MAXIMIZING THE VALUE OF INVESTMENTS USING

LIFE CYCLE COST ANALYSIS

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CONTENT

ACKNOWLEDGEMENTS

We would like to thank those who served on the ASCE Industry Leaders Council (ILC) and the Committee on America's Infrastructure, who helped to shape the concept of this work and provided substantial feedback.

In addition, we would like to thank those individuals at each agency that provided us substantial support for this report. For each case study we interviewed the leaders in life cycle cost analysis at each agency. Thank you so much to those of you who helped shape our work from the Pennsylvania Department of Transportation, the North Carolina Department of Transportation, the Metropolitan Transportation Commission, the Port Authority of New York and New Jersey, the U.S. Army Corps of Engineers, and the Regional Transit District.

Special thanks to our peer review team: Former Louisiana DOT Secretary William Ankner, Matthew Hardy of the American Association of State Highway Transportation Officials (AASHTO), Beth Osborne of T4 America, and Eric Sundquist of the State Smart Transportation Initiative (SSTI).

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EXECUTIVE SUMMARY

Life cycle cost analysis (LCCA) is a data-driven tool that provides a detailed account of the total costs of a project over its expected life.

When making funding decisions under constrained budgets, it is tempting for decision-makers and elected officials to think in the short-term. In an effort to construct projects within limited capital budgets, high importance is placed on the up-front costs, with little attention to costs in the future. In order to improve our long-term decision-making, planners and policy-makers in the United States need to begin thinking more strategically about how we maintain and operate our transportation network and manage its assets. With the focus of funding shifting toward system preservation, greater use of analysis that looks at both upfront and long-term costs can ensure the sustainability of future budgets and better management of our vital infrastructure.

Life cycle cost analysis (LCCA) is a data-driven tool that provides a detailed account of the total costs of a project over its expected life. Recognizing its benefit, several agencies have implemented LCCA programs and have successfully saved significant sums of money. However, there are still many challenges to creating or expanding the use of LCCA in transportation. This report provides an exploration of the regulatory framework that currently exists to encourage LCCA, and discusses the experiences of agencies that have begun to incorporate LCCA in the decision-making process.

Within the transportation sector, holistic LCCA calculates up-front development, capital and financing costs, discounted operating and maintenance costs, and end-of-life costs associated with a specific asset or project. LCCA can also factor in uncertainty, risk, and other elements including environmental and equity considerations. When performed correctly, LCCA enables a more accurate and less biased comparison of differing life cycle costs between transportation projects and alternatives. Using LCCA has been proven to create short-term and long-term savings for transportation agencies and infrastructure owners by helping decision-makers identify the most beneficial and cost effective projects and alternatives.

LCCA was first introduced into the transportation decision-making process to help agencies determine the best pavement option for their project. Beyond its applications in the pavement design process, broader use of LCCA on infrastructure projects has been limited. While there is widespread agreement among governmental agencies and the private sector that economic and financial analyses such as LCCA should inform decision-making, in practice it has had little application.

Use of LCCA has been much more prolific in the private sector as there typically is a need to defend financial investment needs and decisions with an analytical tool, and owners often have multiple potential uses for available funds. But within the public sector, there is little incentive to use LCCA. This is one of several barriers to consistent and widespread implementation of LCCA by transportation agencies.

Use of LCCA has been much more prolific in the private sector as there typically is a need to defend financial investment needs and decisions with an analytical tool.

This paper helps policymakers gain a deeper understanding of the potential benefits of LCCA, the barriers that exist to its broader implementation, and approaches that can be used to overcome those barriers. We profile six agencies that have incorporated LCCA or a similar analysis tool into their decision-making and planning processes. Examples from Pennsylvania, North Carolina, California, New York/New Jersey, the Army Corps of Engineers, and Colorado offer substantial guidance for successful use of LCCA economic analysis. Specific successes include over $30 million saved by the

Pennsylvania Department of Transportation since the 1980s, $140 million saved on an airport runway expansion project at the Port Authority of New York and New Jersey, and $300 million saved on a rail project at the Regional Transit District in Denver.

The case studies included in this report unveiled a number of tangible lessons that can be used to encourage the implementation of LCCA at transportation agencies across the country. We found that the benefits of LCCA have not been properly communicated, leaving many agencies to believe that its inclusion in the decision-making process is more of a hindrance than a benefit. Those who have identified the benefits of LCCA have found that its inclusion in the decision-making process must be done through an iterative process that is transparent. Further, LCCA should not be the only factor in the decision-making process, and its implementation should be purposefully sensitive to other, non-analytical considerations. Finally, it became clear that the public sector has much to learn from the private sector's process and use of LCCA.

While the benefits associated with the use of LCCA are clear and well documented, the case studies included in this report demonstrated barriers to the adopting the use of LCCA. Based on these findings, the report recommends a set of policy innovations at the federal level and for the local levels.

At the federal level, the report recommends the following:

- **Tie funding to performance.** Congress should give USDOT greater authority to hold grantees accountable to performance standards, allowing USDOT to tie performance to discretionary funding and reward states that make the most cost-effective decisions. Such a structure would incentivize states to reevaluate their decision-making process, and push them to use tools that already exist, including LCCA, that could maximize their performance outcomes.

- **Launch a discretionary grant program targeted toward asset management.** Congress should introduce a new competitive discretionary grant program that provides funding specifically to aid in asset management. Through competitive discretionary grant programs, USDOT can target money to incentivize improved asset management processes.

- **Use an LCCA-driven cost-effectiveness ranking to inform the STIP and TIP.** Congress should direct states and MPOs to use a data-driven, transparent project ranking to inform their Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP), ranking projects from most to least cost-effective. This would help decision-makers prioritize projects by providing information about which projects will create the greatest return on investment.

- **Improve data resources.** The literature and case studies pointed to the lack of consistent data as a barrier to effective use of LCCA. This should be remedied through the creation of data collection standards and the expansion of data retention policies.

- **Fund a development course for LCCA leaders.** To help states and localities develop the ability to conduct LCCA, USDOT should fund the development of a periodic, low-cost or free course aimed at teaching attendees how to best conduct an economic analysis, how to compare data over time, how to manage and incorporate risk, and how to implement and maintain an agency-wide program.

At the state and local level, this report offers the following recommendations:

- **Establish an LCCA pilot program.** An important first step to using LCCA agency-wide is to establish a pilot program. A pilot program allows the agency to ensure manageable implementation, and also allows program leaders to demonstrate to the whole agency the utility of the process.

- **Introduce state level legislation.** Programs where funding is legally tied to the results of LCCA and other economic analysis have the strongest likelihood of longevity, even within a changing political environment. State legislatures should work with the DOTs to create language that will perpetuate and strengthen LCCA programs.

- **Dedicate funding to workforce development.** When surveyed, agencies suggested that additional staff training would be necessary in order to meaningfully incorporate LCCA into the decision-making process. Agencies should dedicate funding to developing and providing training programs to staff and executives who need to understand how to use LCCA.

- **Partner with the private sector.** When agencies engage in appropriate public-private partnerships, they can benefit from the natural incentives that the private sector has to control life cycle costs and innovate new approaches to project design. Through these relationships, public sector employees can learn from their private sector counterparts, potentially encouraging public staff to incorporate private sector tactics into their own purely public projects.

When making funding decisions under constrained budgets, it is tempting to place high importance on the up-front costs and pay little attention to costs in the future, but this is a shortsighted vision. The United States needs to begin thinking more strategically about how it maintains and operates its transportation network and manage its assets in the future. With the focus of funding shifting toward system preservation, greater use of LCCA can ensure sustainability of future budgets and better management of our vital infrastructure.

INTRODUCTION

Given the continued absence of sufficient funding for transportation, it is even more essential for government leaders and transportation agencies to target available funds toward projects with the greatest economic benefits and the lowest long-term costs, allowing the United States to maximize benefits within our limited funding capacity.

Mounting research indicates that the United States is not adequately investing in surface transportation infrastructure.[1] Congress has not increased federal spending levels in real terms over the past decade, and budgets remain tight at all levels of government. Given the continued absence of sufficient funding for transportation, it is even more essential for government leaders and transportation agencies to target available funds toward projects with the greatest economic benefits and the lowest long-term costs, allowing the United States to maximize benefits within our limited funding capacity.[2]

The need to maximize the benefits of limited investments and stabilize budgets is particularly acute for the preservation of our current infrastructure. States and localities are grappling with the fact that many of their critical bridges, roadways, and public transit networks are in need of substantial repair or replacement. Maintenance, upgrades, and replacements are a growing need, and with limited resources it is even more important that decision-makers prudently plan and spend current and future budgets. When the cost of a project is estimated only for design and construction, the long-term costs associated with maintenance, operation, and the retiring of a project are often overlooked. Similarly, comparing project design alternatives by their initial costs can often lead to shortsighted decisions.

A poor choice today can be amplified in future decades as the inflexible and long life nature of infrastructure can create unaffordable requirements in the future.

Without careful examination of the full life cycle costs, investment decisions today could cost an agency even more in years ahead. Something as simple as a bridge replacement provides the opportunity to construct an asset, sometimes with higher upfront costs, in a way that reduces the needs for future revenues dedicated to that asset, often referred to as "sustaining capital." A poor choice today can be amplified in future decades as the inflexible and long life nature of infrastructure can create unaffordable requirements in the future. An examination of the full life cycle costs can help an agency in determining the appropriate investment in an asset given current and future budget constraints.

Several advanced, data-driven economic analysis techniques exist to help decision-makers select projects. One type of analysis that is particularly useful for reducing long-term costs is life cycle cost analysis (LCCA). LCCA, often performed at the preliminary engineering and planning phase, is a financial and economic tool that examines the up-front development and capital costs, discounted operating and maintenance, and end-of-life costs for an asset or project. It can help create better allocation of sustaining capital for operations, maintenance, and other future costs, and can be broadened to include other economic, environmental and equity considerations as well.

When the cost of a project is estimated only for design and construction, the long-term costs associated with maintenance, operation, and the retiring of a project are often overlooked. Similarly, comparing project design alternatives by their initial costs can often lead to shortsighted decisions.

LCCA has several applications, including:

- Helping to select the best alternative to meet a project objective, such as replacing a bridge;
- Evaluating a design requirement within a specified project, such as pavement types;
- Comparing overall costs between different types of projects to help prioritize limited funding in an agency-wide program; and
- Calculating the most cost-effective approaches to project implementation.[3]

LCCA has its limitations because the analysis relies on accurately predicting future costs, and therefore it is subject to substantial estimating risk that can dramatically alter the outcome. The time horizons of the analysis are important to consider as well, as setting different time horizons can have a dramatic effect on the analysis outcome. But challenges associated with these calculations are often rooted in the lack of transparency and full knowledge of how an LCCA works. Many of the challenges can be accounted for in a risk analysis of the LCCA and its inputs, but decision-makers should be aware that an LCCA is not necessarily a foolproof prediction of the future. Regardless of the limitations, a deeper understanding of the benefits and costs over the complete life cycle of an asset can provide better information to decision-makers and help target limited funds to the most beneficial and cost effective projects.

Objectives and Methodology

The purpose of this paper is to demonstrate the value of LCCA, how it can be successfully incorporated into the decision-making process, and what actions public agencies have taken to put LCCA programs in place.

This research is divided into in four sections:

1. The first section provides an overview of potential uses of LCCA and highlights how they are currently discussed in the literature.
2. The second section examines current federal regulations within the transportation planning process and the federal guidance provided for the use of LCCA in the decision-making process.
3. The third section provides a set of case studies demonstrating how economic analysis is currently being used in selecting transportation investments and defines lessons learned and best practices from these studies.
4. The final section offers a set of policy recommendations that could be enacted at the federal and state levels to encourage increased use of LCCA in the decision-making process.

LIFE CYCLE COSTS IN TRANSPORTATION

Nearly every investment decision that is made, whether in transportation or in another infrastructure sector, uses some form of economic or financial analysis. When it comes to evaluating transportation maintenance and replacement projects, agency staffs have some basic idea of the upfront costs, potential future benefits, and maintenance costs that an asset will have during its life cycle. Yet this understanding is often not formalized and is not necessarily data-driven.[4]

Agencies face several challenges and barriers in the implementation of genuine data-driven LCCA. The Federal Highway Administration (FHWA), which has been promoting the use of LCCA for many years, states that LCCA has "yet to become a routine analysis tool in transportation project decision-making."[5] The survey presented later in this paper confirms that this has not changed substantially in the past decade. Since the federal government plays such a vital role in the funding of surface transportation by providing funding to states, it is surprising that there is no federal requirement associated with the acceptance of federal funds for infrastructure projects to track actual operating and maintenance costs.

Lack of LCCA, particularly outside of the pavement selection process, is evident at state agencies, which are primarily responsible for implementing transportation programs and maintaining assets. For example, an analysis of the use of LCCA at the Indiana Department of Transportation cited a "lack of in-house or contractual maintenance data" as a primary problem for considering full maintenance costs.[6] In other states, LCCA "procedures are based on simplistic assumptions" that may include only initial construction costs and future costs of rehabilitation.[7] This suggests that there may be room to expand on existing programs to include a more holistic understanding of life cycle costs.

Though it is not required, FHWA provides guidance for the use of LCCA with its Economic Analysis Primer and Life-Cycle Cost Analysis Primer.[8] According to FHWA, LCCA should be "applied only to compare design alternatives that would yield the same level of service and benefits to the project user at any specific volume of traffic."[9] LCCA "applies the discount rate to the life-cycle costs of two or more alternatives to accomplish a given project or objective, enabling at least one alternative to be identified."[10] LCCA could be expanded, however, to go beyond this guidance, providing a more holistic approach that considers criteria beyond level of service. The important part of LCCA is that it uses a data-driven analysis to assess and anticipate future operating and maintenance costs, and it applies these costs in a way that can be compared across projects and alternatives. Other resources are available that give detail on how LCCA can give a more holistic approach, incorporating risk as well as environmental and equity costs.[11]

The Use of LCCA in the Transportation Industry

The surface transportation industry is unique from other infrastructure-based industries, such as electric utilities, as it is primarily public sector driven. The federal government creates funding streams and programs that are largely implemented at the state and local level. Thus, it is worthwhile to evaluate how the implementing agencies use LCCA and other analyses to aid in the decision-making process.

Most state agencies use LCCA in their pavement design process, but implementation beyond this use varies widely.[12] An investigation by Caltrans examined the use of LCCA in 17 states across the country and found a broad range of parameters and types of LCCA tools used. Some specific criteria are more standardized while other important factors are not included: over half the states reviewed used a discount rate of four percent, yet six states—Illinois, Minnesota, New York, Ohio, Virginia, and Wisconsin—did not include user costs within their evaluation.[13] A similar study sponsored by the South Carolina DOT showed that while 94 percent of the responding states used LCCA for pavements, the application beyond pavements was less extensive and the range of parameters used was not consistent.[14]

In the spring of 2014, the American Society of Civil Engineers (ASCE), in conjunction with the Governing Institute, commissioned surveys evaluating to what extent governmental entities across the United States use LCCA in their decision-making process. This went beyond similar surveys to include senior-level representatives from city

and county governments that play a role in planning transportation infrastructure. Figure 1 shows the type of organization affiliating or employing survey respondents.

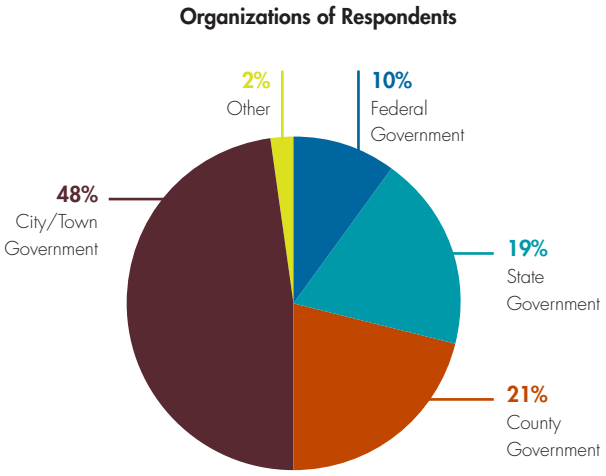

Figure 1: Responding Agencies to the ASCE/Governing Survey, April 2014

The results from the survey highlight several key issues related to the use of LCCA. First, there was general agreement that within the environment of limited available funding, budgets should be focused primarily on sustaining capital (maintenance, operations, etc.), where LCCA can be crucial. Over half of the respondents said that they expect their budgets to either decrease or remain the same over the upcoming years. Meanwhile the needs at the agencies were primarily focused on "significant upgrades/replacements" and "general maintenance." Only eight percent of respondents cited new infrastructure as their most pressing need.

Regarding the use of LCCA, nearly all respondents agreed that LCCA should be a part of the decision-making process, yet only 59 percent said that they currently employ some form of it. Less than half of the respondents said that they have set up an "operations plan" as part of the project planning process, and a combined 72 percent said that their current LCCA practice needs improvement, is barely adequate, or is inadequate. Within their LCCA process, most respondents reported using upfront costs, maintenance costs, and operational costs, and 62 percent incorporated user impacts into their LCCA. These responses are in agreement with the literature and suggest that the use of LCCA in the industry is limited and the process can be significantly refined.

The survey also highlighted some of the barriers to the implementation of LCCA at agencies. Nearly half of respondents cited a "lack of LCCA coordination" between parties within their organization from the design through the operation stage. Further, 48 percent responded that predicting future costs is "extremely" difficult for their organization. The ability for agencies to carry out LCCA effectively and accurately is a critical component in making them useful in the decision-making and design process, and survey results suggest a need for better tools, data, and coordination.

While the initial survey evaluated the use of LCCA within the public sector, ASCE conducted a subsequent survey of their civil engineer members in order to gauge the experience and barriers within their membership. Over 70 percent of the respondents of this second survey were employed in the private sector. The results from the private sector were very similar to the results from the public sector, primarily because the public sector serves as the primary funder and planner for transportation infrastructure, and the private sector engages as consultants to assist in the design and construction. The private sector respondents felt that, like the public sector, they also had room for improvement in their current approach to LCCA, and 65 percent responded that they would be interested in expanding their knowledge of LCCA. There was significant consensus among private sector respondents that they were willing and able to perform LCCA for projects, but indicated that they needed public sector leadership to move forward in this area.

Literature Review

The existing body of literature includes extensive research from academia, the federal government, and trade groups demonstrating why and how to apply LCCA. Additionally, as explored later in the case studies, there are several publications from practitioners that help to bridge the gap between literature and implementation. There is evidence in the literature that employing LCCA when selecting project alternatives or when determining how best to maintain and rehabilitate an asset can be useful for making cost-effective tradeoffs and better investment decisions, managing risk, and ensuring long-term affordability for the general public.[15] Using analysis such as LCCA can "support long-term economic growth [and] help solve larger problems such as budget deficits."[16] The literature demonstrates tangible benefits of using LCCA within the decision-making process, such as higher quality projects, increased industry competition, and improved credibility.[17] As the case studies in this paper demonstrate, a substantial amount of money can be saved through LCCA, sometimes on the order of hundreds of millions of dollars for large projects.

Several government-based guidebooks, including the FHWA *Life Cycle Cost Analysis Primer*, are readily available to help agencies conduct these analyses. The private industry has also contributed to broader knowledge on LCCA, including the "Life Cycle Analysis" framework for conducting a comprehensive, holistic evaluation.[18]

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Beyond FHWA's guidance and the Life Cycle Analysis method, other resources include, but are not limited to, the American Association of State Highway and Transportation Officials' *User and Non-User Benefit Analysis for Highways*, the Office of Management and Budget's *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, California Department of Transportation's *Life Cycle Cost Analysis Procedures Manual*, the National Cooperative Highway Research Program's *Bridge Life Cycle Cost Analysis*, and Kara Kockelman's *The Economics of Transportation Systems: A Reference for Practitioners*.[19] Most of the publications discuss LCCA within the context of "asset management", a concept that incorporates a long-term analysis of transportation assets and the management of their life-cycle costs. Asset management is discussed in several sources, including the Government Accounting Standards Board.[20]

Aside from literature, handbooks, and guides, a number of software resources exist for LCCA. This includes FHWA's *RealCost software*, which aides with pavement design, AASHTO's *AASHTOWare Pavement ME Design*, also for pavement design, and The National Institute of Standard's and Technology's *BridgeLLC*, which provides assistance with bridges.[21] In short, there is no lack of resources for agencies and organizations to develop their own process of using LCCA. Though much of the existing use of LCCA is limited to pavement design, LCCA can be applied to a much greater range of projects and uses. These tools exist as a means to help organizations not only begin the implementation of LCCA but also to expand their reach to more aspects of asset management and planning within the public sector.

Much of the literature discusses the broader application of various types of economic analyses in the decision-making process aside from LCCA, including Benefit Cost Analysis (BCA) and Economic Impact Analysis (EIA). These examples can provide insights into how LCCA can be better incorporated in the decision-making process. For instance, *Engineering Economic Analysis Practices for Highway Investment*, published by the Transportation Research Board (TRB) in 2012, explored transportation entities using engineering economic analysis in their decision-making processes. TRB used a case study approach, which revealed a number of characteristics of agencies that successfully applied economic engineering techniques, including the establishment of fleshed-out guidance, willingness to innovate, and inclination to engage experts.[22] Yet, the use of economic analysis, including LCCA, remains limited in the industry.

Some of the literature highlights the barriers that exist to further the application of LCCA in transportation. The lack of "definitive and reliable" data—a crucial input for conducting a full LCCA—remains a challenge.[23] Problems with data include unreliable, inconsistent, and incomplete reporting across agency branches, and a lack of historical material price records.[24] These data inputs are important for creating reliable and credible estimates of future costs. Another key component that hinders the ability of agencies to conduct LCCA is the lack of personnel training on new software programs and methods that can conduct LCCA in a way that can be useful to compare projects consistently and accurately.[25] In other cases, institutional momentum has not given the proper incentives to overcoming barriers and implementing an expanded LCCA approach.

The review of the literature demonstrates four key factors:

1. The benefits of LCCA on improved decision-making is well documented;
2. LCCA is not just limited to pavement selection but can be used in a range of applications for project selection and design;
3. The resources and tools for conducting and performing meaningful LCCA exists; and
4. Barriers in terms of data, training, and incentives are a major inhibitor to employing expanded use LCCA in transportation infrastructure provision.

The literature, however, does not suggest many methods for overcoming the barriers to implementing broader use of LCCA. Aside from the data and educational factors, other barriers must have hindered states and localities from making changes to internal processes and adopting a broader use of LCCA. The next few sections look at the use of LCCA within federal policy, a significant funder of transportation infrastructure, and then examine several state and local case studies. The case studies provide insight into how they use LCCA or other economic analyses and how these processes came to be part of their decision-making process.

EXISTING FEDERAL POLICY

Federal requirements for LCCA have varied over the past few decades. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) was the first major surface transportation bill to include consideration of life cycle costs in the design of bridges, tunnels, and pavement.[26] This was made more explicit in 1995 when the National Highway System Act required states to conduct LCCA and Value Engineering Analysis for every National Highway System project that exceeded $25 million in costs. Though this was initially seen as an improvement, the requirement was removed in 1998 with the passage of the Transportation Equity Act for the 21st Century (TEA-21), as states cited having trouble meeting the requirement.[27]

Current federal policy regarding life cycle costs is focused on creating resources for states to implement their own LCCA programs.

Current federal policy regarding life cycle costs is focused on creating resources for states to implement their own LCCA programs. As such, FHWA's LCCA guidance and assistance to state transportation agencies is mostly advisory.[28] Under current federal surface transportation legislation, Moving Ahead for Progress in the 21st Century (MAP-21), little, if any, economic analysis is required for states and localities to receive the bulk of their federal funds for their capital programming, and as the earlier survey noted, this has not encouraged many public agencies to use expanded LCCA.[29] This section explores how the federally mandated planning processes work and how LCCA currently fits into federal policy.

Life Cycle Costs in the Federal Transportation Planning Process

In order to receive federal formula funds, states and localities must develop transportation plans under the Continuing, Cooperative, and Comprehensive (3-C) process between state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), transit operators, and other stakeholders. This process is important when it comes to the use of LCCA because this is how the vast majority of federal funds are distributed to the states. This section summarizes the planning process, and demonstrates where LCCA fits into the process under the "fiscal constraint" rules.

State DOTs—with input from MPOs—are responsible for planning, programming, and project implementation for their entire jurisdiction. MPOs are policy bodies comprised of elected officials and local representatives from the region, and transit operators. Their primary responsibilities include creating a long-range transportation plan for the state and developing a statewide transportation improvement program. Each urbanized area with a population greater than 50,000 is required by federal law to be represented by an MPO.[30] MPOs are required to conduct alternative options studies for transportation improvements, as well as develop metropolitan transportation plans (MTPs) and transportation improvement programs (TIPs).

All projects that are scheduled to receive federal funding must be included in the MPO's TIP. The TIP has the following characteristics under federal law:[31]

- Defines projects for a minimum of four years and must be updated every four years;
- Employs fiscal constraint;
- Is in accordance with the State Implementation Plan for air quality;
- Is approved by the MPO, and then the governor; and
- Is directly incorporated into the Statewide Transportation Improvement Program (STIP).

The STIP defines the state's priority projects, and commits future funding to those projects. It includes projects from MPO's TIPs as well as projects from non-urbanized areas. Importantly, projects within the STIP adhere to the fiscal constraint principle.

"Fiscal constraint," as defined by current rulemaking, is the ability to demonstrate the availability of sufficient funding to build and maintain the proposed plan. This gives it the potential to be directly relevant to the use of LCCA. Per federal requirements, funding to

Instead of requiring LCCA to meet the fiscal constraint requirement, states must prove only a limited analysis of current and future funds.

meet fiscal constraint can be from federal, state, local, and/or private sources and must be abundant enough to provide all the necessary revenues to build the project, as well as to operate and maintain the resulting asset.[32] However future maintenance and operations are only needed for a few years beyond the plan's implementation, not over the life of the asset. Instead of requiring LCCA to meet the fiscal constraint requirement, states must prove only a limited analysis of current and future funds. FHWA and Federal Transit Administration (FTA) are reluctant to decertify or withhold funds from a state or MPO due to the likelihood of strong political pushback.

After projects are approved through this STIP process, they are eligible for formula apportionment funding through the federal government's Highway Trust Fund (HTF).[33] Projects that do not use federal funds are often shown in the STIP, which functionally turns the STIP into the state's work program. The fact that the STIP plays such an integral role for the full state work program and the existence of the "fiscal constraint" principle, demonstrates how LCCA could, if enforced, have much broader use.

Current Legislation

The current policy governing federal surface transportation, MAP-21, provides a number of provisions guiding the use of economic analyses, including LCCA, in the decision-making process. Included in these provisions is the direction to GAO to review best practices for LCCA to provide states guidance on ways to improve their current practices.[34] The report, which focused on LCCA application to pavement design, found that 13 of the 16 agencies surveyed used LCCA. While a substantial portion of agencies surveyed used LCCA, their methods for implementation varied.

MAP-21 requires each state to "develop a risk-based asset management plan for the National Highway System to improve or preserve the condition of assets and the performance of the system."[35] By statutory definition, asset management does include the consideration of life cycle costs. Technically, per MAP-21, funding for the asset management performance program may be withheld

LCCA in Other Sectors

While the use of LCCA within the transportation sector is limited, other infrastructure sectors are taking the lead and demonstrating that the incorporation of LCCA into the decision-making process is not only possible, but that it can also yield tangible benefits. The building construction industry uses well-defined assessment tools to evaluate life cycle costs and performance of building materials and components. These tools can help developers or agencies assess the sustainability of their buildings and reduce their overall environmental burden. For federal projects, which must meet renewable energy goals, the U.S. Department of Energy provides guidance and resources for performing life cycle cost analyses to increase efficiency, as well as LCCA guidance for water conservation projects.[36] California, among other states, encourages the use of LCCA in determining the cost-effectiveness of energy efficiency and conservation projects.[37] In the private sector dominated energy transmission industry, it is standard to employ LCCA when planning projects over a given time horizon. The transportation industry can look to these sectors for both guidance and leadership.

Discretionary programs constitute a small portion of the federal budget, but they play a significant role in creating incentives for states to overcome barriers to economic analyses.

should a state not meet this requirement.[38] In addition, MAP-21 also includes a transit asset management requirement that directs FTA grantees to develop transit asset management plans.[39] Further, MAP-21 also includes a "national policy in support of performance management."[40] Performance management is an evaluation approach that allows states and localities to set priorities, make goals, and measure the outcomes.[41] Asset management is a consideration within the statutory performance management requirement.[42]

While the current federal level legislation provides only an outline for effective LCCA at the state and local levels, some USDOT programs do include a federal level benefit-cost analysis component. Though it is not specifically LCCA, these federal discretionary programs are instructive on how to create incentives for use of different types of economic analysis, which could involve LCCA in some cases. Introduced in 2009 through the American Recovery and Reinvestment Act (ARRA), Transportation Investment Generating Economic Recovery (TIGER), a multi-modal discretionary grant program, was the first USDOT program to require benefit-cost analysis in its evaluation process.[43]

Other programs, including the Transportation Infrastructure Finance and Innovation Act (TIFIA), Projects of National and Regional Significance (PNRS), and Transit New Starts, all developed before 2009, also required potential grantees to submit an economic analysis of the project with their application. Instead of requiring that states and localities conduct an in-depth analysis for all federal dollars, these discretionary programs offer incentives for prospective grantees by providing funding competitively based in part on the analysis.

Though these programs were successful in encouraging economic analysis, they ran into several problems related to the capacity of grantees to conduct them effectively. For example, under TIGER, USDOT found that potential grantees had minimal experience with the required Benefit-Cost Analysis (BCA), which according to FHWA's definition "considers life cycle benefits as well as life cycle costs."[44] The lack of experience resulted in many grantees submitting analyses that needed modification and improvement to be accepted.

To overcome this barrier, the TIGER Task Force developed detailed guidance on how to execute the required BCA calculations. The Task Force also reached out to potential applicants with presentations, webinars, and how-to manuals on how to conduct BCAs. Though the use of economic analysis in TIGER has been far from perfect, the competitive nature of the program has "encouraged state agencies to better analyze their own projects" and it provides a level of analysis far beyond what is typically required of federal transportation dollars.[45] Discretionary programs constitute a small portion of the federal budget, but they play a significant role in creating incentives for states to overcome barriers to economic analyses.[46]

LIFE CYCLE COST ANALYSIS AT THE STATE AND LOCAL LEVEL

Several state and local agencies across the country have taken the initiative to increase the use of LCCA to improve their investment decisions. This section explores a targeted sampling of different types of agencies that use innovative and robust approaches to LCCA, and investigates how they are incorporating LCCA into their decision-making and planning processes. The case studies were chosen based on a preliminary scan to provide a cross-section of what is happening across the country; these cases are not intended to be an exhaustive list of best practices.

The case studies examine the following entities:

- Pennsylvania Department of Transportation
- North Carolina Department of Transportation
- Metropolitan Transportation Commission (San Francisco Bay Area MPO)
- Port Authority of New York and New Jersey
- U.S. Army Corps of Engineers
- Denver Regional Transit District (RTD)

Pennsylvania Department of Transportation

The Pennsylvania Department of Transportation (PennDOT) is responsible for distributing over $6 billion in funding to maintain and improve 120,000 lane-miles of state and local roadways, 32,000 bridges, and all the large urban public transit networks in the state.[47] PennDOT began implementing LCCA for pavement in the 1980s and has been highlighted by FHWA as a leader for its use in making pavement decisions.[48] The agency uses a 50-year life horizon and includes the up-front cost of paving and future rehabilitations discounted at a five year rolling average of the annual 30-year Real Interest Rate on Treasury Notes and Bonds. The data-driven process uses historical and projected estimates of costs from PennDOT's internal databases.[49] There has been an estimated cost savings of over $30 million since implementation in the 1980s.[50]

In the late 1970s, spending on rehabilitating Pennsylvania's pavement had reached historically high levels. As agency work zones popped up all over the state, users were experiencing increasing delays. In response, in the 1980s PennDOT developed an LCCA for pavements to determine the alternatives that would minimize future rehabilitation needs and lower costs over the lifetime of the pavement. To develop this program, PennDOT created a policy that required LCCA to be applied to interstate highway projects with estimated costs of over $1 million and all projects with estimated costs of over $10 million.[51] In conjunction with this policy, multiple manuals were developed including the Highway Geometric Design Manual and the Pavement Policy Manual.

While PennDOT's LCCA program has experienced multiple decades of success and refinement, implementation was not simple. The greatest challenge was building stakeholder consensus among the various pavement industry leaders. PennDOT addressed this challenge through working groups that were comprised of PennDOT, FHWA, and industry leaders to discuss concerns and fashion a program that fit everyone's needs. This working group proposed changes to the policies within PennDOT and after review the process was refined.

The creation of PennDOT's LCCA program has yielded numerous benefits. According to FHWA, PennDOT's use of LCCA has allowed it to improve the performance of pavements, lower costs for maintenance, and bolster credibility of the agency's work.[52] The LCCA program has yielded millions of dollars in savings since the 1980s and has increased competition within the paving industry. PennDOT also expands its LCCA program within the state, providing LCCA tools to MPOs to aid in their project selection process.[53]

But aside from pavement selection, Pennsylvania is facing a growing problem as much of the state's infrastructure is reaching the end of its useful life. Pennsylvania contains the highest percentage of structurally deficient bridges in the nation, and a large portion of the transportation budget is spent trying to keep the system in a state of good repair.[54] Without sufficient funds to address all of their maintenance problems, the convention at PennDOT is that all maintenance projects are worthwhile and it is

Using data-driven economic analysis, including LCCA that evaluated the maintenance and operation costs, MTC saved hundreds of millions of dollars by not investing in a project that was not worth the full cost.

PennDOT's job to ensure that the system remains open. PennDOT does not use LCCA to prioritize projects; rather it is used only for improving design alternatives on a project-by-project basis.

PennDOT has considered expanding the use of the LCCA and employing other economic evaluation tools.[55] Recently, the agency evaluated practices across the country to determine if implementing new evaluation methods would provide a significant improvement. Recognizing that the state has no shortage of projects that warrant funding, the agency chose not to expand its use of economic analysis and has continued with its current planning process. This is consistent with most states in that LCCA for pavements and the maintenance of existing infrastructure is typically the extent of their use of economic analysis.

North Carolina Department of Transportation

North Carolina, on the other hand, has recently created a program to evaluate the economic and social value of proposed capital projects, targeting funding to the most valuable projects. This specific program at the North Carolina Department of Transportation (NCDOT) does not offer an example of LCCA, but instead provides a method for introducing a new decision-making approach, highlighting the potential benefits as well as the challenges of the process. As a capital investment program, it considers the upfront costs and benefits of a project, and does not evaluate the cost of ongoing maintenance. This case demonstrates the role leadership and legislation can play at the state level to implement a new program that uses data-driven economic analysis.

Under their new methodology, the NCDOT allocates available capital funding for transportation projects via a formula based on "data-driven scoring and local input."[56] North Carolina's Strategic Transportation Investments (STI) law, introduced in 2013, guides this process. Under law, STI funds are allocated by formulas, which are publically available, that consider upfront costs, congestion, benefit-cost, economic competitiveness, safety, and multimodal benefits.

Projects that have statewide significance receive 40 percent of the available funding, projects with regional significance receive 30 percent of the funding, and projects with local significance receive 30 percent of the funding.[57] At each level, projects compete against one another, and projects with the greatest quantified benefits receive funding. Projects that do not receive funding at the state level may compete at the regional and local levels.

At each level, projects compete against one another, and projects with the greatest quantified benefits receive funding.

Remarkably, this approach to decision-making has been supported on both sides of the aisle, as both parties looked for a way to reduce the political influence in new capacity project selection. In 2007, NCDOT identified the need to improve its decision-making process and evaluate its efficiency by bringing in a management consultant.[58] The consultants suggested that the creation of a prioritization process would facilitate better decision-making. NCDOT soon began crafting a framework, and in 2009 a newly elected Democratic governor helped to solidify this approach through Executive Order.[59] The first step towards data-driven project selection was introduced soon after and focused primarily on highway investment and emphasized safety, mobility, and infrastructure health.[60]

NCDOT made a point to make this framework simple, transparent, and accessible to encourage political and community buy-in. The second iteration of the process went a step further than its predecessor and evaluated existing conditions, economic competitiveness, and long-term benefit cost. In 2013, with the election of a new Republican governor, the program was further solidified and codified into law in a way that would directly link available funding to data-driven project selection.

NCDOT developed its program on the basis of a shared vision between the agency and the state's political class, which favored a move towards more analysis in the project selection process. It was able to create and maintain support by rolling out the program incrementally, creating a working group for input,

and displaying strong leadership within the administration and the legislature. Public support was further bolstered by the transparency of the selection criteria. Based on the success of the program, in 2013 the state legislature enacted a law to refine standards for money allocation and codify the current practice into law.[61]

However, NCDOT's approach does not incorporate LCCA, and it is unlikely to do so in the future. This is in part due to the STI funding being for new capital projects, and therefore disconnected from funding that is used for asset management. But inclusion of LCCA could further enhance the decision-making process for STI funds. Though this case is not specifically focused on LCCA, it demonstrates that strong leadership, both politically and within a department, can have substantial influence over the culture of an organization and how decisions are made.

Metropolitan Transportation Commission (San Francisco Bay Area)

MPOs are not typically very involved with promoting the use of LCCA or other data-driven economic analyses within the selection process.[62] However, some do stand out as leaders in this area and have implemented robust programs that have had measurable effects on decision-making. One example of an MPO that has unusually large power over funding decisions as well as innovative selection processes is the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area. MTC is responsible for distributing nearly $1 billion in federal, state, and local funding to the 26 transit agencies and other entities within the region. Aside from providing funding for transit, MTC also manages the Bay Area Toll Authority and the Service Authority for Freeways and Expressways.[63]

As the arbiter of a significant portion of the region's financial resources, MTC has substantial sway over how regional transportation investments are made. Through creating a performance measurement system, MTC was able to consider many economic components to potential transportation investments, including life cycle costs. In 2000, it became clear to MTC's leadership and the state legislature that MTC would need to introduce the use of economic analysis into its decision-making process to better target funding under constrained budgets.[64] In 2002, California Governor Gray Davis signed SB 1492 into law, which mandated that MTC "establish certain goals and transportation objectives for planning corridors and sub-corridors for, and to establish performance measurement criteria to evaluate certain new transportation projects and programs in, the regional transportation plan."[65]

MTC has since successfully created a formalized and technical analysis procedure, effectively improving its decision-making process. MTC conducted its first performance assessments for its 2001 regional plans, which it routinely creates every four years.[66] The Progress Performance Assessment was designed to help identify outliers by comparing costs (upfront and life cycle) to performance objectives, similar to a benefit-cost analysis.[67] The move toward increased economic analysis required buy-in from politicians, the community, and the operators.[68] A committee was created to facilitate this process, with the ultimate aim of not deviating from general consensus. They settled on processes based on the suggestions and findings of multiple resources available and tailored to the needs of the Bay Area.[69]

The Progress Performance Assessment allowed MTC to recognize projects that readily fit into its goals as well as those that did not. High-performing projects were included in the Commission's plans, while the rest were subjected to further scrutiny. Projects that localities particularly wanted, even if they did not perform well in the assessment, could be formally defended and potentially incorporated into MTC's plans. This provided a means to fast-track programs that the data supported and to closely inspect those that the data did not support.[70]

The Assessment was further refined in 2005 and 2009. For MTC's Transportation 2035 Plan, released in 2009, analysts aimed to make their recommendations available to have greater influence decision-making.[71] To do this, MTC created specific performance metrics, some of which included costs over the lifetime of an asset, which were part of an overall vision, and then completed the Progress Performance Assessment.[72] As part of this process, MTC

identified low and high performers per the BCA, and went forward with community input on selecting projects for funding.

This process gave MTC data-driven analysis on which to make its final decisions on funding, including not funding portions of several projects. For example, a planned commuter rail project in North Bay area did not meet the performance target of having a BCA greater than one, indicating that the expected benefits were not greater than the life cycle costs.[73] Based on the analysis, and upon compromise with the local agency, MTC only committed funding to two of the stations that had a BCA greater than one, recognizing that if the other stations were to be built it would be funded by the localities.

Using data-driven economic analysis, including LCCA that evaluated the maintenance and operation costs, MTC saved hundreds of millions of dollars by not investing in a project that was not worth the full cost.[74] But the process also allowed flexibility to localities that wanted to build a specific project, balancing qualitative and quantitative metrics to create compromises that both felt were fair.

MTC's analysis process is still relatively new, and it intends to refine the approach as more data and technologies become available. Similar to the experience at NCDOT, MTC had support within the organization and state leadership to create a new approach to project selection. This critical support moved the process forward, fostering future support from outside stakeholders. Additionally, MTC's experience demonstrates that a data-driven selection process that considers life cycle costs can target the funding to the most valuable projects.

The Port Authority of New York and New Jersey

Another example of a public agency that benefits from LCCA is the Port Authority of New York and New Jersey (PANYNJ). PANYNJ is a unique bi-state agency that was created to facilitate a unified approach to commerce across the Hudson River in the New York City region.[75] PANYNJ currently has jurisdiction over the region's airports, six tunnels and bridges, three bus terminals, the Port Authority Trans-Hudson (PATH, a transit system between New Jersey and Manhattan), and several real estate holdings.[76] As a bi-state agency, PANYNJ has a unique funding portfolio derived from tolls, landing fees, and fare revenues, and it does not rely on appropriations from either state.[77] Though this configuration gives the PANYNJ some freedom over its funding priorities, it also gives additional incentive to make every dollar count.

PANYNJ identified the need to repair the Bay Runway at John F. Kennedy International Airport in 2007 and the George Washington Bridge in 2010, both critical pieces of infrastructure in the New York City region.[78] These projects were going to consume a large portion of the PANYNJ budget, so there was an incentive to be sure that the current costs, use impacts, and future costs were kept to a minimum. With attention toward innovative approaches, the Port Authority decided to use LCCA to determine the best way to move forward with each project.[79] Through the use of LCCA, PANYNJ saved $140 million over 40 years on the JFK Bay Runway replacement project and $100 million over 20 years on the George Washington Bridge Repair.[80]

After the successful implementation of LCCA on these two projects, the Engineering Department and the Office of Capital Planning recommended using LCCA throughout the agency.[81] This catalyzed the development of a pilot program that selected four projects from departments across the agency to test the use of LCCA. The pilot LCCA was used on four projects of various complexities, with estimated costs of between $4 million and $450 million. Through this pilot program, PANYNJ found that though many project teams were using some form of economic analysis and evaluating project alternatives, there was no agency-wide standard. Instead, teams were using varying assumptions and methods that limited the ability for comparing results and experiences across projects.[82] While the overall cost of the pilot was about $67,000, the use of LCCA saved PANYNJ approximately $37 million.[83]

Recognizing the need, PANYNJ created a standardized approach to conduct LCCA. For the most part, the agency was welcome to the change, but some did worry that a new standardized method

While the overall cost of the pilot was about $67,000, the use of LCCA saved PANYNJ approximately $37 million.[83]

could add additional time to their project schedules. Additionally, as the program's roll out began, it was unclear which part of the agency was responsible for which part of the analysis. To overcome this barrier, a consensus was reached and process was defined. Within this newly defined process staff from the Engineering cost management unit prepare the LCCA, Program Management secures ongoing maintenance and operations costs, Capital Planning emphasizes impact users, and Capital Planning and the Office of Financial Analysis review all LCCAs for quality assurance.[84]

The Port Authority now has a 12-page guide detailing how to apply LCCA.[85] It recognizes that design alternatives do not always have comparable benefits and, as a result, benefit cost analysis was included in this document. Further, it was identified that LCCA was too costly for smaller projects, and as such a simple streamlined calculation was developed for smaller projects.[86] PANYNJ uses both forms of economic analysis throughout the agency, which has been credited with facilitating wiser investments and bolstering savings. In addition, the agency has found that they are now more cognizant of the life cycle of their assets, allowing PANYNJ to plan and make decisions accordingly. Finally, in this case, the initiative for the change came from internal leadership and demonstrates the value of standardizing LCCA to compare projects directly.

U.S. Army Corps of Engineers

One of the longest-running examples of economic analysis is the federal government's evaluation of waterways, in place since the 1930s. Since then, the U.S. Army Corps of Engineers (USACE) has developed methods to conduct economic analyses of the life cycle costs and benefits of a project and has learned how to efficiently navigate the environmental regulation process associated with the National Environmental Policy Act (NEPA). The use of economic analysis, including LCCA, has helped to create transparency and to facilitate investment in advantageous projects.

Prior to 2006, the USACE's Inland Marine Transportation System (IMTS) benefitted from an overflowing Inland Waterway Trust Fund (IWTF), but had the disadvantage of an investment approach that did not efficiently prioritize projects. While the 1936 Flood Control Act only authorized USACE to construct dams, levees, and dikes when the benefits exceeded the life cycle costs, the projects that fit this category were plentiful.[87] However, often these projects ultimately had more costs than were originally calculated and took longer than projected to construct.[88] Challenges with accurately forecasting current and long-term costs resulted in an unsustainable approach to investment.

With an emphasis to initiate new projects, USACE found itself spending down the balance in the IWTF. As the funding environment became increasingly constrained, it was determined that a new capital projects business model needed to be created.[89] The FY 2006 Energy and Water Development Appropriations Act helped to dramatically reform the way that investments were made in the IMTS. Specifically, it helped weaken the long-time continuing contracts clause, which had allowed the Corps to award contracts without fiscal constraint of currently available funds, and it encouraged funds "to remain on projects" that they had been appropriated for until they were expended.[90] These two changes helped to increase the usefulness of appropriated funds.

Within this new investment environment, many reforms to the project selection process occurred, including a new contract acquisition strategy, increased evaluation of system-wide benefits, and strengthened peer review of analyses.[91] However, USACE has developed a number of goals that will be incorporated in the next improvement of the capital business model. Included among these goals is the aim to improve the waterway system "through asset management, a risk informed decision-making process that assesses the life-cycle trade offs of a portfolio of projects within a watershed system."[92] Through incorporating the use of full life cycle costs into its asset management approach, USACE will have the ability to make wiser investments.

The almost 80-year history of economic analysis at the federal level demonstrates not only that the tools are available but also that they need to be updated to meet challenges as they arise. USACE's developed processes have the potential to serve as a model for other agencies or private sector practices. The problems with USACE IMTS investments demonstrate that benefit-cost analysis is

Through their LCCA for both operations and maintenance, the bidders proposed innovative designs that fit within RTD's specifications.

not necessarily sufficient as a determining factor for transportation investment. Amid a myriad of other investment policies, USACE found that its cost estimates were insufficient and it was not targeting that money towards the projects with the largest long-term benefits. As USACE improves its program and increases its use of LCCA in its asset management strategy, it will likely have more sustainable future funding streams.

Denver's Regional Transit District

Though the use of LCCA within the public sector is somewhat limited, the private sector's use of in-depth analysis of life cycle costs and benefits when evaluating business opportunities from an economic perspective has been long established. LCCA is typical in the real estate and electric utility fields, where companies control assets and have a direct role in managing operating and maintenance costs for decades. Transportation public-private partnerships (P3s) give public agencies an ability to directly engage the private sector to develop a full LCCA for a new or existing asset.

An example of a recent P3 that employed LCCA in the planning and design phases is the Denver Eagle P3 transit line, a 36-mile commuter rail project that will deliver passengers from downtown Denver to Denver International Airport, the cities of Westminster and Arvada, and Wheat Ridge.[93] The Regional Transit District (RTD), the primary transit operator in the region, developed an extensive transit expansion program known as FasTracks, but due to the economic downturn did not have the financing capability to construct and operate the entire program in-house. Instead, it developed an innovative financing package that included a P3 based on availability payments from a dedicated regional tax that leveraged the various funding sources available.

Private companies competed to win the 34-year contract; the winner was able to bring the upfront costs down and control future costs using extensive life cycle cost analyses for materials, operations, and other aspects of the project.[94] Through their LCCA for both operations and maintenance, the bidders proposed innovative designs that fit within RTD's specifications. For example, the winning bidder was able to single-track some of the railroad while still meeting the operating headway requirements. This, among other savings, ultimately, cut $300 million off the initial cost of the project that the agency said it would never have executed on its own. The $300 million allowed some of the other projects in the program to be advanced.

Like most transit operators, RTD has not historically conducted LCCA to assist in its decision-making processes. In this case, it was able to use the private sector's inherent incentives and existing knowledge to see substantial savings and complete critical infrastructure projects for the region. Further, the staff at RTD gained experience in using LCCA to control costs and find innovative solutions to problems, and RTD now considers life cycle cost when developing plans for their projects.

Though P3s account for a small portion of transportation investment in the United States, they offer two significant opportunities for public agencies interested in using more long-term economic analysis, including LCCA. First, engaging the private sector in the right way can bring direct incentives to find long-term cost savings and other benefits to transportation projects. Second, the exposure of public-sector staff to these kinds of projects can encourage more use of in-house data-driven analysis.

LESSONS LEARNED

For LCCA and other forms of economic analysis to be adopted more widely, a greater federal role in incentivizing these analyses will likely be required.

The cases presented provide snapshots of innovations happening across the country that can help agencies make smarter transportation investments. DOTs, MPOs, and other agencies are creatively revamping their decision-making process for investments using LCCA and other types of analyses. Agencies that have implemented some form of economic analysis have had positive results and have often expanded their programs. However, there are still challenges to creating or expanding use of these types of programs at many agencies. These cases illuminate a number of approaches, which can be used to overcome barriers, as discussed below.

Demonstrating Benefits of LCCA Is Essential

Change within the public sector, as with any large organization, can be very challenging. The implementation of LCCA does not necessarily offer obvious or immediate political benefits to agencies or elected officials that have longstanding project selection methods. This may explain why, in each of the case studies, internal vision, coupled with strong legislative leadership, was needed to overcome the barriers to implementing a new evaluation process.

The cases of PennDOT, NCDOT, MTC, and PANYNJ all tell similar stories of identifying a potential solution to constrained budgets and using that solution to craft an agency-wide vision. Each of those organizations cited budget constraints and the need to make smarter investments as the impetus to encourage action. But while PennDOT was able to create an LCCA program for a portion of their project selection, they found that budget constraints were also a barrier and were limited in dedicating staff to tackle new programs.

For the USACE, NCDOT, and MTC, new legislation played an important role in creating and solidifying their programs. It was a new statute that mandated USACE use economic analysis in its decision-making process. Similarly, California and North Carolina enacted new laws instructing MTC and NCDOT, respectively, to incorporate economic analysis into their decision-making processes. Simultaneously employing top-down (through legislation) and bottom-up (through agency action) strategies helps solidify the future of the programs.

To date, state and agency leadership has been the driving factor in the United States' experience with LCCA. However, the overall experience is very limited, suggesting that while state and local leadership can be helpful, incentives for nation-wide implementation do not yet exist. For LCCA and other forms of economic analysis to be adopted more widely, a greater federal role in incentivizing these analyses will likely be required.

Successful Agencies Have Engaged the Broad Range of Existing Resources

Though there are barriers to implementing LCCA programs, a wide range of resources exist to help provide guidance to agencies. Aside from the numerous guides and academic research documents cited in the literature review, agencies can look to peer organizations to evaluate and borrow methodologies. Additionally, many of the case examples used public working groups to evaluate which criteria are most important to local needs and goals. For both MTC and NCDOT, by engaging community members, peer agencies, and the existing literature, the agencies reviewed were able to better understand their needs as well as to communicate to them in a transparent manner how they were making investments.

Courtesy of Paul Swansen

The profit motive inherent in the private sector—when engaged to design, build, operate, and maintain a transportation infrastructure asset over its life cycle—offers a way to realize substantial costs savings.

Economic and Financial Analysis Programs Are an Iterative Process

Developing programs that incrementally incorporate different types of economic analysis, including LCCA, into the decision-making process provides a transparent environment that fosters community and workforce support and buy-in. For many organizations, LCCA for pavements is a gateway process, allowing a relatively simple analysis to use as a communication tool and to demonstrate costs and compare projects. Pilot programs are part of this iterative process: PANYNJ developed a pilot program that incorporated LCCA for a select set of projects. At the conclusion of the program, executives found that they were better able to leverage funds, cultivating cross-agency buy-in allowing them to develop a more mature program. NCDOT has also created an incremental program that builds on itself with each iteration, using feedback from local communities and the industry. This allowed the NCDOT to ramp up its evaluation process while learning from the challenges that it faced in the earlier iteration. USACE is still making improvements to its process after 80 years. Building a thorough LCCA program in many cases involves changing the culture of the organization, and executive management needs to be actively involved from the start.

Data-driven Analysis Should be Just One Aspect of the Decision-making Process

Each case stressed that the economic analysis is only an informative part of the decision-making process. Public organizations are beholden to the public, and constituents often want their dollars invested into specific projects or components regardless of what an objective LCCA might indicate. To effectively account for this, MTC created an appeal process to evaluate projects that received low scores from the data. This allowed important issues that could not be translated into numbers to be considered.

Most transportation agencies already incorporate some form of community engagement in their decision-making process, but this becomes even more important when developing a data-driven analysis such as LCCA. By soliciting and incorporating feedback from members of the public in a process that is not overly rigid, agencies are likely not only to build stronger programs but are also able to develop transparency and trust with the community, potentially helping them increase revenues in the future.

The Private Sector can Facilitate the Introduction of Life Cycle Cost Analysis

Finally, the private sector has played a very limited role in the public procurement of infrastructure. But when it comes to using data-driven analysis, the private sector has a lot to offer, particularly with respect to cutting costs. The profit motive inherent in the private sector—when engaged to design, build, operate, and maintain a transportation infrastructure asset over its life cycle—offers a way to realize substantial costs savings, as demonstrated in the $300 million cost reduction in the Eagle P3 in Denver. This also allows a public agency to see the benefit of such analysis and incorporate some aspects of economic and financial analyses into the institutional decision-making process.

POLICY RECOMMENDATIONS

The benefits associated with the use of LCCA are clear and well documented. LCCA can yield tangible cost savings and improve long-term sustainability for budgets. Yet our case studies demonstrated barriers to adopting the use of LCCA, including the lack of agency expertise and the inability to dedicate resources to the development of LCCA within project selection and asset management. Other, more institutional, barriers include the short-term political cycle, which lends itself to favoring short-term benefits and upfront cost savings rather than a focus on costs spread over several decades. In addition, many agencies that construct projects are not responsible, or have separate budgets, for the on-going operations and maintenance costs after the project's construction is completed. Notwithstanding, many barriers can be overcome through properly designed incentives that encourage agencies to embrace change. Based on the findings in this paper, this section provides recommendations for federal, state, and local governments to help encourage the use of LCCA in the decision-making process.

Federal Recommendations

The federal government influences the selection of projects through planning regulations and the federal aid grant program. By introducing new programs and building on pre-existing programs, Congress and USDOT can create a space that facilitates the expansion of data-driven project selection and asset management programs at the state and local levels.

Tie Funding to Performance

The largest policy change in the 2012 MAP-21 legislation was the introduction of performance evaluation into the planning process. Informed by specific national goals outlined by Congress, USDOT was directed to set minimum standards for bridge and pavement management systems. MPOs, RPOs, and transit agencies were directed to set their own performance targets for projects and asset management for all other categories. The introduction of performance measures was an important step towards creating a framework that could tie agency performance to funding.

Our research demonstrates that it is challenging to implement an LCCA program without federal incentives. Strengthening this preexisting federal level legislation could encourage states and metropolitan areas to incorporate LCCA, among other types of analysis, into the broader decision-making process. Congress should give USDOT greater authority to hold grantees accountable to their performance standards, allowing USDOT to tie performance to discretionary funding and rewarding states that make the most cost-effective decisions. Such a structure would incentivize states to reevaluate their decision-making process, and push them to use tools that already exist, including LCCA, that could optimize their performance outcomes.

Launch a Discretionary Grant Program Targeted Toward Asset Management

As evidenced in the survey results, maintenance and rehabilitation of existing assets is a growing concern for transportation agencies. Through competitive discretionary grant programs, USDOT can target money to incentivize improved asset management processes. Congress should introduce a new competitive discretionary grant program that provides funding specifically to aid in asset management. To apply for this 'Asset Management Grant', agencies would detail how they have traditionally conducted asset management for their system, and then propose a new approach that improves that system and saves money over the long-term. The top applicants with the greatest lifetime cost savings and demonstrating the largest improvement will receive a grant, for example, equal to 25 percent of their annual asset management cost, up to a set amount. Many applicants will be motivated to use LCCA, an important tool in creating a long-term asset management system by this program.

Use an LCCA-Driven Cost-Effectiveness Ranking to Inform the STIP and TIP

Within the current planning process neither MPOs nor states are required to rank the projects within their TIPs or STIPs, respectively. Congress should direct states and MPOs to use a data-driven,

transparent project ranking methodology to inform their STIP and TIP, ranking projects from most to least cost-effective. This would help decision-makers identify projects for their priority lists, providing information about which projects provide the greatest economic benefit. LCCA can be used to compare projects and would be an important aspect of compiling a priority list, as projects with lower life cycle costs would rank higher on the priority list, assuming that the associated benefits were equal. The project ranking list would be created transparently and would be publicly accessible. List creation would not only encourage the use of LCCA, but it would also help to build support for the most economically viable investments. Though this would be a new mandate on states, the benefits of improved life cycle costs would likely outweigh the short-term costs of establishing an LCCA program.

LCCA can be used to compare projects and would be an important aspect of compiling a priority list...

Improve Data Resources

The literature and case studies pointed to the lack of consistent data as a barrier to effective use of LCCA. This should be remedied through the creation of data collection standards and the expansion of data retention policies. This can be done at the state level, with a specific emphasis on the inputs needed to conduct an LCCA. The federal government should be involved to ensure that a consistent database is available to agencies across the country so that key data elements can be shared from state to state. Other federal agencies, such as the Department of Defense, have already created similar databases for their industries. Crucial data elements cited in the literature include historical material costs, maintenance costs, labor costs, and operational activities.

Fund Development of a Course for LCCA Leaders

Our research revealed that a consistent barrier to employing LCCA was that state and local planning staffs were often not sufficiently experienced in developing and implementing data-driven project selection and asset management techniques. This was also identified at the federal level with the experience of the use of analysis in the TIGER discretionary grant program. Though there are substantial resources available to help agencies conduct LCCA, this has so far proven insufficient.

To help states and localities develop the ability to conduct LCCA, USDOT should fund the development of a periodic, low-cost or free course aimed at teaching attendees how to best conduct an economic analysis, compare data over time, manage and incorporate risk, and implement and maintain an agency-wide program. At the end of the course, attendees would be able to return to their agency with the skills necessary to begin program development.

State and Local Recommendations

While federal level policy can help to provide incentives for states and localities to establish decision-making programs with LCCA, the development of a rigorous and effective program, with broad applicability, has to come from the local level. Our case studies illuminated both lessons and approaches to developing strong LCCA programs.

Establish an LCCA Pilot Program

As our case studies demonstrated, successful LCCA programs have been developed slowly and through a number of iterations. An important first step to using LCCA agency-wide is to establish a pilot program. Within a pilot program, an agency selects a set of specific projects to be evaluated with LCCA, and it includes industry stakeholders and organizational members to ensure that sufficient feedback is given on the design and implementation of

When surveyed, agencies suggested that additional staff training would be necessary in order to meaningfully incorporate LCCA into the decision-making process.

the pilot. The program should be transparent and open to stakeholder input throughout the process. At the conclusion of the pilot program, the agency should measure the results of this program, determining the benefits and costs of the approach. A pilot program allows the agency to ensure manageable implementation, and also allows program leaders to demonstrate to the whole agency the utility of the process. If successful, future iterations of the program can expand its reach as well as refine the approach to fit the specific agency's needs.

Introduce State Level Legislation

Pilot programs are an important first step towards incorporating LCCA into the decision-making process. Our cases suggested that LCCA introduction was generally initiated at the agency staff level, and slowly worked its way up to the higher echelons. Some of the clearest successes, however, included the introduction of state-level legislation to codify and solidify the programs that were developed at the agency level. Programs where funding is legally tied to the results of LCCA and other economic analysis have the strongest likelihood of longevity, even within a changing political environment. State legislatures should work with the DOTs to create language that will perpetuate and strengthen LCCA programs.

Dedicate Funding to Workforce Development

When surveyed, agencies suggested that additional staff training would be necessary in order to meaningfully incorporate LCCA into the decision-making process. Agencies should dedicate funding to developing and providing training programs to staff and executives who need to understand how to use LCCA. This training should teach staff how to implement a broad LCCA program within the agency, conduct an analysis, and refine an analysis so that it is comparable across a set of projects. Though agencies often have limited time and budget to dedicate to training programs, LCCA can offer savings many times greater than the cost of the training. If employees are trained to conduct LCCA, agencies and the industry can focus their attention on improving construction methods and materials to monitor and reduce overall costs.

Partner with the Private Sector

As our P3 case illustrated, the private sector has a long history of incorporating LCCA into its proposals and contract development, as it is a crucial aspect of being selected for a contract. When agencies engage in appropriate public-private partnerships, they can benefit from the natural incentives that the private sector has to control life cycle costs and innovate new approaches to project design. Where it is appropriate, the private sector can be engaged in a competition to design, build, operate, and maintain infrastructure assets over their full life cycle. In order to create and execute a successful contract, public sector employees should be trained to increase their comfort level with the private sector's approaches. Through these relationships, public sector employees can learn from their private sector counterparts, potentially encouraging public sector staff to incorporate private sector tactics into their own purely public projects. It is important that the private sector operate as a partner with the public sector so that the agency employees can retain and improve the institutional knowledge.

CONCLUSION

With the focus of funding shifting toward system preservation, greater use of LCCA can ensure sustainability of future budgets and better management of our vital infrastructure.

When making funding decisions under constrained budgets, it is tempting to place high importance on the up-front costs and pay little attention to costs in the future. This is shortsighted. The United States needs to begin thinking more strategically about how it maintains and operates its transportation network, and manages its assets in the future. With the focus of funding shifting toward system preservation, greater use of LCCA can ensure sustainability of future budgets and better management of our vital infrastructure. An LCCA program is undoubtedly a challenging endeavor for a state agency to undertake, but just because it is challenging or has not been done before does not mean that it cannot be done.

Though federal policy encourages the use of economic analysis, particularly LCCA, its use is not mandatory or incentivized with funding. Some state and local agencies have implemented successful programs, but these programs have resulted from unique situations under strong political and agency-level leadership. LCCA can be more widely implemented through direct action at the federal, state, and local level that requires and encourages the development of more robust, data-driven analysis programs at relatively low cost to agencies. LCCA should be the standard in any capital programming process. Given the ongoing funding challenges at the federal and state levels, it is an even more urgent initiative today.

When making funding decisions under constrained budgets, it is tempting to place high importance on the up-front costs and pay little attention to costs in the future.... LCCA should be the standard in any capital programming process.

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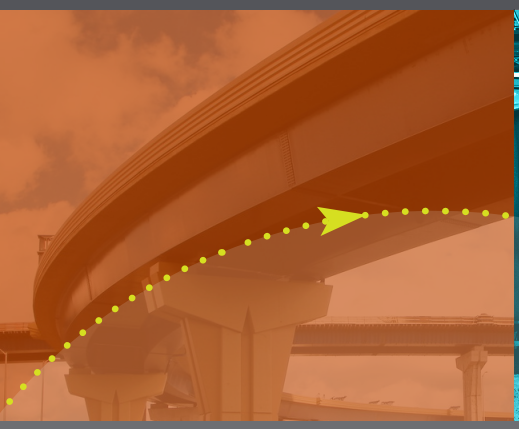

This report was prepared by the Eno Center for Transportation and the American Society of Civil Engineers.

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