Agencies gain a bridge lifecycle assessment tool

Software program standardizes materials and design comparisons

By Mark A. Ehlen, Ph.D.

State departments of transportation (DOTs) are currently in the difficult position of having backlogs of bridges to repair and increasingly smaller budgets. Nationally, these repair costs are large, totaling as much as $90 billion, according to one report. Consequently, many of these agencies are looking for ways to make their bridges less costly to build and longer lasting. New construction materials — such as high-performance concrete (HPC), FRP composites, high-performance steel and new applications of wood and aluminum — show promise toward reducing the sum of a bridge's construction, maintenance/repair, and disposal costs, also known as its "lifecycle" cost. Their technical performance can be verified using standard methods, but agencies still need a tool for assessing the lifecycle cost effectiveness of the materials.

The National Institute of Standards and Technology (NIST) has recently completed the beta version of BridgeLCC, a Windows lifecycle costing software program for bridge engineers. Based on ASTM Practice E 917 for measuring the lifecycle costs of buildings and building systems, BridgeLCC provides a standardized, user-friendly tool for comparing the lifecycle costs of alternative bridge materials and bridge designs. The software is designed to accommodate new construction materials but works equally well for comparing conventional materials.

The program begins with bridge costs that are most familiar to engineers: the "engineer's estimate" of initial construction costs. When making a preliminary design of a new bridge, engineers typically estimate the construction costs of two or more alternative designs, such as a concrete-beam design versus a steel-beam design. BridgeLCC allows the user to input the engineer's estimate for each alternative and then the remaining costs in the ASTM Practice — operation, maintenance, and repair (OM&R) and disposal costs. Using an NIST cost classification scheme, engi-

Mark A. Ehlen is an engineer and economist in the Office of Applied Economics at the Building and Fire Research Laboratory, National Institute of Standards and Technology.

The National Institute of Standards and Technology (NIST) has recently completed the beta version of BridgeLCC, a Windows lifecycle costing software program for bridge engineers. Based on ASTM Practice E 917 for measuring the lifecycle costs of buildings and building systems, BridgeLCC provides a standardized, user-friendly tool for comparing the lifecycle costs of alternative bridge materials and bridge designs. The software is designed to accommodate new construction materials but works equally well for comparing conventional materials.

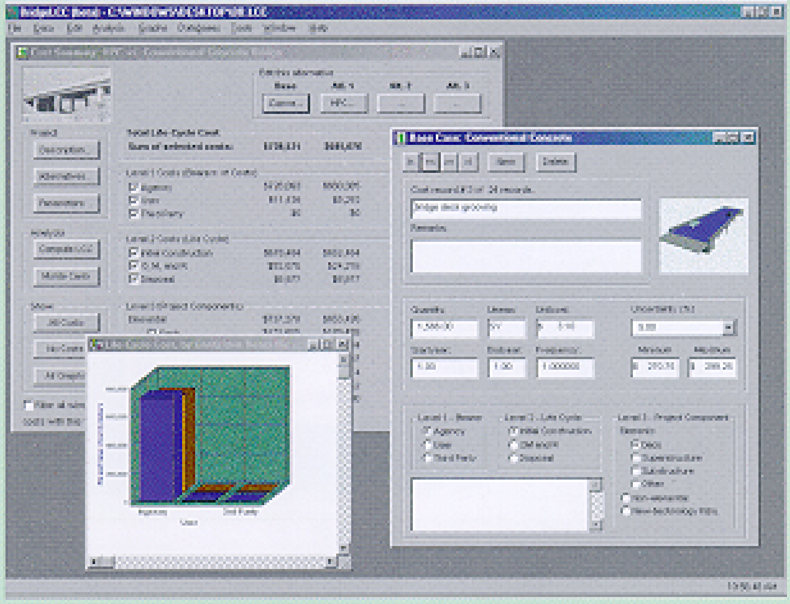

Figure 1

neers also can enter user costs and third-party costs. User costs are incurred by automobile drivers on and under the bridge, and third-party costs are incurred by third parties who are not direct users of the bridge but are affected by bridge construction activities, such as lost revenues of businesses whose customers are blocked by bridge work.

If detailed OM&R records are unavailable, DOT personnel can often estimate these costs, such as the number of workers and workdays it takes to repair a 25-year-old bridge deck. User-cost statistics can be obtained from the DOT transportation engineering division, while third-party costs can be obtained from field experts or from the affected third parties, such as the affected business which is adjacent to the bridge.

BridgeLCC can quantify technical and cost uncertainties. Technical uncertainty regards how a new material will perform: Will it carry loads as designed? Will it last longer than or not as long as the conventional material currently being used or proposed for use? Engineers can use the sensitivity analysis features in BridgeLCC to conduct "what if" scenarios to see to what extent changes in expected technical performance affect the cost effectiveness of the material.

Cost uncertainty relates to how sure a designer is about a particular cost. For example, an engineer may know that the cost to install a conventional-concrete bridge deck is between $160 and $170 per square meter ($15 and $16 per square foot), but knows the cost of an alternative, new-technology deck to be between $160 and $220 per square meter ($15 and $20 per square foot). BridgeLCC allows the user to choose these ranges of costs for deck installation. The software can then perform a "Monte Carlo" simulation to compute the ranges of potential lifecycle costs for each alternative.

BridgeLCC analyses follow nine ASTM-based steps

The first step specifically defines the project objective, which includes the performance requirements of the structure. For example, the project objective could be to build, maintain, and eventually dispose of a two-lane overpass. The performance requirements could be that the structure routes Interstate 95 traffic over Interstate 40, that it carry AASHTO HS-20 design loads, and that it last 75 years, given some maintenance and repair work. This formal set of steps (See Figure 1, page 43) helps engineers address a wide range of bridge decisions, such as whether to construct a new bridge from concrete or FRP composites, whether to repair or replace an existing bridge, and whether to paint a steel bridge every 10 or every 20 years.

Case illustration shows how program can be utilized

Consider an engineer who is deciding whether to build a two-lane, 100-meter by 13.5-meter (328-foot by 44-foot) highway bridge either from a new, high-performance concrete (HPC) or from a conventional concrete currently being used. The HPC chosen allows the engineer to specify fewer beams than in a conventional-concrete bridge and to predict that deck repair will occur every 40 years instead of every 25 years.

Following the nine BridgeLCC steps, the engineer can assess the cost effectiveness of HPC over conventional concrete for this particular bridge.

The engineer first defines the project objective, such as building a bridge that is 100 meters (328 feet) long and 13.5 meters (44 feet) wide, is designed to carry HS-20 loads, and lasts 75 years. He defines the alternative designs — conventional-concrete deck and beams versus high-performance-concrete deck and beams — establishes assumptions about traffic on and under the bridge that occurs over the life cycle; compiles the construction, OM&R (operation, maintenance, and repair) and disposal costs for the two alternative structures; and then he computes the lifecycle cost of each bridge by discounting each year's costs to present value using a published discount rate. The BridgeLCC Cost Summary window lists the lifecycle cost of each alternative: $739,531 for the Conventional-Concrete Bridge, and $685,678 for the HPC bridge.

The BridgeLCC Cost Summary window presents three cost-breakdown sections: Bearers of Costs (Level 1), Life Cycle (Level 2), and Project

"BridgeLCC can quantify technical and cost uncertainties. Technical uncertainty regards how a new material will perform: Will it carry loads as designed? Will it last longer than or not as long as the conventional material currently being used or proposed for use?"

The first step specifically defines the project objective, which includes the performance requirements of the structure.This formal set of steps (See Figure 1, page 43) helps engineers address a wide range of bridge decisions, such as whether to construct a new bridge from concrete or FRP composites, whether to repair or replace an existing bridge, and whether to paint a steel bridge every 10 or every 20 years.

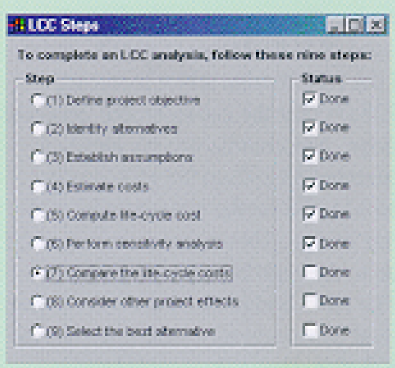

Figure 2

The BridgeLCC Cost Summary window presents three sections: Bearers of Costs (Level 1), Life Cycle (Level 2), and Project Components (Level 3). The "Level 1" section presents costs according to Agency, User, and Third Party. The "Level 2" section presents costs according to lifecycle phase: Initial Construction, OM&R, and Disposal. The "Level 3" section presents costs according to project component.

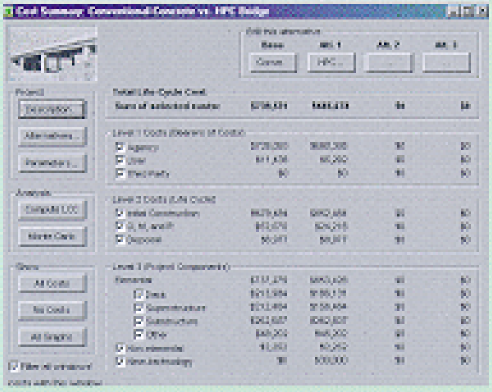

Figure 3

Components (Level 3). The "Level 1 Costs" section in the window presents costs according to the bearers of the costs: Agency, User, and Third Party. Note that, for each alternative, the sum of agency, user, and third-party costs equals the total lifecycle cost. In a similar fashion, the "Level 2 Costs" section presents costs according to the lifecycle phase of the project: Initial Construction, OM&R, and Disposal. Finally, the "Level 3" section presents costs according to project component: an element such as the deck, a non-element such as mobilization, and a new-technology activity such as static-load testing of a previously unspecified HPC beam. This level-based classification compares the advantages and disadvantages of each alternative according to the bearer of the costs, the lifecycle phase when the costs occur and the project components that generate the costs.

In our case illustration, the HPC bridge costs less for the agency and for the users, as illustrated by the Level 1, cost bearer categories. The DOT incurs a total of $680,385 over the life cycle of the HPC bridge while incurring $728,093 for the conventional-concrete bridge. Automobile drivers incur an estimated $5,292 on the HPC bridge and $11,438 on the conventional-concrete bridge. These user costs are small due to the rural location of the bridge.

The HPC bridge also costs less during initial construction — $652,484 versus $678,484 — and during OM&R — $24,216 versus $52,070 — as illustrated by the Level 2, lifecycle categories. But disposal costs are the same for the two alternatives — $8,977.

Comparing costs by Level 3, project component categories, the HPC bridge has lower deck costs due to the fewer deck repairs, and lower superstructure costs due to the fewer beams. The HPC bridge does, however, have new-technology costs: The HPC-beam contractor charges an additional $30,000 for a static-load test of one of the new beams. In the short term, the agency pays this expense to insure that the bridge will perform as planned; in the long term, if the HPC beams become accepted practice, this cost will probably diminish. Note that even with the new-technology costs the HPC bridge is lifecycle cost effective.

The ability of BridgeLCC to help interpret the cost advantages and disadvantages of each material lies specifically in the check boxes to the left of each cost type in the Cost Summary window. BridgeLCC will tabulate only the cost types that have check marks by them. For example, the engineer can compare the long-run "engineer's estimates of each alternative by checking only the Agency, Initial Construction, and Elemental cost types. User costs can be left out of the calculations by not check-marking the User cost type. The long-run and short-run lifecycle costs of each alternative can be compared by check-marking and not check-marking the new-technology cost type.

The beta version of BridgeLCC is being used by seven state DOTs, all members of the American Association of State Highway & Transportation Officials HPC Lead State Team, to assess the cost effectiveness of their new HPC bridges when compared to conventional bridge designs. Version 1.0 is slated for release in early 1999.

BridgeLCC runs in Windows 3.1, 95/98, and NT 4.0, and is specifically designed so it installs without affecting the Windows environment: No files are copied to the system directory and no changes are made to the registry. It comes with a users manual that includes an example analysis. Information about BridgeLCC, its user manual, and information on ASTM standard E-917 and other lifecycle costing publications are posted on the Office of Applied Economics web site, http://www.bfrl.nist.gov/oae/oae.html.