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FEDERAL-AID HIGHWAYS

Improved Guidance Could Enhance States' Use of Life-Cycle Cost Analysis in Pavement Selection

GAO-13-544

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GAO Highlights

Highlights of GAO-13-544, a report to congressional committees

Why GAO Did This Study

LCCA provides state transportation agencies with a tool to evaluate and select the most cost-effective type of pavement, one of the major cost components of many highway projects. Given the high demand for federal highway funding, the federal government has an acute interest in helping states use LCCA to make cost-effective decisions when investing federal-aid highway funds. Accordingly, it is important that FHWA's guidance on LCCA aligns with best practices. The Moving Ahead for Progress in the 21st Century Act directed GAO to review LCCA best practices. GAO (1) described how state transportation agencies conduct and use LCCA and (2) assessed the extent to which FHWA's LCCA guidance conforms to the GAO *Cost Guide's* cost-estimating best practices.

GAO reviewed states' LCCA practices and interviewed officials from 16 states (visiting 4), selected to provide information on a wide range of LCCA approaches and a wide geographical distribution. Information gathered from these states is not generalizable to all states. GAO also interviewed FHWA officials. GAO assessed the extent to which FHWA's LCCA guidance, including software and documentation, conforms to best practices.

What GAO Recommends

To better ensure federal-aid highway funds are invested effectively, FHWA should update LCCA guidance to fully incorporate the *Cost Guide's* best practices. The Department of Transportation agreed to consider this recommendation and provided technical comments that were incorporated as appropriate.

View GAO-13-544. For more information, contact James R. McTigue, Jr., at (202) 512-2834 or McTigueJ@gao.gov.

What GAO Found

Thirteen of the 16 state transportation agencies GAO contacted used Life-Cycle Cost Analysis (LCCA) to select the pavement type (e.g., asphalt or concrete) for certain road construction and rehabilitation projects. Officials in all 13 states indicated that LCCA helped ensure that the agency selected the pavement that was most cost-effective over the long term, but states' specific LCCA practices varied. In general, these states used LCCA for larger projects, but each state had unique criteria to determine which projects should be subject to an LCCA. Likewise, the broad categories of LCCA inputs—such as agency costs, timing of future road work, and discount rate—are similar, but state transportation agencies handled each of these inputs in different ways. For example, estimates of when future roadwork would occur for a particular pavement type were based on state-specific factors, such as past experience with pavements and climate. Furthermore, state agencies used different criteria to decide if LCCA results clearly indicated a pavement type with the lowest life-cycle cost. In 9 of the 13 states that used LCCA, the Federal Highway Administration's (FHWA) LCCA guidance was an important influence on state practices, according to state transportation officials, and 7 states used LCCA software developed by FHWA.

FHWA's LCCA guidance largely aligns with the GAO *Cost Guide's* best practices for two of the four phases of the cost-estimating process and partially aligns with two other phases. FHWA's guidance in the *Initiation* phase, which includes initial planning steps, aligns with best practices overall. Agency guidance covers about half of the best practices of the *Assessment* phase, but does not, for example, discuss the use of independent cost estimates for comparison and cross checks, an important quality step to ensure the estimate's credibility. In the *Analysis* phase, FHWA's guidance does a good job explaining how to address the variability inherent in cost estimation, but could better address how LCCA should be documented for subsequent review. Lastly, in the *Presentation* phase, FHWA's guidance does not include sufficient information on how to present LCCA results to management for decision-making and on when an LCCA should be updated. By better incorporating best practices in the guidance, FHWA could help states produce credible and accurate cost estimates and make more cost-effective federal-aid highway fund investment decisions.

Federal Highway Administration's Guidance Compared to GAO *Cost Guide's* Best Practices

Cost estimating phase	Initiation	Assessment	Analysis	Presentation
Overall phase assessment	Aligns	Partially aligns	Substantially aligns	Partially aligns

Key:

Aligns	Substantially aligns	Partially aligns	Minimally aligns	Does not align
Completely satisfied the best practice	Satisfied a large portion of the best practice	Satisfied about half of the best practice	Satisfied a small portion of the best practice	Did not satisfy the best practice

Source: GAO analysis of Federal Highway Administration documents.

Contents

Abbreviations

AASHTO	American Association of State Highway Transportation Officials
ASCE	American Society of Civil Engineers
FHWA	Federal Highway Administration
LCCA	Life-Cycle Cost Analysis
OMB	Office of Management and Budget
TRB	Transportation Research Board

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The Honorable Barbara Boxer
Chairman
The Honorable David Vitter
Ranking Member
Committee on Environment and Public Works
United States Senate

The Honorable Lamar Smith
Chairman
The Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

The Honorable Bill Shuster
Chairman
The Honorable Nick J. Rahall, II
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

Billions of federal-aid highway dollars are obligated each year for projects in states for the construction and rehabilitation of road pavements. There are multiple pavement types and designs that can be used to construct or rehabilitate roads, and selecting the appropriate material and design to meet a specific road's performance needs is a highly technical engineering task.[1] Pavement types, for example, include many combinations of asphalt, concrete, and advanced material alternatives. Through the federal-aid highway program, administered by the Federal Highway Administration (FHWA), the federal government provides about $40 billion in funding to state transportation programs each year. Thus, the federal government has a significant interest in helping state transportation agencies make informed and prudent pavement-type selection decisions, particularly as states face limited transportation funding, both from federal and state sources, and many are struggling to meet road-building and maintenance needs. Though federal-aid highway

[1]GAO, *Information on Materials and Practices for Improving Highway Pavement Performance*, GAO-13-32R (Washington, D.C.: November 2012).

funds are used by states for a wide range of project types—such as bridge building and repair, road maintenance, and safety projects—that do not involve large amounts of pavement, major road construction or reconstruction projects can include costly pavement components. As the interstate highway system ages, there is potential that these types of major projects may become more frequent. Life-Cycle Cost Analysis (LCCA) is an important economic tool to evaluate and help select the pavement-type for a particular project that will minimize costs over the long term, rather than just minimizing initial construction costs. Nevertheless, state transportation agencies may not use LCCA, or may not conduct it well, for a variety of reasons, including limited experience with LCCA, historical material preferences, and data limitations.

To facilitate the use of LCCA in pavement-type selection decisions, FHWA issued interim guidance in 1998 and has since provided LCCA software—called RealCost—that states can use to conduct LCCA, among other guidance and assistance. Because FHWA has a pivotal role in assisting states in the execution of the federal-aid highway program, it is important that FHWA's guidance on LCCA aligns with best practices for cost estimation. Congress, FHWA, and state transportation agencies may benefit from a better understanding of the LCCA practices currently used by states and what federal actions, if any, could better support these practices and ensure federal transportation investments are made wisely. We conducted this study in response to a mandate adopted in the Moving Ahead for Progress in the 21st Century Act, the most recent federal surface transportation authorization act.[2] The mandate called for a GAO examination of LCCA best practices and recommendations on specific technical elements of LCCA conduct. We designed our review to identify any potential opportunities for FHWA to advance the state of LCCA practices, recognizing that there may not be one correct approach to addressing the technical elements of LCCA. Specifically, this report (1) describes how state transportation agencies currently conduct and use LCCA and (2) assesses the extent to which FHWA's guidance for conducting LCCA conforms to best practices identified in GAO's *Cost Estimating and Assessment Guide* (*Cost Guide*).[3] The *Cost Guide* consolidates best practices that federal cost-estimating organizations and

[2]Pub. .L. No. 112-141, § 52,003(a), 126 Stat. 405, 875 (2012), codified as positive law at 23 U.S.C. § 503(b)(3)(D)(ii).

[3]GAO *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs.* GAO-09-3SP (Washington, D.C.: March 2009).

industry use to develop and maintain reliable cost estimates throughout the life of a government acquisition program. These criteria are applicable to FHWA's guidance because both the GAO *Cost Guide* and FHWA's guidance describe cost estimation processes for capital investment decision making.

To determine how state transportation agencies conduct LCCA for federally funded highway projects, we visited 4 states to interview FHWA division office officials, state transportation agency officials, and representatives from the asphalt and concrete pavement industry associations and conducted telephone interviews with state transportation agency officials in 12 additional states. We selected states based on criteria that allowed us to gather information from state transportation agencies with a wide range of LCCA approaches and a wide geographical distribution. The results of our interviews are not generalizable to all states. Additionally, we reviewed states' pavement selection and design manuals in the 16 selected states and reviewed relevant literature on LCCA from researchers, industry, and professional organizations. To assess FHWA's guidance, we identified the key LCCA guidance provided by FHWA to state transportation agencies and compared the guidance to GAO's *Cost Guide* best practices.[4] We determined whether FHWA's guidance aligns (provided complete evidence that satisfies the best practice), substantially aligns (provided evidence that satisfies a large portion of the best practice), partially aligns (provided evidence that satisfies about half of the best practice), minimally aligns (provided evidence that satisfies a small portion of the best practice), or does not align with these best practices (provided no evidence that satisfies any of the best practice). Finally, to inform all our objectives, we conducted interviews with appropriate FHWA officials, pavement industry stakeholders, and other relevant groups. See appendix I for more details on our scope and methodology.

We conducted this performance audit from August 2012 to June 2013 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our

[4]We reviewed the FHWA guidance *Life-Cycle Cost Analysis in Pavement Design,* Pavement Division Interim Technical Bulletin, Publication No. FHWA-SA-98-079 (September 1998); the most recent, publicly available, draft FHWA *Life-Cycle Cost Analysis – RealCost User Manual v. 2.5* (October 2010); and FHWA, *Life-Cycle Cost Analysis Primer* (August 2002).

findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

LCCA is a type of economic analysis that evaluates the long-term financial costs of a capital investment—such as highway construction—by comparing estimates of both initial cost and likely future costs of different investment alternatives. By considering all of the costs associated with each alternative over the life of the investment, as opposed to considering only initial investment costs, the lowest *overall* cost alternative can be determined. In brief, LCCA involves developing alternative investment scenarios that meet project objectives, estimating the timing and costs of activities associated with constructing, using, and maintaining each alternative over a set analysis period, and discounting future costs into present dollar terms. Finally, initial and discounted future costs for each alternative are summed and compared. Costs that are considered include direct costs incurred by the transportation agency (agency costs), such as the cost of materials, and costs that other individuals or entities may incur due to the investment. For example, in addition to direct costs, a state transportation agency may chose to consider the costs of motorists being delayed during the construction of the different alternatives. LCCA does not evaluate the benefits—such as increased mobility—of different alternatives and, consequently, should only be used to compare alternatives that provide equivalent benefits. Other types of economic analysis may be used to compare alternatives which have differing benefits.[5]

LCCA can be applied to investments in road infrastructure because there are multiple pavement design and pavement-type alternatives that can meet the level of performance needed in road projects. Using standard design tools, engineers can design a road using different pavement types that are functionally equivalent in terms of lanes, traffic capacity, ability to

[5]GAO, *Highway and Transit Investments: Options for Improving Information on Projects' Benefits and Costs and Increasing Accountability for Results*, GAO-05-172 (Washington, D.C.: January 2005).

handle heavy trucks, and other factors.[6] For example, a new road could be built with a variety of asphalt or concrete designs; LCCA provides a method to compare the costs of a concrete or asphalt design, or the costs of different designs using differing types of the same material. The agency cost of these alternatives may vary in terms of prices for materials, labor, and future maintenance, rehabilitation, and reconstruction work. For example, the initial construction costs of a concrete road may be higher than an asphalt design, but may require less frequent maintenance and rehabilitations. Further, alternatives may impose different user costs upon motorists due to, for example, travel-time delays associated with initial construction and future roadwork, and, as noted above, these costs may also be included in LCCA.[7]

As part of its responsibilities to ensure federal funds are used effectively, FHWA encourages the use of LCCA in pavement-type selection decisions.[8] However, there is no current requirement that LCCA be conducted or used to select among pavement types used on federally

[6]State transportation agencies often use guidance developed by the American Association of State Highway Transportation Officials (AASHTO) to design pavements. In 2011, AASHTO released a new software program (Pavement ME Design). Many states are in the process of evaluating this software and a few states have adopted this software for routine pavement design. The new software may indicate a different thickness of pavement material should be used that, in turn, would change the total cost of materials for that design. This software must be calibrated for conditions in individual states because, for example, the same design may perform differently in different climatic conditions and differently based on the available construction materials and stone in the state. Additionally, the *Practical Guide to Cost Estimating* released by AASHTO in 2013 provides states with guidance on how to develop cost estimates for highway projects.

[7]Any costs or activities that are expected to be the same for all alternatives—such as lane painting—may be excluded from an LCCA. Consequently, a life-cycle cost estimate may not include all the costs of a project. Likewise, environmental costs, such as noise and emissions, are generally not included in LCCA for pavement-type selection because of the difficulty in monetizing these factors, though public agencies may have an interest in minimizing such costs.

[8]We have previously reported on the benefits and risks for the federal-aid highway program due to FHWA's partnership with state transportation agencies. To advance the federal-aid highway program, FHWA engages in a range of activities, including providing technical assistance and developing solutions to indentified problems—to encourage the effective and efficient use of federal-aid highway funding. GAO, *Highway Infrastructure: Federal-State Partnership Produces Benefits and Poses Oversight Risks*, GAO-12-474 (Washington, D.C.: April 2012).

funded highway projects.[9] Accordingly, FHWA's LCCA guidance and assistance to state transportation agencies is advisory. Furthermore, FHWA recommends LCCA be used as a decision support tool—not for planning or programming projects—within the framework of each state's own pavement management processes. As shown in table 1, FHWA first issued printed LCCA guidance in 1998 with an interim technical bulletin, which was followed by additional guidance and LCCA software. Each piece of guidance covers slightly different aspects of LCCA, at different levels of detail, and reflects the state of FHWA's guidance at the time of publication. For example, FHWA's 1998 *Life-Cycle Cost Analysis in Pavement Design* interim technical bulletin and the 2002 *Life-Cycle Cost Analysis Primer* pre-date the release of FHWA's RealCost software and associated *User Manual* and, consequently, do not reference or discuss these tools. FHWA has been in the process of updating the 1998 interim bulletin since 2009. FHWA also provides LCCA training, which, like other FHWA training, is typically offered based on state interests and requests. Collectively, FHWA's guidance and assistance is intended to provide state transportation agencies with sufficient information and tools to conduct and use LCCA to make cost-effective pavement-type selection decisions. Furthermore, the Office of Management and Budget (OMB) provides federal agencies with guidance about many of the technical aspects of conducting economic analyses, such as LCCA. For example, OMB has issued guidance related to the selection of a discount rate.[10]

[9]The Intermodal Surface Transportation Efficiency Act of 1991, Pub. L. No. 102-240, § 1024(a), 105 Stat. 1914, 1958 (1991), codified as positive law at 23 U.S.C. § 134(f)(12), had an LCCA requirement, but this requirement was dropped by the Transportation Equity Act for the 21st Century, Pub. L. No. 105-178, 1203(f)(1), 112 Stat. 107, 174 (1998), which replaced 23 U.S.C. § 134(f). Federal-aid highway projects on the National Highway System with total costs above $50 million for highway projects and $40 million for bridge projects are required to have value engineering analysis, a type of economic analysis designed to identify more efficient and less costly engineering approaches to executing a project. Value engineering analysis may include LCCA. There is also no federal requirement that states use LCCA for bridge projects.

[10]Office of Management and Budget, *Circular A-94* and associated clarification memorandums, including M-12-06 and an unnumbered correspondence to agencies dated September 20, 2012 on inflation, discounting, and life-cycle cost time periods.

Table 1: Federal Highway Administration (FHWA) Guidance and Assistance Available to States on Life-Cycle Cost Analysis (LCCA), 1998-Present

FHWA guidance and assistance	Description
Life-Cycle Cost Analysis in Pavement Design interim technical bulletin (1998)	Describes how LCCA can be used to inform pavement-type selection and how to conduct LCCA. Currently being revised.
Life-Cycle Cost Analysis Primer (2002)	Summarizes LCCA techniques and benefits.
RealCost LCCA software (first released in 2002, most recent version 2011)	Facilitates the conduct of LCCA by providing a computational tool.
RealCost LCCA *User Manual* (updated in 2010)	Explains how to use RealCost software and discusses LCCA concepts and practices.
LCCA training by FHWA	Provides training on a variety of LCCA concepts and tools, including RealCost.

Source: GAO analysis of FHWA materials.

In 2009, GAO issued the *Cost Guide* to provide guidance on best practices for cost estimation to address a gap in federal guidance about processes, procedures, and practices needed for ensuring credible cost estimates.[11] These best practices delineate the process that should be followed to develop a reliable, high-quality cost estimate, including appropriate consideration of life-cycle costs. These best practices represent an overall process of established, repeatable methods that result in high-quality cost estimates that are comprehensive and accurate and that can be easily and clearly traced, replicated, and updated. Each of the practices is important for ensuring that high-quality cost estimates are developed and delivered in time to support important decisions. The *Cost Guide* delineates a four phase process with 12 constituent steps (table 2).

[11]GAO-09-3SP.

Table 2: GAO's Cost-Estimating Process Best Practices

Phase	Best practice	Summary of tasks within best practices
Initiation	Define estimate's purpose	Determine purpose, scope, required level of detail of estimate, as well as who will receive estimate.
	Develop estimating plan	Determine cost estimating team, schedule, and outline tasks in writing.
Assessment	Define program characteristics	Identify technical characteristics of planned investment, quality of data needed, and plan for documenting and updating information.
	Determine estimating structure	Define the elements of the cost estimate, including best method for estimating costs and potential cross-checks, and standardized structure.
	Identify ground rules and assumptions	Define what the estimate will include and exclude, key assumptions (such as life cycle of investment), schedule or budget constraints, and other elements that affect estimate. Assumptions should be measurable, specific, and consistent with historical data. Assumptions should be based on expert, technical judgment and approved by management.
	Obtain data	Create data collection plan, identify sources, collect valid and useful data, analyze data for cost drivers and other factors, and assess data for reliability and accuracy.
	Develop a point estimate and compare it to an independent cost estimate	Develop cost estimation model and calculate estimate, in constant dollars for investments that occur over multiple years, and other cross checks and validation, and compare estimate to an independent estimate and previous estimates. Update as more data are available.
Analysis	Conduct sensitivity analysis	Test the sensitivity of cost elements to changes in input values, ground rules, and assumptions.
	Conduct risk and uncertainty analysis	Determine which cost elements pose technical, cost, or schedule risks; analyze those risks; and recommend a plan to track and mitigate risks. A range of potential costs, based on risks and uncertainties, should be identified around a point estimate.

Phase	Best practice	Summary of tasks within best practices
	Document the estimate	Document all steps used to develop the estimate so it can be recreated, describing methodology, data, assumptions, and results of risk, uncertainty, and sensitivity analysis.
Presentation	Present estimate to management for approval	Develop briefing on results, including information on estimation methods and risks, making content clear and complete so those unfamiliar with analysis can comprehend estimate and have confidence in it.
	Update the estimate to reflect actual costs and changes	As technical aspects of project change, the complete cost estimate should be regularly updated and, as project moves forward, cost and schedule estimates should be tracked.

Source: GAO.

States' Life-Cycle Cost Analysis Practices Vary, Though They Are Often Informed by FHWA Guidance

State Life-Cycle Cost Analysis Practices Vary

Most of the selected states we reviewed use LCCA in some capacity to help ensure the long-term cost-effectiveness of investment decisions. Thirteen of the 16 states included in our review used it in some capacity.[12] State transportation officials in all 13 of these states indicated that the goal of LCCA was to help ensure that the agency makes long-term, cost-effective investment decisions. Some state officials also noted that LCCA can help the state transportation agency communicate to stakeholders—pavement industry representatives, state legislators, and taxpayers—that

[12]A Transportation Research Board (TRB) project surveyed state transportation agencies and reported that 29 of 35 states that responded to its survey use LCCA for new construction or reconstruction projects. Transportation Research Board of the National Academies, National Cooperative Highway Research Program, *Report 703: Guide for Pavement Type Selection* (Washington, D.C.: 2011).

it is making sound decisions. For example, according to transportation officials in Florida, LCCA results have helped communicate to the legislature that higher initial cost projects may offer long-term value for some road projects. Officials in some states, however, noted that budget constraints made it difficult to pursue higher initial cost projects even if those projects made sense in the long term. Conversely, 3 of the state transportation agencies we examined do not use LCCA as part of their pavement-type selection process. State transportation officials for these states explained that it was not a consideration in pavement selection decisions for several reasons, including initial cost constraints, engineering reasons for pavement selection, and institutional resistance to consideration of pavement-type alternatives not historically used in the state.

In general, selected states use LCCA for larger projects, be they new or reconstruction projects, but states had different specific policies for determining which projects should have an LCCA conducted. In the states we reviewed, these policies included conducting an LCCA when a project dollar threshold is met, such as when pavement material costs exceed $2 million, when a project adds new capacity, or when a specified amount of pavement material would be used, among others. Because a state may have few projects that meet the state's threshold, LCCA may be used infrequently. Officials in 6 states indicated that fewer than five LCCAs were typically conducted each year. However, when LCCAs are conducted, the projects tend to be among the state's largest or most expensive transportation projects. For example, the California Department of Transportation used LCCA to help select the pavement type for a major interstate improvement project between San Francisco and Sacramento, with life-cycle costs estimated to be over $50 million for each project alternative.

Of the 13 states we reviewed that conduct LCCAs, 10 perform LCCA early during project design (e.g., when 30 percent of design work is completed), but practices varied among states about reviewing and updating LCCAs later during the project. By making a pavement selection early, transportation officials from 3 states indicated that they are able to make decisions about right-of-way acquisitions or other project elements

that are contingent on the selection of a pavement-type.[13] When an LCCA is completed early in project design, 2 or 3 years may pass before project construction. In 5 of the 10 states that indicated that LCCAs were conducted early, officials indicated that LCCAs were not updated later during design; officials in the other 5 of these 10 states indicated they had procedures to update LCCA, noting that pavement decisions can be reevaluated and changed, if warranted. The 3 remaining states performed LCCA later in the design process. Some state officials reported that completing an LCCA takes agency staff anywhere from a couple days to several months, depending on the project's complexity, the data collection needed to conduct the analysis, and the sophistication of the LCCA technical approach used.

State transportation agencies generally consider the same categories of inputs in their analysis, but state agencies handle each of these inputs in different ways. Key categories of inputs include agency costs, timing of future roadwork, user costs, analysis period, discount rate, and the treatment of the risk and uncertainty that are associated with these inputs. For example, we found that states use different analytic approaches in regard to risk and uncertainty; 9 states conducted deterministic LCCA and 4 conducted probabilistic LCCA of the 13 we reviewed.[14] Table 3 provides additional information about key inputs and the variation in state practices. The fact that states do not treat all key inputs similarly does not necessarily indicate that one state's LCCA is of a higher quality than another because there could be more than one legitimate approach to

[13]For new construction projects, or reconstruction projects that involve changes in road location, the state may need to acquire additional land, or right—of—way, to build a project. In some cases, the amount of land needed may be contingent on the pavement design selected for the project.

[14]Two different computational approaches can be used in LCCA—deterministic and probabilistic. The methods differ in the way they address the variability associated with the LCCA input values. In the deterministic approach, the analyst assigns each LCCA input variable a fixed, discrete value that is used to compute a single life-cycle cost estimate for the alternative under consideration. The deterministic approach, however, does not address simultaneous variation in multiple inputs, and does not convey the degree of uncertainty associated with the life-cycle cost estimates. The probabilistic approach entails defining individual input variables by a frequency/probability distribution, rather than by discrete values. It represents a risk analysis of the life-cycle costs of a particular design alternative. A probabilistic analysis provides a much greater understanding of the variability associated with inputs, its effects on projected life-cycle costs, and how it can be managed to increase the reliability of results and the confidence in identifying the most economical alternative.

addressing these inputs. Some variations may reflect that state agencies used LCCA inputs that make sense given their state's particular historical experiences, circumstances, and needs. We found that estimates used in LCCA of when future roadwork would occur for a particular pavement

type and design were based, for example, on past experience with the durability of the materials and climatic conditions, among other influences on the pavement life within the state.

Table 3: Key Inputs for Conducting Life-Cycle Cost Analysis (LCCA) and GAO's Summary of Selected State Practices

Input and description	Importance for LCCA	Summary of state practices
Agency Costs: Estimated cost of initial construction project and of expected future road work	Estimating costs is fundamental to accurate LCCA, particularly as material prices fluctuate over time.	All 13 states considered agency costs, but sources varied, including historical statewide bid prices, regional prices, and engineers' estimates. Cost estimates for each project alternative were developed either by project engineers, cost estimation specialists, or based on general cost estimates for projects of certain types.
Timing of Future Road Work: Estimate of when future road work will be needed for each design alternative. Timing determines how many rehabilitations or reconstructions fall in the analysis period.	Comparing differences in the cost of future work between alternatives is essential for deciding if a higher initial cost option is cost effective over a project's life cycle.	All 13 states estimated future needed road work. We found timing ranged from 3 to 35 years after the original project, depending on, for example, traffic volume, climate, material, and design. Estimates were based on the state's historical experience with similar roadways, engineering judgment regarding design and material properties, or pavement industry estimates.
User Costs: Costs that are not paid by the agency but are incurred by the traveling public in the form of delay or vehicle operating costs, for example.	Costs incurred by users can, in some cases, be large. By including these costs in selecting a pavement-type, an agency may decide to procure a more costly pavement type or make changes in construction timing (e.g., day time vs. night construction) to lower user costs.	Eight states considered user costs—3 included only travel time delays, 5 included vehicle operating costs, and 1 included crash costs. Four of these 8 gave user costs equal weight to agency costs in their LCCAs. Of the 5 states that did not consider user costs, 2 indicated that the affect on users might be considered in making a final pavement-type selection outside of the LCCA framework. FHWA's RealCost or state-specific data may be used to determine the value of travel time delay reductions.
Analysis Period: Length of time over which estimated future costs of different alternatives are analyzed	Longer periods will typically include more occurrences of future road work. The correct length analysis period allows for the LCCA to reflect the long-term cost differences associated with each alternative.	In all 13 states, analysis periods ranged from 25 to 55 years, per state policy decisions or FHWA guidance, but generally were set to include a least one occurrence of major future road work for each alternative.

Input and description	Importance for LCCA	Summary of state practices
Discount Rate: Discounting incorporates the time value of money and allows future costs to be compared with current costs in terms of present value.	The higher the discount rate, the lower the present value of anticipated future costs and the less impact future costs have on LCCA results.	Among the 13 states, discount rates ranged from 0.1 to 5 percent, per Office of Management and Budget (OMB) or FHWA guidance, state interpretation of OMB or FHWA guidance, or state economic policy.[a] Some state agencies updated their discount rate routinely (e.g. annually or biennially) whereas others did not have a formal practice to update the rate.
Treatment of risk and uncertainty: Analysis inputs in LCCA are based, to some extent, on estimates that may prove incorrect. To address such risk and uncertainty, inputs can be specified as a range of probable values rather than as point estimates.	Addressing risk and uncertainty in LCCA can provide a more reliable analysis and more robust pavement-type selection decisions, but adds technical complexity.	Nine of 13 states used point estimates calculated in a deterministic LCCA analysis, and some stated it was because the deterministic analysis was simpler to conduct or easier to communicate results. Four of 13 states conducted some form of probabilistic analysis, varying at least some of the technical inputs. All of the selected states that conducted probabilistic analysis used FHWA's RealCost software to do so.

Source: GAO analysis of Federal Highway Administration and state data.

[a]OMB provides annual updates to discount rates recommended for use in economic analysis. FHWA's 1998 guidance on LCCA cites OMB as a source for information on selecting an appropriate discount rate, noting that historical rates applicable to LCCA ranged from 3 to 5 percent. In recent years, OMB has recommended rates ranging from about 1 to 3 percent for long-term capital investment due to declines in 30 year Treasury bill rates, upon which OMB's discount rates are based.

The accuracy and appropriateness of the inputs used is important for LCCA results to be credible. In some states and nationally, there is debate among states and pavement industry stakeholders about many of these inputs because they can determine the final LCCA result. One approach used in some states to help ensure the accuracy of inputs was to involve pavement industry stakeholders in LCCA review. For example, Colorado and Florida had formal processes to solicit industry comments on LCCAs prior to making pavement-type selection decisions. Other state agencies had other approaches with industry stakeholders. Washington and California, for example, collaborated with industry stakeholders, to varying degrees, regarding overall LCCA policies and procedures, rather than on project-level LCCA inputs.

Lastly, state agencies used different criteria to decide if LCCA results clearly indicated a lowest life-cycle cost pavement-type and had different approaches for documenting LCCA results. Seven of the 13 state transportation agencies that we interviewed that conduct LCCA for pavement-type selection concluded that the assessed alternatives were "equal" (as opposed to clearly identifying a lowest life-cycle cost alternative) when the estimated life-cycle cost of different alternatives were within 5 to 20 percent of one another. By contrast, one state defined the preferred alternative strictly as having the lowest life-cycle cost. In 10

of the 13 states we reviewed, when LCCA results indicated a clear preferred alternative, state officials said that the transportation agency usually selected that pavement. When the LCCA does not result in a clear preferred alternative, final pavement selection was generally based either on a range of factors that were not considered within the LCCA or through an alternative bidding process, in which the agency accepts bids for both pavement types. For example, the agency may consider the ease of maintenance or the duration of construction for pavement alternatives to minimize workers' exposure traffic and increase safety, or the agency may opt for the alternative with the lowest initial cost. Additionally, state agencies document the results of an LCCA and the agency's decisions in different ways. We found no standard template for reporting LCCA results. LCCA documentation is important so that, decision makers fully understand the strengths, assumptions, or limitations of the analysis. Further, when stakeholders have a clear understanding for the basis of a pavement-type selection, decisions will not seem arbitrary or unfounded.

State Practices Are Often Informed by FHWA Guidance

Selected states often used FHWA's guidance in developing their LCCA policies. In the 13 states we reviewed that conduct and use LCCA, FHWA's guidance was a central influence on state policy for 9 states, according to state transportation officials. FHWA support was especially important as some state transportation agencies initially developed LCCA policies and procedures. For example, in 3 of the 4 states we visited, state transportation officials stated that assistance from FHWA personnel or information provided in FHWA's guidance was central to the LCCA policies and procedures established by the state agency. Many states reported that FHWA has provided valuable training on LCCA or useful LCCA tools (e.g., RealCost). Additionally, peer exchanges sponsored by FHWA, in which officials from multiple states could share their experiences, were noted by officials in 4 states as helpful. Furthermore, officials in 2 of the 4 states we visited indicated that FHWA assistance could be particularly helpful to state agencies that are interested in incorporating LCCA into their pavement-type selection process. Officials we interviewed in all 13 states that conducted LCCA indicated that they would consider any new or additional FHWA guidance on LCCA. Specific areas in need of clarification cited by state officials included technical clarifications about discount rate and user costs, among others.

FHWA LCCA guidance, assistance, and tools also are used by many—but not all—of the states we reviewed when conducting and using LCCA to make pavement-type selections for specific projects. In some states, FHWA officials are active in pavement-type selection, such as when the

results of an LCCA are close between alternatives. For example, for federal-aid highway projects in Colorado, when the cost of alternatives is within 10 percent, a selection committee that includes a representative from FHWA is convened to review the project and make a selection. The FHWA representative reviews the state analysis and provides comments on technical inputs, adherence to the state's LCCA policy, and factors not considered in the LCCA that may affect pavement selection. In other states, FHWA staff may have little involvement in project-level analysis, but may, for example, participate in the review or revision of the state's LCCA policy or process. In addition, FHWA tools are central to how many of our selected states conducted their LCCAs. Specifically, 7 of the 13 states we reviewed used FHWA's RealCost software, with one using a customized version for the state. In general, many state officials indicated that RealCost was very helpful software, though some noted that the many inputs required in RealCost made it too complicated, and consequently, they preferred to do LCCA on simpler tools developed by the state.

FHWA LCCA Guidance Aligns with About Half of the Cost-Estimating Best Practices

FHWA's LCCA guidance largely aligns with best practices for two of the four phases of the cost-estimating process and partially aligns with two other phases. As we have previously found,[15] there are a number of best practices that can help ensure credible and reliable cost estimates. FHWA's LCCA guidance includes many elements of those best practices.[16] In particular, FHWA's guidance in the initiation and analysis phases aligns or substantially aligns with best practices, but only partially aligns with best practices in the assessment and presentation phases (see fig. 1).[17] As discussed earlier in this report, FHWA's guidance is a central influence on state policies, so inclusion of cost-estimating best

[15]GAO-09-3SP.

[16]GAO's *Cost Guide*, which is based on input from cost community experts and extensive research of best practices for estimating program schedules and costs, indicates that a high-quality, valid, and reliable cost estimate should be well documented, comprehensive, accurate, and credible. As discussed earlier in this report, the cost estimation process contains 12-steps which occur within four overarching phases: initiation, assessment, analysis, and presentation.

[17]We reviewed the FHWA guidance *Life-Cycle Cost Analysis in Pavement Design,* Pavement Division Interim Technical Bulletin, Publication No. FHWA-SA-98-079 (September 1998); the most recent, publicly available, draft FHWA *Life-Cycle Cost Analysis–RealCost User Manual v. 2.5* (October 2010); and the FHWA *Life-Cycle Cost Analysis Primer (*August 2002).

practices in FHWA's LCCA guidance is important to facilitate the best use of LCCA.

Figure 1: Summary of GAO's Assessment of Federal Highway Administration Life-Cycle Cost Analysis Guidance

Cost estimating phase	Overall phase assessment	Best practices	Best practices assessment
Initiation	Aligns	Define estimate's purpose	Aligns
		Develop estimating plan	Substantially aligns
Assessment	Partially aligns	Define program characteristics	Partially aligns
		Determine estimating structure	Substantially aligns
		Identify ground rules and assumptions	Substantially aligns
		Obtain data	Partially aligns
		Develop point estimate and compare it to an independent cost estimate	Partially aligns
Analysis	Substantially aligns	Conduct sensitivity analysis	Aligns
		Conduct risk and uncertainty analysis	Aligns
		Document the estimate	Partially aligns
Presentation	Partially aligns	Present estimate to management for approval	Minimally aligns
		Update the estimate to reflect actual costs and changes	Partially aligns

Aligns → Completely satisfied the best practice

Substantially aligns → Satisfied a large portion of the best practice

Partially aligns → Satisfied about half of the best practice

Minimally aligns → Satisfied a small portion of the best practice

Does not align → Did not satisfy the best practice

Source: GAO Analysis of Federal Highway Administration documents.

Initiation

FHWA's guidance aligns with the best practices for the first phase of cost estimating by defining the cost estimate's purpose and substantially aligns with describing how to develop an estimating plan. As stated in the *Cost Guide,* guidance on the work to be performed in this phase is important to help states understand why the estimates should be conducted, the level of detail required in the estimate, and the time required to prepare the estimate.

- *Define estimate's purpose: Aligns.* FHWA describes the LCCA purpose and process in detail, in both FHWA's *Life-Cycle Cost Analysis Primer (Primer)* and FHWA's *Life-Cycle Cost Analysis in Pavement Design*, Pavement Division Interim Technical Bulletin *(Technical Bulletin)*. The documents describe when a LCCA should be completed, what the purpose of the LCCA is, and what a LCCA should include. FHWA's *Life-Cycle Cost Analysis—RealCost User Manual (User Manual)* also describes the purpose of a LCCA consistent with the description in the *Technical Bulletin*.
- *Develop estimating plan: Substantially aligns.* FHWA presents the steps to develop a LCCA estimating plan—such as establishing pavement alternatives, estimating agency and user costs, and analyzing results—in detail in both the *Primer* and *Technical Bulletin* documents. The description of the process states that the scope and level of detail should be identified. However, we found that the guidance did not include a proposed schedule for when these steps should be completed. Without adequate time to develop a competent estimate, a team may be unable to deliver an estimate of sufficiently high quality. According to the *Cost Guide,* a schedule ensures that an estimating team has sufficient staff time to perform the estimate.

Assessment

FHWA's guidance partially aligns with best practices in the second phase of the cost estimation process. In this phase, we found that FHWA provided guidance that substantially aligned with best practices on how to develop an estimating structure and how to identify ground rules and assumptions, which can help state transportation agencies better understand LCCA and how to conduct LCCAs more efficiently. However, the guidance partially aligned with best practices of defining the program's characteristics, obtaining data, and developing a point estimate for comparison with an independent cost estimate. Providing additional guidance in these three areas, consistent with best practices, could help ensure the technical execution of an LCCA is optimal.

- *Define program characteristics: Partially aligns.* FHWA's LCCA guidance identifies the type of technical information needed, such as route; location; annual average daily traffic, including the percentage of which is trucks; speed limit; and other details to define the project characteristics required to perform a LCCA, but the guidance does not include adequate discussion on developing plans for updating technical information to stay current with the project requirements. If the technical information is not updated, then as the project changes, the estimate may no longer be credible. For example, if the cost of a pavement-type alternative used in the LCCA is based on initial technical information assumptions, and those assumptions change after the LCCA is completed, resulting in the pavement being designed to a different thickness with a different cost, then an alternate pavement type may be more cost-effective but not identified unless the LCCA is updated.

- *Determine estimating structure: Substantially aligns.* FHWA's LCCA guidance contains cost categories identifying which cost elements are to be collected, including costs to the transportation agency and user costs. However, FHWA's LCCA guidance does not provide enough information on how to create the estimating structure, or what it should look like, both of which are elements of the best practice in the *Cost Guide*.[18] The use of a standardized estimating structure allows the collection of data to be standardized and shared across organizations, and facilitates the comparison of cost elements across projects, all of which makes the estimating process more efficient.

- *Identify ground rules and assumptions: Substantially aligns.* FHWA's LCCA guidance states that the ground rules and assumptions for an estimate should be identified, reasonable, and conform to accepted practices. However, it does not mention that assumptions should be developed in coordination with the technical community and approved by management, both of which are elements of the best practice. Coordination with the technical community and management's acceptance of these ground rules and assumptions is important, because the rejection of even one of these assumptions can influence

[18]The cost estimating structure (referred to as the work breakdown structure in the GAO *Cost Guide*) is a framework for defining the detailed work necessary to complete the project. It provides a basis for identifying the resources and tasks required for developing a project cost estimate.

the cost estimate and the resulting decisions made based on the cost estimate. The assumptions also play an important role in the execution of sensitivity and risk analysis used to determine the possible variability of the estimate and can also be beneficial in helping management fully understand the estimate.

- *Obtain data: Partially aligns.* FHWA's LCCA guidance states the importance of obtaining and using historical data, but it does not include guidance on validating that the data are reliable, statistically analyzing the data to determine whether it applies to the given estimate, or continually collecting, protecting and storing data for future use. These factors in data quality affect the estimate's overall credibility. The *Cost Guide* states that collecting valid and useful historical data is a key step in developing a sound cost estimate. In our selected states, we found that states generally used historical data, when available, for items such as construction costs and the length of time before the pavement is to be rehabilitated; however, pavement industry officials in 2 of the 4 states we visited commented that they were not confident in the application of that data in LCCAs in their state. Officials in 2 of the 4 states we visited also noted that in some cases they were not confident in how the data were being selected for use and that there could be some bias in the estimates. For example in one state—where their regional offices perform the LCCA and a headquarters staff member reviews it—officials stated that they have found that one of the department's regions has some bias in their estimates of the length of the service life of pavement rehabilitations and initial costs that reflects a desire to utilize a specific pavement type. Guidance on how to validate that data are reliable and appropriate for an LCCA could help state transportation agencies improve the credibility of their estimates.

- *Develop point estimate and compare it to an independent estimate: Partially aligns.* FHWA's LCCA guidance emphasizes the different methods for estimating the life-cycle costs and tools to automate portions of the process when developing a point estimate of the life-cycle cost. However, no mention was made of using either an independent estimate for comparison or cross checks for the point estimate's major cost drivers. The *Cost Guide* states that independent estimates are important to ensure confidence in LCCAs by making sure the LCCA cost estimates are credible, reasonable, objective, and unbiased. The extent to which the selected states we reviewed had independent estimates varied. For example, one state's transportation agency officials stated that LCCAs prepared by their regional offices

are independently reviewed by both the central office and on some occasions by pavement industry representatives, and that these reviews were very important to ensuring that the LCCAs were accurate and based on reasonable inputs. Another state transportation agency we reviewed does not conduct an independent estimate; however, each year, agency officials conduct a compliance review of approximately 25 percent of their projects to see if the staff followed official policy and processes. However, this review would not result in a revised LCCA, only additional staff training and other corrective actions to improve future LCCAs. Guidance on using independent LCCA cost estimates and cross checks of major LCCA cost drivers could help state transportation agencies ensure their estimates are credible, objective, and unbiased.

Analysis

FHWA's guidance substantially aligns with the best practices in this phase; however, improvements could be made in defining how LCCA results should be documented. Without clear guidance on how to document LCCAs, states may not obtain all the benefits of the process. The *Cost Guide* states that good documentation enables the LCCA to be easily updated and replicated and can help establish an estimate's validity and credibility, as well as support the agency's decision making. Good documentation can also help demonstrate the agency's commitment to good financial decisions.

- *Conduct sensitivity analysis* and *conduct risk and uncertainty analysis: Aligns with both.* FHWA did a good job of identifying practices that address the risk and uncertainty in the analysis to ensure that state transportation agencies can determine how sensitive their analysis is to the inputs used in the model. For example, FHWA's RealCost software enables users to conduct probabilistic LCCAs where technical inputs are specified as ranges of values instead of single values, allowing the analysis to better quantify risk and uncertainty inherent in the cost estimation process. The *Cost Guide* notes that guidance on quantifying risk and uncertainty is important, because these analyses provide a way to assess the possible variability (range) of the estimated costs and this range allows the estimator to demonstrate to decision makers a level of confidence in achieving the most likely cost.

- *Document the estimate: Partially aligns.* FHWA's LCCA guidance states that good documentation of the estimate is an important part of an LCCA, but it does not provide guidance on what constitutes good documentation or state what documentation should be included. The

RealCost software creates good documentation of the data input into the software and the results; it does not, however, provide good documentation of any costs or other inputs into the LCCA that are determined outside of RealCost. For example, if a state develops its own user costs and inputs them into RealCost, then RealCost only records the input number, not the various components that went into that cost. In another example, construction costs for each alternative are input into RealCost as a single cost. As a result, the underlying information (such as material prices and quantities of materials) included in that cost are not documented in RealCost and cannot be reviewed unless the agency takes additional steps to document those costs. A state agency may include this additional information in customized versions of RealCost, but FHWA does not provide guidance on what additional steps states that currently do not provide this documentation may consider or find helpful. Documenting an estimate is essential for validating and defending an estimate that is independently reviewed by stakeholders, especially if they question its credibility. Pavement industry officials in 2 of the 4 states we visited commented that due to the lack of available documentation, they are not able to fully review LCCAs and make a determination of the validity of the LCCAs. Guidance on what constitutes good documentation, and that documentation should be required, could help state transportation agencies ensure their estimates are valid, credible, and defendable.

Presentation

FHWA's guidance partially aligns with best practices in this final phase of the cost estimation process. We found that FHWA's guidance included some aspects of presenting information to management and updating estimates; however, the guidance does not provide sufficient information on how LCCA results should to be presented to management and when an LCCA should be updated, in accordance with best practices in the *Cost Guide*. Presenting the LCCA estimate to management for approval is important, as is briefing management on how the estimate was developed, including the risks associated with underlying data and methods. It is also important to inform those conducting LCCAs that the cost estimates be updated as the project progresses to determine whether the preliminary information and assumptions remain relevant and accurate. Additional guidance on how to present the results of LCCA to management and when to update an LCCA may enhance the use of LCCA by states.

- *Present estimate to management for approval: Minimally aligns.* Our analysis of FHWA's guidance showed that there were brief references

in the guidance to presenting information about the LCCA to management, but there were no discussions of what should be included in the presentation. We heard from one state transportation official that it would be beneficial to have guidance on how to present the results of a probabilistic LCCA analysis to management, because their management's limited understanding of a probabilistic analysis was a barrier to their using it. State transportation agency officials in another state, which does not currently use LCCA, felt that guidance on how to communicate the results and benefits of using LCCA to their state legislators would be beneficial to their possibly adopting it as a tool.

- *Update the estimate to reflect actual costs and changes: Partially aligns.* The *Technical Bulletin* supports using updated input values and information. For example, it refers to using updated data to determine user costs due to vehicle crashes in areas under construction. However, the *Technical Bulletin* and *User Manual* do not include a discussion about updating the estimate as a whole. According to the *Cost Guide,* updating the estimate gives decision makers accurate information for assessing alternative decisions. Without updating estimates, state transportation agencies lack assurance that the LCCA results are still valid. As discussed above, 10 of our 13 selected states complete their LCCA early in the project, and officials in 5 of these states indicated that they did not update their LCCAs close to the time the project is advertised for bids to construct the project. When the final LCCA is conducted too far in advance of the project being advertised for bids, material costs may change sufficiently to affect the selection of the most cost-effective pavement type. Officials in one state found it can be advantageous to update their LCCAs and reconsider a pavement material type selection closer to the completion of project design to determine whether the original assumptions or data have changed. This update can be very important in time periods where construction material costs are fluctuating or when the pavement designs changed significantly from the design at the time the LCCA was conducted, as the chosen material type may no longer be the most cost-effective. Guidance on when to update the complete LCCA estimate could help state transportation agencies provide more accurate information to their decision makers resulting in more cost-effective pavement-type selection decisions.

Providing consistent guidance that fully incorporates GAO's 12 cost-estimating best practices could help ensure that states make accurate, cost-effective, and credible cost estimates. GAO's *Cost Guide* was issued

in 2009, and was developed to address gaps in then-available cost-estimating guidance, so it is not unexpected that FHWA's guidance that pre-dates the *Cost Guide* does not include all the best practices identified in the guide. While FHWA has updated its RealCost software and *User Manual* in recent years, FHWA has been in the process of updating the *Technical Bulletin* since 2009, but has not yet issued an updated version, which it had planned to do in 2011. FHWA officials stated that it has taken longer than expected to complete the update because they wanted to incorporate information from guidance that was under development by others into FHWA's LCCA guidance.

Conclusions

LCCA offers state transportation agencies an important tool for making sound, long-term, cost-effective investment decisions. While LCCA practices vary among states, so too do state processes for making decisions about road projects. Some variation in LCCA use is, therefore, to be expected and, to the extent that the technical elements of LCCA are handled well, some variation is not itself problematic. Nevertheless, correct execution of LCCA is important for LCCA results to be accurate and for decisions based on LCCA results to be justified. FHWA's guidance has been an important influence on states' LCCA practices and, given the willingness of state transportation officials to consider future FHWA guidance, this influence should continue.

Current FHWA guidance—which was issued as interim guidance in 1998 and not yet finalized— includes some, but not all, best practices for cost estimation. Each of the 12 best practices, however, is important for assuring the credibility and accuracy of cost estimates and, ultimately, the cost-effectiveness of investment decisions. FHWA's ongoing effort to revise its guidance on LCCA provides the agency with an opportunity to more fully incorporate GAO's cost-estimating best practices, including those related to the data necessary to conduct LCCA, how to corroborate LCCA results independently, how to document and when to update LCCA results, and how to present LCCA results to decision makers. Particularly given FHWA's role in overseeing the federal-aid highway program and in light of current infrastructure funding challenges, it is critical that FHWA do the utmost to aid states in making cost-effective investment decisions. Enhanced guidance that better incorporates all best practices for conducting LCCAs will better position states to do so.

Recommendation

The Secretary of Transportation should direct the FHWA Administrator to issue updated LCCA guidance to fully incorporate the cost-estimating best practices in GAO's *Cost Guide*, including guidance regarding the following:

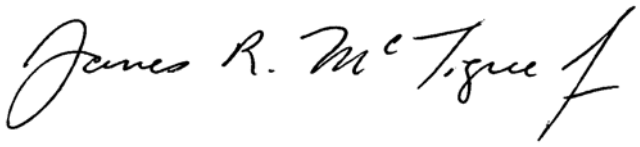
- input data quality and reliability,
- use of independent cost estimates,
- documentation of the analysis,
- how to present the analysis for management approval, and
- describing when the estimate should be updated.

Agency Comments

We provided a draft of this report to the Department of Transportation for comment. The department agreed to consider our recommendation. The department also provided technical comments that were incorporated as appropriate.

We are sending copies of this report to the Administrator of FHWA, the Secretary of the Department of Transportation, and interested congressional committees. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2834 or McTigueJ@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix II.



James R. McTigue, Jr.
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Appendix I: Objectives, Scope, and Methodology

The 2012 Moving Ahead for Progress in the 21st Century Act (MAP-21)[1] amended the United States Code to mandate that GAO conduct a study of the best practices for calculating life-cycle costs and benefits for federally funded highway projects. This report (1) describes how state transportation agencies currently conduct and use Life-Cycle Cost Analysis (LCCA) to inform pavement-type selections for federally funded highway projects; and (2) assesses the extent to which Federal Highway Administration's (FHWA) guidance for conducting LCCA conforms to cost estimating best practices.

To examine how state transportation agencies are currently conducting and using LCCA to inform pavement-type selections for federally funded projects, we interviewed FHWA's Office of Transportation Performance Management, Office of Asset Management, and Office of Program Administration officials, and reviewed FHWA documentation regarding LCCA. We also interviewed officials from the American Association of State Highway and Transportation Officials (AASHTO), the American Society of Civil Engineers (ASCE), the Transportation Research Board (TRB), the research community, the concrete industry, and the asphalt industry at the national level. We collected, reviewed, and summarized documented pavement-type selection practices from pavement selection and design manuals for 16 selected states, practices that were then confirmed by officials from those states as current practices or corrected to reflect current practices. We also reviewed research and surveys regarding states use of LCCA for pavement-type selection that was conducted by researchers for TRB and state transportation agencies. In 4 selected states—California, Colorado, Florida, and Washington—we visited and interviewed FHWA division office officials, state transportation agency officials, and industry association officials representing the asphalt paving and concrete paving industries in these states. The results on these interviews are not generalizable to all industry officials. In 12 additional selected states—Arizona, Maine, Maryland, Michigan, Minnesota, Missouri, Nevada, North Dakota, South Carolina, Tennessee, Texas, and Wisconsin—we interviewed, via teleconference, state transportation agency officials regarding their state transportation department's use, or non-use, of LCCA in pavement-type selection and LCCA practices.

[1]Pub. .L. No. 112-141, § 52,003(a), 126 Stat. 405, 875 (2012), codified as positive law at 23 U.S.C. § 503(b)(3)(D)(ii).

We selected the 16 states to visit and interview based on the states having a variation of practices when performing LCCA. For example, we selected states that did and did not include user costs, states which used probabilistic and states which used deterministic means of calculating their life-cycle costs, and states with high and low discount rates. To identify states with a variation of LCCA practices, we used data from a 2008 survey conducted by Applied Research Associates for use in National Cooperative Highway Research Program Report 703 issued in 2011 as the basis for making these selections. The survey was limited to 35 responses (including DC and Puerto Rico), but we found these data to be sufficient for use in the selection of states for a nongeneralizable sample because respondents included states with a broad range of LCCA practices. To ensure we did not omit any states that have LCCA practices which are important for us to include in our study, but did not respond to the survey, we reviewed the states in this survey against recommendations made to us during interviews of FHWA, researchers, professional organizations, and industry associations and considered for inclusion in the interview list those states which they believe to have advanced or noteworthy LCCA practices. Finally to make sure that there were no geographically based reasons for differences in the use of LCCA, we ensured that the selected states were geographically spread across the country. For the 4 states—of the 16—which we selected to visit, we selected only those which used LCCA and had been recommended by FHWA, researchers, professional and industry associations, as states that had an advance use of LCCA. The use of selected states does not allow us to generalize the findings of LCCA practices to all states.

To determine the extent to which FHWA guidance for conducting LCCA conforms to cost-estimating best practices we interviewed and analyzed documentation from the FHWA Office of Transportation Performance Management and Office of Asset Management. We also interviewed officials from AASHTO, ASCE, TRB, the concrete industry, and the asphalt industry at the national level. In 4 selected states (described above), we visited and interviewed FHWA division office officials, state transportation agency officials, and industry association officials representing the asphalt paving and concrete paving industries in these states; and from 12 additional selected states (described above) we interviewed, via teleconference, state transportation agency officials.

To assess the extent to which the FHWA guidance for LCCA is supported by a reliable cost estimating process, and if not reliably supported, why not, we compared FHWA's *Life-Cycle Cost Analysis in Pavement Design,*

Pavement Division Interim Technical Bulletin; *Life-Cycle Cost Analysis—RealCost User Manual*; and *Life-Cycle Cost Analysis Primer*[2] with the 12 steps of a high-quality cost estimate, identified in GAO's *Cost Estimating and Assessment Guide (Cost Guide).*[3] GAO's *Cost Guide*, consolidates best practices that federal cost-estimating organizations and industry use to develop and maintain reliable cost estimates throughout the life of a government acquisition program. These criteria are applicable to FHWA guidance because both, the GAO *Cost Guide* and FHWA's guidance, describe cost estimation processes for capital investment decision making.

The *Cost Guide*, which includes input from cost community experts and extensive research of best practices for estimating program costs, indicates that a high-quality, valid, and reliable cost estimate should be well documented, comprehensive, accurate, and credible and contain the 12 steps that high-quality, valid, and reliable cost estimates should follow. We reviewed the cost-estimating best practices mentioned in FHWA's LCCA guidance against these 12 steps and rated each step as being either: Aligns, Substantially aligns, Partially aligns, Minimally aligns, or Does not align. The ratings were determined as follows: Aligns: FHWA's guidance documents provided complete evidence that satisfies the best practice; Substantially Aligns: FHWA's guidance documents provided evidence that satisfies a large portion of the best practice; Partially Aligns: FHWA's guidance documents provided evidence that satisfies about half of the best practice; Minimally Aligns: FHWA's guidance documents provided evidence that satisfies a small portion of the best practice; and Does Not Align: FHWA's guidance documents provided no evidence that satisfies any of the best practice. After completing this review, a GAO cost analyst developed an assessment using this 5-point scale. A second analyst then verified this assessment of FHWA's LCCA guidance. To establish the overall phase assessment rating, we assigned following values to each of the 12 step ratings: Aligns = 4, Substantially aligns = 3, Partially aligns = 2, Minimally aligns = 1, and Does not align = 0. We added the ratings for the steps in each phase and averaged them. The averaged phase ratings that were 0.5 to 0.99, 1.5 to 1.99, 2.5 to 2.99, 3.5 to 3.99 were each rounded up to the next whole number, below those

[2]*Life-Cycle Cost Analysis in Pavement Design,* Pavement Division Interim Technical Bulletin, Publication No. FHWA-SA-98-079 (September 1998),; the most recent, publicly available, draft FHWA *Life-Cycle Cost Analysis – RealCost User Manual v. 2.5* (October 2010); and the FHWA *Life-Cycle Cost Analysis Primer* (August 2002).

[3]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009).

ranges were rounded down to the next whole number, and those whole numbers were used to set the overall phase assessment rating.

We conducted this performance audit from August 2012 to June 2013 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

James R. McTigue, Jr., (202) 512-2834 or mctiguej@gao.gov

Staff Acknowledgments

In addition to the contact named above, Heather MacLeod (Assistant Director), Sharon Dyer, Jennifer Echard, Bert Japikse, Delwen Jones, Terence Lam, Leslie Locke, Sara Ann Moessbauer, Joshua Ormond, Karen Richey, and John Stambaugh made key contributions to this report.