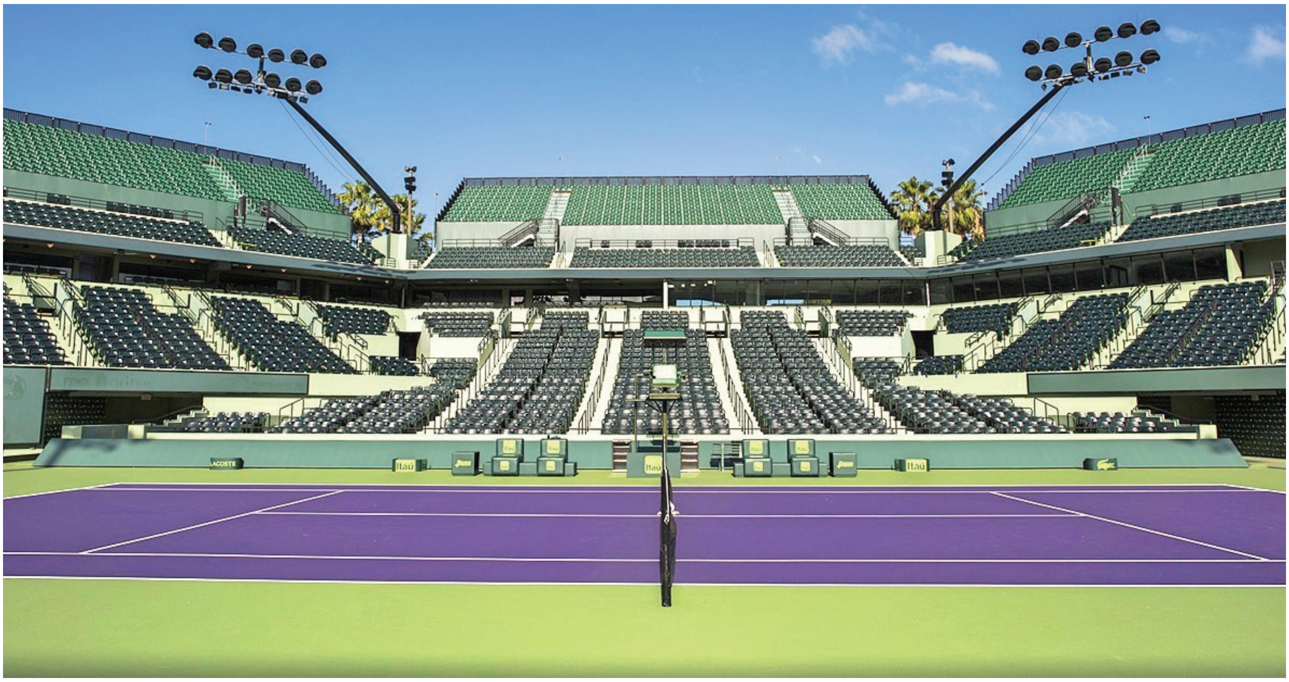
Presented by ASCE Industry Leaders Council

LIFE-CYCLE COST ANALYSIS: SHIFTING THE ENGINEERING CALCULUS



GM Selby Inc. used life-cycle cost analysis throughout the design process for the new lighting and structural poles in the Miami-Dade Crandon Tennis Center revitalization project. PHOTO: Gerald Zadikoff

ASCE's Industry Leaders Council brought together experts and stakeholders for two roundtable discussions during the spring of 2017 to explore civil engineering topics crucial to the ASCE Grand Challenge. The ASCE Grand Challenge aims to reduce infrastructure life-cycle costs by 50 percent by 2025 and foster the optimization of infrastructure for society by focusing on four areas: performance-based standards, life-cycle cost analysis, innovation, and resilience.

The second roundtable, moderated by Christopher M. Stone, P.E., LEED AP, F.NSPE, F.ASCE, the chief executive officer of Clark Nexsen, an architecture and engineering firm based in Virginia beach, Virginia, focused on life-cycle cost analysis. This is a summary of the key points from that discussion.

At its core, life-cycle cost analysis is a tool; a means to an end.

Life-cycle cost analysis (LCCA) uses data to estimate the total cost of a project over its entire lifetime. It accounts not only for first costs, but also for maintenance and operations as well as decommissioning and disposal.

Encouraging widespread adoption of LCCA took on new urgency with the adoption of the ASCE Grand Challenge, aimed at reducing infrastructure life-cycle costs by 50 percent by 2025.

But that, in itself, is a challenge.

LCCA represents a massive shift in civil engineering; a transition that doesn't simply alter the way civil engineering is practiced but also the fundamental ways civil engineers think.

"My goal now as an engineer is not necessarily to build things; my goal as an engineer is to deliver a function," said Michael Salvato, the director and program executive of enterprise information, asset management, and strategic innovation for the State of New York's Metropolitan Transportation Authority.

Christopher Stone served as the moderator for the roundtable discussion.

> "My goal now as an engineer is not necessarily to build things; my goal as an engineer is to deliver a function,"
> – Michael Salvato

"The actual physical creation of a thing is less important to me than the creation of the service or the outcome I'm trying to provide.

"As a society we're moving from building things to maintaining them to sustaining them for generations. So, our mind-set has to move to a sustainable philosophy that asks us to take responsibility for the whole, including cradle-to-grave for the products and services we're providing."

The cradle-to-grave approach is central to life-cycle cost analysis. And life-cycle cost analysis is central to achieving ASCE's Grand Challenge.

Think 'Like an Owner'

LCCA can help make infrastructure projects more efficient, sustainable, resilient, and ultimately more affordable.

Michael Parker, the U.S. infrastructure advisory leader for Ernst & Young Infrastructure Advisors, said it's about thinking like an owner.

"If I have operating costs for my house or I have mortgage payments, they're all types of payments," he said. "And so once I'm thinking about both sides of my budget … the operating and financing costs, as long as I'm thinking about the total budget in the future, I can make different types of decisions."

The potential benefits are many.

Instead of locking in on one design or one project plan, LCCA encourages engineers to examine a whole series of options, which can lead to better-informed decisions on every level.

That doesn't just show itself in the plans and designs owners select, but also in the ones they don't pursue. Plans with high projected costs for maintenance and operations get eliminated early in the process.

"It's forcing you to be disciplined," said Csaba Kertesz, P.E., M.ASCE, the chief of design for the Port Authority of New York and New Jersey. "It's forcing you to look at … different alternatives, and it's actually allowing you to better manage your assets.

"We have to change the mind-sets so that people look not to the [one-]year but to a five-year plan or a ten-year plan."
The consideration of the longer-term performance of the project also encourages innovation. New materials and creative designs are likely to return more value when performance is measured over a longer time period.

"Often, new tools are more expensive up front than the traditional methods, but provide better performance in the long run," said Matthew Adams, Ph.D., an assistant professor of civil and environmental engineering at the New Jersey Institute of Technology. "LCCA can help to quantify this difference."

Data is fundamental to LCCA, so improved monitoring and maintenance methods will be needed. Owners must be able to regularly compare the project's performance against projections.

Nick DeNichilo, P.E., F.ASCE, the president and chief executive officer of Mott MacDonald North America, has a simple metaphor for the benefits of LCCAs: more expensive but longer-lasting light bulbs versus cheap but short-lived ones. "Like I mention to my children—they have homes now—'Would you rather buy a light bulb that's going to last a week or do you want to buy a light bulb that will last nine years?'" DeNichilo said. "It will cost you a little bit more money, but overall it makes sense."

LCCA In Practice Now

LCCA is actually a concept that is decades old. As such, there isn't an infrastructure sector that hasn't been touched by the life-cycle approach, and there are plenty of success stories.

Lillian Borrone, a retired assistant executive director of the Port

Michael Salvato, of the State of New York's Metropolitan Transportation Authority, sees life-cycle cost analysis as a piece of a larger asset management strategy.

Authority of New York and New Jersey and a member of the board of directors of STV Inc., said that two STV projects that benefited from life-cycle considerations are a firehouse at a government facility and a government office building. Both used energy cost-saving measures to save a total of nearly $600,000.

Likewise, Kertesz said that a life-cycle cost analysis determined that $85 million could be saved by rehabilitating, rather than replacing, the upper-level orthotropic deck of the main span of the George Washington Bridge in New York City.

Dan Frangopol, Ph.D., P.E., F.EMI, F.SEI, Dist.M.ASCE, a life-cycle engineering pioneer and perhaps the leading educator in life-cycle analysis in the profession of civil engineering, worked with ArcelorMittal to demonstrate the cost benefits of a corrosion-resistant stainless steel that will not require maintenance over the entire service life of a bridge.

"Over an estimated 100 years' service life of a bridge, the use of traditional carbon steel would cost up to twice as much as the new steel," Frangopol said. "There are six bridges in the United States and two in Canada that are built with this, and they are doing well. … Invest more at the beginning, you are going to economize in time."

And there are other examples.

Gerald Zadikoff, P.E., F.ASCE, the chief executive officer of G.M. Selby Inc., worked on a tennis center that required a delicate balance between LCCA and the more prescriptive local zoning codes. The center saw an overall savings of $2.5 million.

"This is where the engineers come into play, the innovative engineer," Zadikoff said. "We actually performed a lot of innovative techniques to basically accommodate both sides of the equation. Not easy to do, but it can be done."

Leif Wathne, P.E., M.ASCE, is the executive vice president of the American Concrete Pavement Association. Public sector spending plays a huge role in his industry, and he's seen life-cycle cost analysis used to tremendous success in those decisions.

"We spend about $50 billion a year on pavements in the U.S. – most of that has federal aid dollars involved via the federal aid highway program," Wathne said. "The states that use LCCA do so to help make a more fiscally sound decision – taking not just first costs into account, but also accounting for long-term costs such as maintenance and rehabilitation. This way they are better able to use their highway resources cost-effectively over the long haul. Unfortunately, not all agencies use LCCA to make pavement investment decisions, and thereby potentially forgo significant long-term cost savings. This is why the Grand Challenge is such a terrific opportunity."

Asset Management

Asset management is one of the most natural fits for applying LCCA. If you own multiple infrastructure assets, it only makes sense that your assessments would encompass the entire lifetime of each piece. Or, as Wathne said, "I don't see how you could do an asset-management program without relying on LCCA."

Maj. Gen. (Ret.) Bo Temple, P.E., PMP, F.ASCE, served as acting chief of engineers and acting commanding general for the U.S. Army Corps of Engineers before retiring in 2012. He established the asset management system for the Corps's inland waterway transportation system, and lowered costs by using a variety practices informed by LCCA.

At MTA, Salvato has used LCCA to help create a management system that enables fact-based decision making. When life-cycle costs are considered at every level, it creates a system of interoperability that can inform intelligent decisions on a grand scale.

"We have a social obligation now as engineers to transition our society from an unsustainable state to a sustainable state," Salvato said. "That is a massive undertaking. And I think we can make the argument that total asset management at the enterprise level, whole-life decision making at the planning level, life-cycle cost analysis at the project level, and reliability life-cycle analysis at the component level are all part of those conversations."

Barriers and Solutions

Despite its obvious benefits, LCCA does present barriers to be overcome, not the least of which is the question of liability. Christopher Stone, P.E., LEED AP, F.NSPE, F.ASCE, the chief executive officer of Clark Nexsen, stated the problem concisely: "If we, as a designer, are telling an owner, 'There's going to be additional cost up front because we're expecting over the life of this piece of infrastructure that you're going to save money in the end, but it's dependent upon you as the owner maintaining this piece of infrastructure,' and then five years, ten years down the road, that infrastructure isn't performing as it was designed, whose responsibility is it?"

There's still enough apprehension about the answer to that question to scare owners away from the entire life-cycle concept. Successful P3s, like the Denver rail, provide hope.

The collection, dissemination, and appropriate use of data present other hurdles. LCCA relies on data—often probabilistic data. It is not easy to get good data inputs for each individual piece of technology within a project, nor to anticipate how the technological changes will affect maintenance.

> "And so using the private sector incentive to turn a profit to then encourage the lowest life-cycle cost possible can go a really long way [toward] getting it infused into the project. But the other spinoff benefit [is that] when we talked to the folks at RTD, they said, 'Yeah, because we learned and worked with the private sector, we're actually incorporating more of this kind of thinking in-house.'"
>
> – Paul Lewis

THE TAK

Defining life-cycle cost analysis

- Uses data to consider costs over a project's entire lifetime, not just the up-front costs
- Projects costs for operations and maintenance, as well as removal expenses
- Forms a critical piece—along with resilience, innovation, and performance-based standards—of ASCE's Grand Challenge

Benefits of life-cycle cost analysis

Life-cycle cost analysis considers a variety of options and alternatives for a project, which presents several potential benefits:

- Lowers costs over the long haul term
- Reduces future maintenance
- Measures real performance
- Encourages innovation, including new designs, materials

EAWAYS

What are the barriers?

- Questions of liability: Who is responsible for future maintenance?
- Budget restrictions: There could be a need to spend more up front to save money later
- Difficulties developing strong probabilistic data
- Policy and legislative impediments
- Society's need for instant gratification

Getting started with with LCCA: Keys to success

- **Use the technology** available to gather the best possible data
- **Develop** a systems mind-set that promotes collaboration and interoperability
- **Communicate success stories** demostrating why life-cycle cost analysis can help stakeholders, politicians, and society at large

Sometimes it's not even easy to define performance outcomes. And for existing infrastructure, the problem is exacerbated by sporadic data from disparate data sources.

The entire life-cycle system falls apart if the data isn't good. You get what Parker called a "garbage in, garbage out" scenario. The good news is that the quality of the data being fed into LCCA is improving every day. To conduct a probabilistic LCCA, civil engineers must be familiar with the principles and techniques. Engineering schools have to prepare future engineers to use such methods. Unfortunately, very few engineering schools are doing this, Frangopol said.

The Rutgers University Center for Advanced Infrastructure and Transportation (CAIT), however, has made a good start. It developed the bridge evaluation and acceleration structural test (BEAST) to simulate the deterioration process that occurs over 20 years on full-scale bridge specimens in a matter of mere months. (Read "Rutgers' 'BEAST' Designed to Accelerate Bridge Evaluations" in *Civil Engineering*, February 2016, page 36-38. See www.asce.org/cemagazine.)

"It could [give you] a backbone life-cycle picture for a given system," said Ali Maher, Ph.D., M.ASCE, the director of CAIT. "And then using advanced condition assessment technologies, you could figure where you fit in this life-cycle picture for an existing system."

Another barrier is the fact that the political cycle does not lend itself to long-term planning. Politicians need to win today. "This bridge will save us money in 2042!" isn't exactly a winning campaign slogan.

It's up to civil engineers, Borrone said, to clearly communicate why saving money over the long term is important. "I think you really have to say to the community leader, the politician, 'You might take some hits up front, but if you and the community can really start engaging based on your social capital … you can make a difference,'" Borrone said. "I think people are willing to adapt good ideas… from wherever they can, if you can show that it's going to be meaningful and successful for their self-interest."

Changing Mind-sets

Changing the public's perspective toward meeting long-term goals involves what Salvato described as focusing on outcomes rather than individual pieces of infrastructure.

"We need to buy verbs, not nouns," Salvato said. "We need to buy outcomes rather than a thing."

Embracing LCCA holistically as a philosophy requires a new mind-set among owners, designers, and engineers alike, and that shift requires a certain amount of humility.

"It's in essence admitting that they may not have been doing everything that they should have been doing to begin with," Wathne said.

The mind-set that doesn't need to change is the desire to protect the safety, health, and welfare of the public, values so intrinsic to the civil engineering profession. LCCA simply considers that protection over a longer time period.

"We have to establish frameworks with collaboration, where 'systems thinking' is the norm and where siloed, first-dollar thinking is considered an evil," Salvato said. "And where everyone recognizes that we've created a culture—bottom up, top down—where collaboration in the public good is considered the foundation of how we work together as a society."

THE
ROUNDTABLE PARTICIPANTS

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