cost-benefit analysis) to the broader highway construction community in 1960, as the interstate highway program approached its apex.

In AASHTO's 1986 *Guide for the Design of Pavement Structures*, the use of LCCA was encouraged, and a process was laid out to evaluate the cost-effectiveness of

Illustration by Edd Hickingbottom

Better Roads

# Elements of LCCA Unfold Throughout the Decades

alternative designs. The AASHTO Design Guide encouraged the concept of life cycle costing and gave detailed discussions about the various costs that should be considered in life cycle cost analysis. AASHTO continued its emphasis in its 1993 Design Guide.

The National Highway System (NHS) Designation Act of 1995 specifically required states to conduct life-cycle cost analysis on NHS projects costing $25 million or more. But this requirement was rolled back by 1998's Transportation Equity Act for the 21st Century (TEA-21) , the surface transportation bill preceding the current SAFETEA-LU. Still, FHWA is working to promote life-cycle costing of pavements – as well as other themes such as pavement preservation – via its Office of Asset Management, created in February 1999.

While the FHWA is vigorously researching and promoting life-cycle cost analysis, the states are doing their share as well, with widespread penetration of this analysis into state Department of Transportation planning.

## LCCA required by law

For example, today Colorado DOT requires that a life-cycle cost analysis supporting the pavement type selection be prepared for all appropriate projects with more than $1 million initial cost of the pavement. "LCCA is a process used by the CDOT to compare concrete to asphalt pavements, or compare alternative rehabilitation techniques," reported George Paul Demos in Colorado DOT's 2006 report, *Life-Cycle Cost Analysis and Discount Rate on Pavements for the Colorado Department of Transportation*. Colorado's life-cycle cost analysis procedures were adopted in 1981 and have been updated periodically.

In the 1990s, the Texas DOT funded a project to develop a Rigid Pavement System (RPS), a computer program which performs a life-cycle cost analysis of rigid pavements and ranks alternate designs by total life cycle cost (see below).

While it's not required by edict, states are adopting LCCA because it makes sense. "Performing LCCA to develop more economical strategies is becoming more important for transportation agencies as traffic volumes increase, highway infrastructure deteriorates, and their budgets tightens," said Prasada Rao Rangaraju, Serji Amirkhanian, Zeynep Guven, Clemson University, in their 2008 paper for the South Carolina DOT, *Life-Cycle Cost Analysis for Pavement Type Selection*.

"To be able to perform a LCCA, the parameters used in the analysis must be applicable and appropriate," they said. "All factors must be considered in the analysis such as user-delay costs and salvage value. Also, regional factors such as types of rehabilitation measures employed for each alternative, or the past performance of pavements must be considered."

Their work was commissioned by the DOT because at its writing South Carolina used LCCA infrequently for its pavements. "Presently," they said, "South Carolina DOT employs a simple procedure that considers only initial construction costs and future costs of rehabilitation. Often the difference between the net present values of the alternatives is so close that there will be significant uncertainty in the decision-making process. Also, the current procedure employed by SC DOT is deterministic, which does not take into account the uncertainty associated with the input parameters."

To show the state's position on LCCA in regard to other states, the authors conducted a valuable survey that provides a snapshot of LCCA use by state DOTs throughout the United States. Of the total of 33 states and two Canadian provinces that participated in the preliminary survey, 94 percent of the agencies indicated that they use LCCA as part of the decision process for selecting pavement type. Only one, Maine, stated it did not use LCCA.

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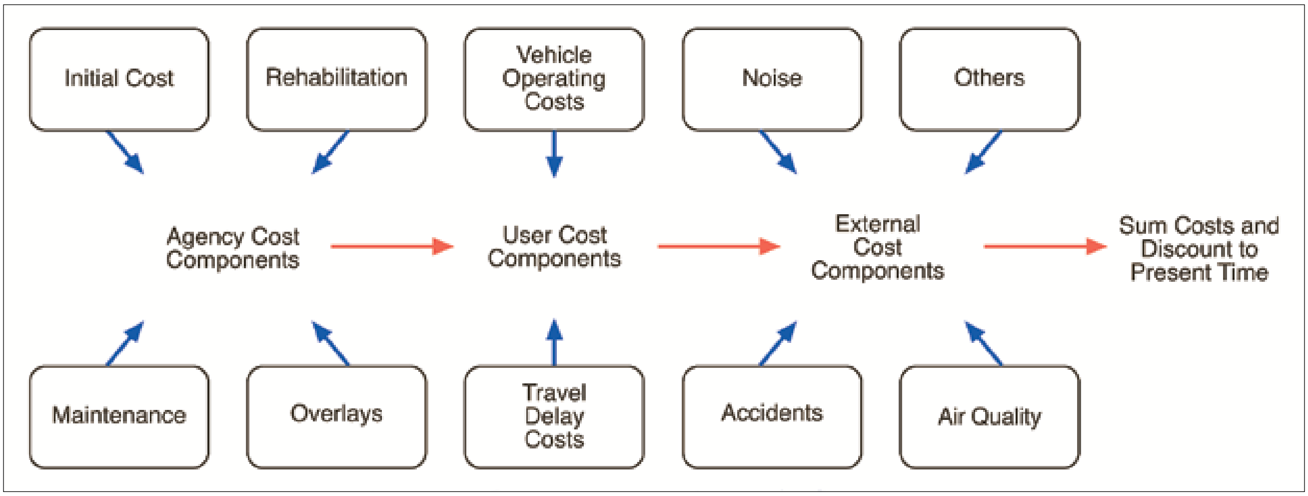


*Fig. 1: Cost inputs to three aspects of a life cycle cost analysis result in a comprehensive, reliable LCCA for any pavement type or design*

*Chart courtesy of the Center for Transportation Research, University of Texas-Austin*

*Portland cement concrete pavements are a long-time favorite for durability*

*Photo courtesy of American Concrete Pavement Association*

Transportation officials were also asked if they included user costs in the analysis. "Most of the responding states – approximately 60 percent, 19 out of 32) do not consider user costs in LCCA calculations," the authors wrote.

And the FHWA's software standard, RealCost, is becoming the LCCA program of choice. "Based on the results of this survey," they wrote, "it appears that after the release of the RealCost program in 2002 by FHWA, more state agencies have adopted this program than other software for conducting their LCCA calculations."

The Clemson University report for South Carolina may be downloaded at *www.clemson.edu/t3s/scdot/pdf/projects/SPR656Final.pdf*.

## Getting analysis period right

The life-cycle cost analysis period is the complete time line over which costs and pavement design alternates are considered. It must be long enough to provide meaningful long-term cost differences, perhaps three to four decades or longer.

"LCCA is an analysis technique that builds on the well-founded principles of economic analysis to evaluate the over-all-long-term economic efficiency between competing alternative investment options," FHWA said in its 1998 report, *Life-Cycle Cost Analysis in Pavement Design: Interim Technical Bulletin*. "It does not address equity [social justice] issues. It incorporates initial and discounted future agency, user, and other relevant costs over the life of alternative investments. It attempts to identify the best value (the lowest long-term cost that satisfies the performance objective being sought) for investment expenditures."

While FHWA's LCCA Policy Statement recommends an analysis period of at least 35 years for all pavement projects, including new or total reconstruction projects as well as rehabilitation, restoration, and resurfacing projects, an analysis period range of 30 to 40 years is not unreasonable, FHWA said. "The Net Present Value (NPV) is the economic efficiency indicator of choice," FHWA said. Other indicators include benefit/cost ratio (B/C), equivalent uniform annual cost (EUAC), and internal rate of return (IRR).

For an LCCA, FHWA said, future cost and benefit streams should be estimated in constant dollars and discounted to the present using a real discount rate. Although nominal dollars can be used with nominal discount rates, use of real/constant dollars and real discount rates eliminates the need to estimate and include an inflation premium. In any given LCCA, real/constant or nominal dollars must not be mixed (i.e., all costs must be in real dollars or all costs must be in nominal dollars).

Further, the discount rate selected must be consistent with the dollar type used (i.e., use real cost and real discount rates or nominal cost and nominal discount rates). The discount rates employed in LCCA should reflect historical trends over long periods of time.

Life-cycle cost analysis unfolds within a logical framework in which each step leads to better understanding and more details.

In 2002's *Life-Cycle Cost Analysis Primer*, FHWA's Office of Asset Management lists these five steps for a successful program:

- Establish design alternatives
- Determine activity timing
- Estimate costs (agency and user)
- Compute life-cycle costs, and
- Analyze the results.

The Center for Transportation Research at the University of Texas-Austin took that concept much further in its Project Summary Report 1739-S, *A Life- Cycle Cost Analysis of Rigid Pavements*, by Rob Harrison, Steve Waalkes, and William James Wilde.

## Texas develops modular LCCA

The Texas DOT wanted to promote LCCA of rigid pavements throughout its districts by developing a uniform methodology for performing life-cycle cost analyses that would eventually include all pavement types. The project developed a comprehensive, modular life cycle cost methodology that could evaluate existing and future projects.

"In developing the framework for a new life-cycle cost methodology, all possible aspects of pavement performance, rehabilitation, social and economic impacts, and public safety were studied, considered, and included, where appropriate," the authors wrote. "Many of these components are neither fully understood nor easily calculated, yet an attempt to quantify and valuate each aspect was made in developing the framework."

The first step in the framework is to determine the initial cost of the pavement alternative, based on design inputs such as pavement thickness, number of layers, aggregate type, and concrete properties.

The next step in the framework is to evaluate how well the pavement design alternative will perform over its intended lifetime. "This evaluation is performed by predicting the distresses that will occur in the pavement at the end of each year in the lifetime of the pavement," the authors wrote. "If the distresses are severe enough to require attention, rehabilitation and maintenance activities will be specified and the associated costs will be calculated."

Associated user costs (based on construction activities or work zones) and other external costs are calculated. The researchers developed a schematic flow chart which highlights the stages of LCCA develop; see Fig. 1.

In this decade, life-cycle cost analysis for bridges also has been refined. In 2003, NCHRP Project 12-43, *Life-Cycle Cost Analysis for Bridges* resulted in NCHRP Report 483, and CRP-CD-26, a CD bound within the report that contains bridge LCCA software which considers agency and user costs while enabling the user to consider unpredictables and uncertainty in the analysis.

The report is in two parts, a report, and guidance manual, which outlines the concept of life-cycle costing, identifies sources for data, and explains the methodology by which life-cycle costing can be conducted.

In combination, the report, guidance manual, and software are a powerful tool that can be applied to the decision-making process for the repair or selection of cost-effective alternatives for the preservation of bridge assets for short-term and long-term planning horizons. Find out how to order the materials at *http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_483a.pdf.* ❖

*Full-depth asphalt sections like hot mix asphalt perpetual pavements give portland cement concrete competition in long-term performance with minimal associated costs*

*Photo courtesy of Flexible Pavements of Ohio*