An Economic Analysis of the Proposed Material-Specific Discount Rate for Commodity Pricing in Highway Construction Life-Cycle Cost Analyses

White Paper — Special Report 203

NATIONAL ASPHALT PAVEMENT ASSOCIATION

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Contents

Executive Summary

This white paper examines the proposed introduction of material-specific discount rates to highway construction life-cycle cost analyses (LCCAs). A recent version of the Financial Services and General Government Appropriations Bill (H.R. 2434) would have mandated that the Office of Management and Budget (OMB) publish these material-specific discount rates. Other recent legislation proposals such as the Consolidated Appropriations Act, 2012 (H.R. 3671) and the Moving Ahead for Progress in the 21st Century Act, or MAP-21 (S. 1813) envisioned review of best practices in regards to LCCAs and discount rates.

Discount rates are used in LCCAs to translate the future costs of an infrastructure project to present values for the purposes of comparing the costs of project design alternatives. Life-cycle cost analysis calculates the total lifetime costs of a project, including initial construction, rehabilitation, maintenance, and salvage value.

Several methods exist for the analyst to properly compute project costs in either real or nominal terms. These methods include:

1) Conduct in today's dollars and deflate for opportunity value of time.
2) Conduct in future dollars (where available, such as in a rent or lease agreement) and deflate for both opportunity value and inflation.
3) Inflate today's dollars to reflect "expected future changes in relative prices…where there is a *reasonable basis*," (OMB Circular A-94, emphasis added) and deflate for both opportunity value and inflation.

Another method, proposed by the Concrete Sustainability Hub (CSH) at the Massachusetts Institute of Technology (MIT) in a paper entitled "The Effects of Inflation and Its Volatility on the Choice of Construction Alternatives," uses a computation shortcut within Method 3 that combines theoretically distinct estimations of inflation for individual materials and discount rates. The CSH paper, funded by the Portland Cement Association (PCA) and National Ready Mixed Concrete Association (NRMCA), proposes a model that uses historical commodity prices and statistical simulation to combine material-specific rates of inflation and discount rates. In an effort to become the pavement of choice in highway construction, the concrete pavement industry is promoting the methodology developed in this paper as proof of concrete pavement's future lower costs. The concrete pavement industry is also conducting a lobbying and outreach effort to influence federal legislation and introduce this new methodology to infrastructure LCCA calculations nationwide.

This white paper examines three issues related to the use of material-specific discount rates:

Best Practices: The use of material-specific discount rates is not accepted as valid by the economics profession. It is endorsed neither in OMB Circular A-94, the relevant federal guidance, nor in any other state, academic, or private-sector literature. In fact, the only mention of this methodology is in the CSH paper, in which the authors state that such a methodology should only be used as a "computational workaround."

Predicting Commodity Prices: LCCAs require the projection of prices for commodities and services over years and decades. The CSH paper forecasts future prices using historical price inflation information. However, no theoretical or empirical evidence is provided to support this methodology. Numerous studies, which are referenced in this white paper, have demonstrated

that predicting future price trends for inflation or for commodities such as oil beyond periods as brief as six months is no more accurate than repeating the last known price in perpetuity. Methodological contributions such as Hotelling's rule as well as empirical analyses by the Congressional Research Service (CRS) and others argue that the current prices of nonrenewable resources such as oil encompass future supply and demand considerations.

The Bill of Goods, Asphalt Innovation, and Other Concerns: Estimating the bill of goods (which includes the actual costs and usage of production inputs, including materials and labor) to construct and maintain a highway over time is difficult to predict due to a multitude of potential circumstances and the effects of technological change. For example, the CSH paper's calculation of the standard bill of goods is inaccurate and overly simplistic: Larger contributors to the bill of goods, such as wages and overhead, are underestimated and are not inflated along with materials. The assumed life cycle for an asphalt resurfacing is lower than observed by almost every state DOT. The CSH paper also does not consider recent and anticipated innovations in asphalt engineering that would markedly alter the cost component, such as recycling and the use of warm-mix asphalt.

In light of these issues, this white paper concludes that mandating the use of material-specific discount rates would run counter to current best practices and is not defensible given the state of the art in commodity price forecasting and accuracy. However, further study of LCCA techniques and discounting methods, as proposed in the Consolidated Appropriations Act, 2012 (H.R. 3671) and the Moving Ahead for Progress in the 21st Century Act (MAP-21, S. 1813), is recommended.

About the Authors

The National Asphalt Pavement Association is the only trade association that exclusively represents the interests of the asphalt producer/contractor on the national level with Congress, government agencies, and other national trade and business organizations. NAPA supports an active research program designed to improve the quality of asphalt pavements and paving techniques used in the construction of roads, streets, highways, parking lots, airports, and environmental and recreational facilities. The association provides technical, educational, and marketing materials and information to its members; supplies product information to users and specifiers of paving materials; and conducts training courses. The association, which counts more than 1,100 companies as its members, was founded in 1955.

Jack Faucett Associates, Inc. (JFA) was founded in 1963 and is based in Bethesda, Maryland. JFA has completed over 750 contracts and 1,500 studies since its founding for clients including the Federal Highway Administration, Federal Transit Administration, numerous other U.S. DOT agencies, dozens of state DOTs, regional governments and MPOs, and other clients. JFA provides consulting services for a wide range of clients in many disparate fields, but primarily focusing on transportation issues, economic analysis and greenhouse gas mitigation strategies. Some of JFA's recent and ongoing project work includes the analysis of fuel usage factors in price adjustment clauses for the National Cooperative Highway Research Program (NCHRP), the general use of price adjustment clauses in highway construction contracting (also for NCHRP), the development of a tool for the Federal Highway Administration (FHWA) as part of a team headed by ICF International that will enable state DOTs to tabulate highway construction emissions for their short and long term transportation plans, the development of the National Highway Construction Cost Index for the FHWA, a highway cost allocation study for the state of Oregon, the development of price indexes to adjust the Uniform Act benefit ceiling for FHWA, the development of the annual cost of living indexes for the Office of Personnel Management, and the calculation of the costs of owning and operating automobiles for the FHWA.

The primary author of this report is **Mr. Jonathan Skolnik**, Master of Public Policy, Georgetown University, Vice President of JFA, and a senior transportation and economic analyst with over 30 years of experience. Mr. Skolnik was assisted by **Mr. Mike Brooks,** Bachelor of Arts, Cornell University, and Research Associate at JFA.

Introduction and Purpose of White Paper

This white paper examines the application of material-specific discount rates to life-cycle cost analyses (LCCAs) used to determine net lifetime costs for transportation infrastructure. The purpose of this paper is to examine efforts by the cement and concrete pavement industries to institute changes to federal regulations regarding the conduct of LCCAs. These efforts are based on the cement and concrete industry's observation that asphalt prices have recently escalated at a higher rate and that mandating material-specific discount rates would result in more precise LCCA results.

The purpose of this paper is to examine the cement and concrete industries' arguments and analyze them through the lens of economics and transportation planning. Specifically, this paper will examine whether the material-specific discount rate is accepted economic policy, whether inflation forecasting by commodity is advisable, and whether such forecasts will be accurate and meaningful when considered against the overall highway construction bill of goods, technological and methodological innovations in the asphalt paving industry, and other factors.

The first section introduces the key concepts and definitions that make up an LCCA, including discounting, and other relevant topics. The second, third and fourth sections detail the three major areas of investigation of this report, including:

- Whether the use of a material-specific discount rate in the context of transportation LCCAs conflicts with accepted economics methodology;
- Whether there is a reasonable basis to accurately predict commodity prices in the long term; and
- The relative contribution of material prices to the overall bill of goods in highway construction projects.

The fifth section provides an overview of current and relevant legislative actions and, in light of these actions, offers conclusions and recommended steps moving forward.

1. Explanation of Concepts and Terminology

Exhibit 1 provides a summary of definitions for the key terms introduced in this white paper. Each term is introduced and defined in approximately the same order as they are introduced in the text.

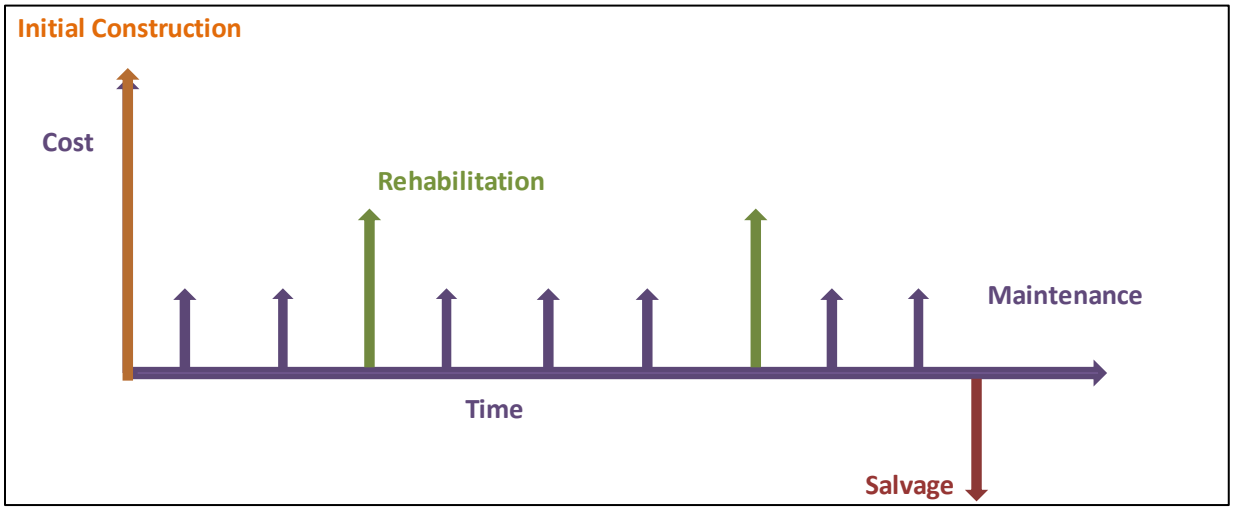
Exhibit 1: Summary Table of Relevant Terms and Concepts

Term	Definition
Life-Cycle Cost Analysis (LCCA)	An analytical technique that is used to calculate the total life-cycle cost of an investment or project. In terms of transportation, this would include the capital costs, maintenance costs, rehabilitation costs, disposal costs, salvage value, and other costs for each design alternative, normalized to the same level of service and traffic/user volume for each alternative over the same time period. An LCCA can be used to compare costs for alternative designs and be used to select the best cost alternative.
Benefit-Cost Analysis (BCA)	A calculation of total benefits and costs for an investment or project. BCA can take alternative designs into consideration, and even whether or not a project is worthy of executing in the first place.
Present Value (PV)	The value, at a given time, of an investment or series of investments made at other future points in time.
Inflation	A rise in the general level of prices for goods/services over a period of time.
Price Index	A time series of normalized prices for goods or services.
Nominal Value	The contemporary, "in-the-moment" value of a good or service. Synonymous with **current value**.
Real Value	The value of a good or service after adjustment to the present time or a pre-determined base year. Synonymous with **constant value**.
Interest	A fee paid for the right to use borrowed assets.
Real Discount Rate (i)	The expected return on an investment minus the effects of inflation; the nominal interest rate minus the inflation rate.
Time Value of Money	The calculation of the future value of money after the effects of interest. This concept is otherwise known as the **opportunity value of time**.
Bill of Goods	The actual costs and usage of production inputs, including materials and labor. The bill of goods is often referred to as the "market basket," which is the expenditures by a person or for a project
Discounting	Calculating the present value of a larger, future amount that has been augmented by the time value of money.
Discount Rate	The multiplication factor used in discounting formulas to express future value in current terms.

Life-cycle cost analysis (LCCA) is a tool used to calculate the total costs of a project throughout the phases of its lifetime, including initial construction, maintenance, rehabilitation, and end-of-life disposal (aka salvage). While the more expansive benefit-cost analysis (BCA) technique may consider differing designs and even whether a project is worthy of undertaking in the first place, LCCA is limited to considering different alternatives after a project design has been selected.

An LCCA stipulates that each alternative under investigation have the same level of service with the same traffic volume. The analysis period for the LCCA should be the same for all alternatives and long enough to include one major rehabilitation cycle. When properly computed, a life-cycle cost analysis provides transportation planners and officials with the total costs of each implementation alternative for a particular infrastructure project, allowing for the selection of the most cost-effective option among the viable alternatives considered.[1] Exhibit 2 displays a sample analysis period for a design alternative within an LCCA.

Exhibit 2: Sample Period of Analysis for a Pavement Alternative within an LCCA



Variable Costs

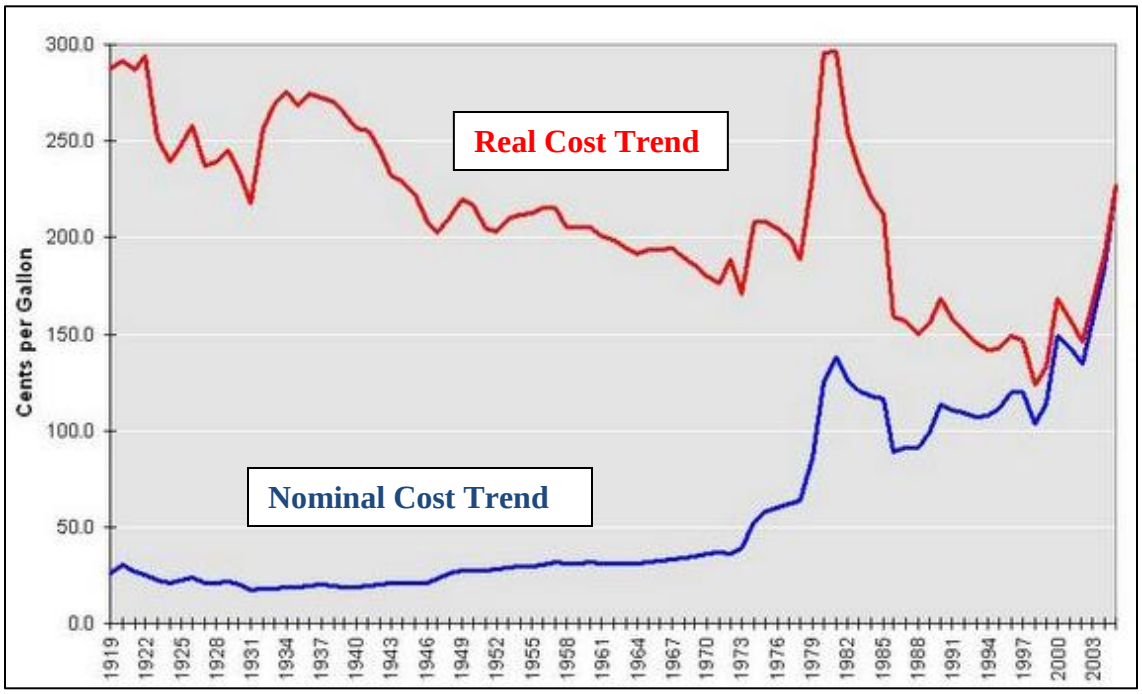
One of the most important considerations regarding LCCA computation is the variable nature of costs. An LCCA expresses total project life-cycle costs in terms of each alternative's present value. Each project will incur costs at various stages of its lifetime beyond initial capital costs. Such costs, usually necessary for maintenance and roadway rehabilitation, are incurred over the course of years and decades.

The observation most germane to this discussion is that the value of money does not remain static over time. Due to the effects of inflation, the nominal value (expressed at any one point during a time period) of currency has increased steadily. "Historical" commodity prices are presented in price indexes, including the Consumer Price Index as well as commodity-specific indexes.

Exhibit 3 displays a price index for gasoline prices in both real (prices adjusted for inflation based on a chosen base year) and nominal dollars (prices that are unadjusted for inflation). Real dollar values are in red, while nominal dollar values are in blue. This graph shows that the nominal price of a gallon of gasoline was less than 50 cents in 1919, while the same gallon of 1919 gasoline costs nearly $3 when considered in real 2005 dollars.

[1] For more information on the application of LCCAs and BCAs to transportation infrastructure, the Office of Asset Management, Federal Highway Administration, U.S. Department of Transportation published a "Life-Cycle Cost Analysis Primer" in 2002. This report, as well as other government guidelines regarding LCCAs and BCAs, is available at http://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm

Exhibit 3: Price Index (Nominal and Real Prices) for Gasoline, 1919-2005 (Base: 2005)[2]



Future Costs and LCCA

These distinctions are important to bear in mind when considering the future costs that are calculated within an LCCA. Due to the effects of interest over time, an investment expressed in a given amount of current dollars will be worth more in future nominal dollars. For example, an investment of $100 today, assuming a 10 percent interest rate, would be worth $110 dollars a year from now. According to the time value of money theory (also known as opportunity value of time), investing $100 at the present time would produce the same value to the investor as investing $110 a year from the present in the above scenario.

Discounting

The process of discounting, which is implemented by applying a discount rate to future dollar amounts, allows for the calculation of a correct present value. A discount rate translates future values influenced by the time value of money to real terms. A real discount rate reflects only the effects of the time value of money and results in a lower, current number when multiplied by a higher future value. The present value (*PV*) of an investment, adjusted to real terms using a discount rate, can be expressed as the sum of the terms:

$$PV = \frac{R}{(1+i)^t}$$

In the above example, *R* equals the net cash flow, *i* equals the real discount rate, and *t* equals the time period from the base year. If the total length of investment is five years, the present value would be the summation of the initial calculation ($t = 0$) and the calculations for the next five years.

[2] http://www.calculatedriskblog.com/2006/05/2006-record-real-gasoline-prices.html

2. LCCA Methodologies in the Economics Profession

The use of material-specific discount rates runs contrary to the established practices of economists and transportation planners. The desired outcome when applying a discount rate to an LCCA is to normalize the total costs, in constant dollars, of project alternatives that accrue costs at varying points in the future. This allows decision makers to compare the total project costs of design alternatives in equivalent terms. The discount rate removes the cumulative effects of the potential interest accrued had project funds been alternately invested, i.e., the opportunity value of time.

Current Accepted Methods of LCCA Calculation

The calculation of present value using the discount rate can be conducted in several different ways, depending upon whether monetary values are expressed in real (constant) or nominal (current) terms.

In the first instance, an LCCA conducted using real dollar values is a simpler computation that only requires the analyst to use real costs throughout a project's life-cycle and then apply the present value formula presented in Section 1 to remove the effects of the opportunity value of time. This formula includes the real discount rate, which is equivalent to the nominal interest rate minus expected inflation. Such an approach is the standard practice among government agencies. For example, the Administration for Children and Families (ACF), a division of the Department of Health and Human Services, remarks in its Cost/Benefit Analysis primer that "Constant dollars do not consider the effect of inflation, are normally used in cost/benefit analyses, and do not require justification to ACF."[3] In its November 1996 Planning Manual, the U.S. Army Corps of Engineers stated that "The general level for prices for outputs and inputs prevailing during or immediately preceding the period of planning is to be used for the entire period of analysis."[4]

The second, more difficult method of calculating present value must be undertaken if future costs are estimated in nominal terms (such as in a rent or lease agreement), which connotes the inclusion of inflation in the present value calculation. Conducting an LCCA using nominal values is not recommended due to the difficulty in projecting future inflation. OMB Circular A-94 states that "Future inflation is highly uncertain. Analysts should avoid having to make an assumption about the general rate of inflation whenever possible."[5] If an analyst decides to calculate future costs in nominal terms, the most commonly available approach is to apply a general inflation assumption, such as the Gross Domestic Product Deflator, to a price index. This can be done with broad indices such as the Consumer Price Index (CPI) and Producer Price Index (PPI) or more industry-or-commodity-specific indices. Analysis that requires a timeframe longer than six years (the Executive Branch's budget horizon) may use the sixth year of the budget forecast in perpetuity.[6]

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[3] "Feasibility, Alternatives, and Cost/Benefit Analysis Guide." Administration of Children and Families, U.S. Department of Health and Human Services. July 1993. Section 3.5. http://www.acf.hhs.gov/programs/cb/systems/sacwis/cbaguide/c3cost.htm#5

[4] "Planning Manual." The Greeley-Polhemus Group, for the U.S. Army Corps of Engineers. November 1996. Page 5.

[5] Circular A-94. Office of Management and Budget. http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c. Page 7.

[6] Circular A-94. Office of Management and Budget. http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c. Page 8.

A third method of LCCA calculation allows the analyst to begin with real dollars and calculate inflation and the discount rate sequentially. The analyst must first decide on the type and quantity of the LCCA material inputs. From there, it is possible to assign material-specific inflation rates. Circular A-94 states that "Such estimates may reflect expected future changes in relative prices…where there is a reasonable basis for estimating such changes." In other words, the analyst may introduce material-specific price forecasting assuming that they have valid data. Whether or not such reliable data exists is problematic, however; the use of historical data in a forward-looking LCCA is not considered valid because possessing past inflation data is not a guarantee that commodities will inflate at the same rate in the future.[7] Once nominal costs have been projected throughout the project life, a general discount rate is then applied to remove the effects of the opportunity value of time. The paramount consideration when using this method is ensuring that inflation and discounting are not calculated at the same time, as this would skew the present value calculation.

OMB Circular A-94

The Office of Management and Budget issued Circular A-94 in October of 1992. Entitled "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," this publication describes the requirements and guidelines for conducting benefit-cost analysis, regulatory impact analysis, asset valuation, and other analyses for the Executive Branch of the federal government. Each of the three above methods are discussed in Circular A-94 and endorsed to various degrees. Section 8 of Circular A-94 explains OMB's discount rate policy and includes a discussion of real and nominal discount rates and the proper discount rate for base case analysis. The circular's section on inflation states that "Future inflation is highly uncertain…Economic analyses are often most readily accomplished using *real* or *constant-dollar values*, i.e., by measuring benefits and costs in units of stable purchasing power. (Such estimates may reflect expected future changes in relative prices, however, where there is a reasonable basis for estimating such changes)"[8] (emphasis in original). Circular A-94 also contains a technical appendix that is re-issued annually with updated discount rates.[9]

The Proposed Concept of Material-Specific Discount Rates

The Portland Cement Association (PCA) and the National Ready Mixed Concrete Association (NRMCA) contracted with the Concrete Sustainability Hub (CSH) at the Massachusetts Institute of Technology (MIT) to study the effects of inflation and changing prices on material cost inputs in life-cycle cost analyses. This paper, entitled "The Effects of Inflation and Its Volatility on the Choice of Construction Alternatives," reviews real price data for four construction materials (concrete, asphalt, steel, and lumber), uses historical real prices to predict future real prices and escalation rates, and concludes with a Microsoft Excel-based calculation tool for planners.

The CSH paper has been used to support the concrete industry's efforts to revise OMB Circular A-94 to require a proposed method of LCCA calculation that uses material-specific discount rates. This method is similar to the third method that begins with real dollars and calculates inflation and the discount rate sequentially; however, the proposed method uses a computational shortcut that combines theoretically distinct estimates of inflation and discount rates. Under the

[7] Mack, Jim. "Comments to Florida Department of Transportation: Additional Comments on Discount Rates." http://www.dot.state.fl.us/construction/PTS_Workshops/Attachments/Sept2010/DiscountRateComments_Mack.pdf
[8] Circular A-94. Office of Management and Budget. http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c
[9] Ibid.

proposed method, an analyst would estimate material type and quantity and then apply a material-specific discount rate to each input.

These efforts to revise OMB Circular A-94 were not in vain, as legislation introduced in 2011 requires at the very least an examination of the possibility of instituting material-specific discount rates within LCCAs. The CSH report is the sole cited source that advocates the use of material-specific discount rates. A PCA two-page fact sheet states that the CSH report "…suggests the use of material-specific escalation rates based on historical data analysis."[10] In reality, the CSH report authors acknowledge the shortcomings of material-specific discount rates:

> "…if an analyst is working with LCCA software that does not allow for an escalation rate, the same calculation can be made by varying the discount rate applied to each material. Varying the discount rate by product is only recommended as a computational workaround." (emphasis in original)[11]

The Lack of Use of Material-Specific Discount Rates in the Economic Literature

None of the federal guidelines, economic journals, and academic papers reviewed during this effort endorsed or even mentioned the concept of a material-specific discount rate. In fact, no mention of this terminology was found outside the CSH paper.

A number of life-cycle cost analysis, benefit-cost analysis planning, and pavement selection studies have been conducted for federal and state transportation agencies. Several of the most relevant studies were reviewed in the research for this white paper. These included the following sources:

- "Life-Cycle Cost Analysis Primer." Office of Asset Management, Federal Highway Administration, U.S. Department of Transportation. 2002.
- "Guide for Pavement-Type Selection." Applied Research Associates, for the National Cooperative Highway Research Program. March 2011.
- "Life-Cycle Cost Analysis in Pavement Design." Federal Highway Administration, U.S. Department of Transportation. September 1998.
- "Life Cycle Cost Analysis for Pavement Type Selection." Clemson University, for the South Carolina Department of Transportation. April 2008.
- "Kansas Rural Interstate Expenditure Study." University of Kansas. May 2002.
- "Benefit-Cost Analysis and the Discount Rate for the Corps of Engineers' Water Resource Projects: Theory and Practice." Congressional Research Service. June 2003.
- "Life-Cycle Cost 2006 Update." Applied Research Associates, for the Ontario Ministry of Transportation. August 2007.
- "Feasibility, Alternatives, and Cost/Benefit Analysis Guide." Administration for Children and Families, U.S. Department of Health and Human Services. July 1993.
- "Planning Manual." The Greeley-Polhemus Group, for the U.S. Army Corps of Engineers. November 1996.

[10] "Accounting for Inflation in LCCA." Portland Concrete Association. 2011.
[11] Lindsey, Lawrence, Richard Schmalensee, and Andrew Sacher. "The Effects of Inflation and Its Volatility on the Choice of Construction Alternatives." Concrete Sustainability Hub, Massachusetts Institute of Technology. August 2011. Page 22.

Each of these studies contains information on discount rates and how they apply to transportation life-cycle cost analyses. None of these studies endorse or even mention the use of material-specific discount rates. Many refer the reader to the annually updated OMB Circular A-94 discount rates.

Although this proposed method is capable of producing the same results as other methods, it combines the separate concepts of inflation on specific inputs and the concept of discounting in a manner not envisioned or recommended in the literature. Since prices and discount rates are always changing over time, they should be estimated separately at the time when the LCCA is performed in order to provide results that are as accurate as possible.

3. Predicting Long-Term Commodity Prices (Material-Specific Escalation)

Life-cycle cost analysis requires a transportation planner to forecast a project's total lifetime cost. This includes both initial capital costs and future service costs, such as maintenance, rehabilitation, and disposal. As OMB Circular A-94 points out, estimates may reflect expected future changes in relative prices. The question is whether there is a reasonable basis for estimating such changes.

The CSH paper notes, "…most Life Cycle Cost Analyses (LCCAs) assume all construction materials have constant real prices … we consider how large an effect changing real prices can plausibly have on a representative project."[12] In order to accomplish this analysis "the past distribution of inflation rates is used to generate a variety of different random possible outcomes."[13]

The implicit assumption by CSH is that past inflation for a commodity such as asphalt over an extended period, in this case 33 years (1977–2010), is a good predictor of future price levels. However, the CSH paper does not support this assumption by reviewing relevant literature or testing their assumptions using backcasting techniques. In contrast, the review of the literature conducted for this white paper found no theoretical or empirical evidence to support the CSH methodology.

Perhaps the most fundamental flaw in using past prices for a commodity such as oil to predict future prices is that the current price already takes into account expected future supply and demand conditions. In other words, the current price already reflects the future as oil producers would not sell their oil now if they expected oil prices to rise at a rate that greatly exceeded future price levels in the economy in general (see Hotelling's rule below). For example, a Congressional Research Service report to Congress on oil prices states, "…expectations concerning future market conditions are quickly embodied in oil prices."[14]

[12] Lindsey, Lawrence, Richard Schmalensee, and Andrew Sacher. "The Effects of Inflation and Its Volatility on the Choice of Construction Alternatives." Concrete Sustainability Hub, Massachusetts Institute of Technology. August 2011. Page 4.
[13] Ibid.
[14] Pirog, Robert. "World Oil Demand and its Effect on Oil Prices." Congressional Research Service. June 9, 2005.

Hotelling's Rule

Harold Hotelling's seminal paper, "The Economics of Exhaustible Resources," argued that the net price of a natural resource should grow at the rate of interest.[15] This is because leaving the oil in the ground yields no dividend, but neither does it deteriorate. Therefore, if asset owners observed price growing by less than the interest rate they would have an incentive to sell and put the money in the bank or in bonds to earn the prevailing interest rate. If price were growing by more than the interest rate, they would have an incentive to keep the resource in the ground, as its appreciation would be higher than the interest that they could earn.

Empirical Evidence

However, even Hotelling's forecast for changes in prices for natural resources appears to have been optimistic. For example, Gérard Gaudet of the University of Montreal found that, over the last century and more, Hotelling's rule does not appear validated by price data for ten natural resource commodities: "In fact, in none of the ten cases is the mean rate of change different from zero."[16]

The Board of Governors of the Federal Reserve System published an issue paper entitled "Forecasting the Price of Oil" in July 2011. Regarding the predictability of future prices, the Board concluded that "…horizons up to six months…tend to be more accurate out of sample than the no-change forecast of the real price of oil…At longer horizons, the no-change forecast of the real price of oil typically is the predictor with the lowest MSPE (mean squared prediction error)…***professional and government forecasts of the nominal price of oil do not significantly improve on the no-change forecast, except in some cases in the very short run, and can be much less accurate***." (emphasis added)[17]

A paper composed by economists at the Bank of Canada and the University of Michigan conducted forecasts of future real prices of oil. The authors note that "Using a newly constructed real-time data set, we provided strong evidence that for horizons up to one year, it is possible to forecast more accurately than the no-change forecast in real time…At longer horizons, the ability of these models to improve on the random walk model quickly dissipates, regardless of whether one is using real-time or ex-post revised data."[18]

Even accurate predictions of the general rate of inflation are difficult over the long term. The economists Tilmann Gneiting and Thordis Thorarinsdottir found that "…at prediction horizons of two or more quarters, even postprocessed SPF (Society of Professional Forecasters) forecasts fail to outperform the simplistic probabilistic no-change forecast." In other words, planners may very well achieve a more accurate forecast by simply extending the last observed cost or price to the end of the LCCA forecast period.[19]

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[15] Hotelling, Harold. "The Economics of Exhaustible Resources." 1931.
[16] Gaudet, Gerard. "Natural Resource Economics under the Rule of Hotelling." The University of Montreal. June 2007. Page 5.
[17] "Forecasting the Price of Oil." Board of Governors of the Federal Reserve System. July 2011. www.federalreserve.gov/pubs/ifdp/2011/1022/ifdp1022.pdf. Pages 68-9.
[18] Baumeister, Christiane and Lutz Kilian. "Real-Time Forecasts for the Real Price of Oil." The Bank of Canada and the University of Michigan. Page 19.
[19] Gneiting, Tilmann and Thordis Thorarinsdottir. "Predicting Inflation: Professional Experts Versus No-Change Forecasts." University of Heidelberg. 2010. Page 22.

Expert Skepticism

In light of the difficulties in predicting future prices and commodity-specific inflation, the use of material-specific discount rates is either viewed with skepticism in the field of economics or ignored outright. In response to a question regarding the utility of material-specific discount rates posed at a U.S. Department of Transportation seminar, one transportation economist remarked, "I don't know how to do forecasts of future year inflation differentially…If you think you have a methodology to forecast differentially…don't work in this field. Go into the futures market. Make yourself some money."[20]

The difficulty in accurately predicting future prices is not limited to petroleum products. Steel demand and consumption has escalated steadily as developing economies such as China and India have prioritized construction and infrastructure projects. Like oil, steel is considered very difficult to forecast accurately. The steel industry publisher Construction News remarks that:

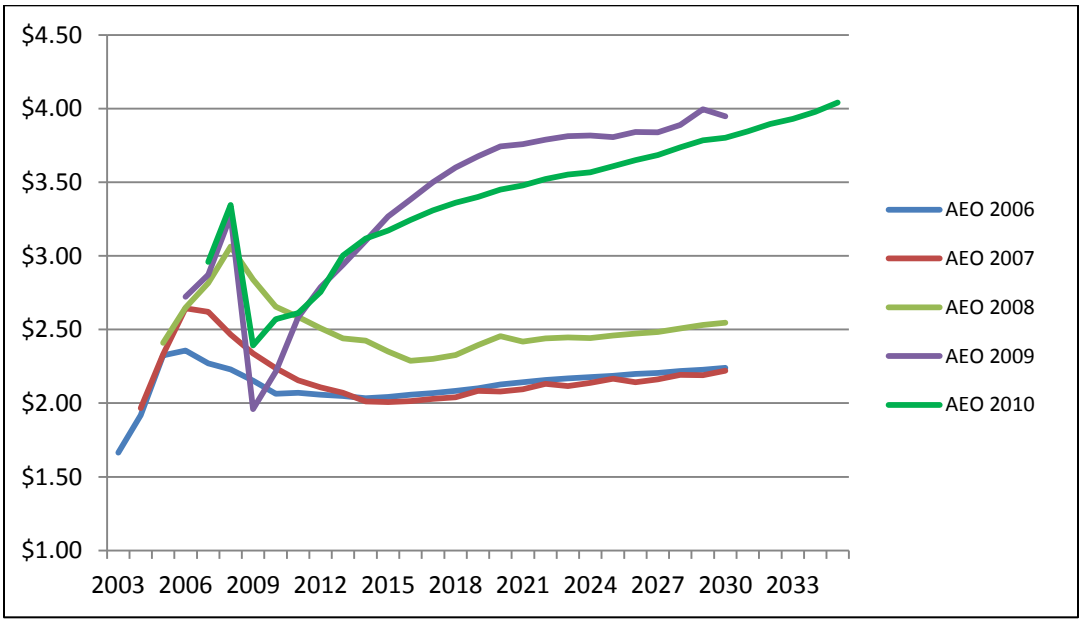
> "He who could predict the price of steel, would no doubt be a very rich man. And the reason why the steel industry is not full of very rich men – at least, not all of them – is because few can predict the price of steel…Sliding variables within one factor can affect change in another. One variable may be offset, or magnified, by another, leading to one big headache when trying to predict the price of steel for financial planning or futures-trading purposes." Factors that upset accurate prediction include fluctuations in the cost of the raw materials of steel, regional and global demand, freight variables, and the global price of oil, to which steel prices are strongly correlated.[21]

An Example of Forecasting Uncertainty: The Energy Information Administration's Annual Energy Outlook

The inability to accurately forecast the price of petroleum resources is further demonstrated in Exhibit 4, which displays projected prices for a gallon of gasoline in real 2010 dollars. The five trend lines represent the forecasts published in the U.S. Energy Information Administration's Annual Energy Outlook (AEO) from 2006 to 2010. The 2006, 2007 and 2008 forecasts predict nearly static prices through 2030 with average gasoline prices actually declining several cents. The 2009 forecast, completed after the upward fluctuations in petroleum prices beginning in the summer of 2008, predicted a rise to nearly $4 per gallon by 2030 and 2035, which is nearly double the 2006-8 projections. The 2010 forecast lowered the 2030 forecast by approximately 20 cents per gallon. An LCCA conducted using prices from AEO 2008 or earlier would have significantly lower commodity cost inputs compared to an LCCA conducted using AEO 2009 or 2010 data.

[20] Arlee Reno, Cambridge Systematics, at U.S. DOT Benefit/Cost Analysis Practitioner's Workshop. May 2010.
[21] Stewart, Jamie. "Predicting the Price of Steel." Construction Week. March 28, 2009. http://www.constructionweekonline.com/article-4755-predicting-the-price-of-steel/1/

Exhibit 4: Predicted Annual Energy Outlook Prices for a Gallon of Gasoline (Real $2010)



Market and Regulatory Effects

The relative price increases of commodities such as asphalt and cement will also be determined by market and regulatory effects that cannot be determined from previous price trends. For example, the future demand for petroleum may be affected by certain market and environmental trends, such as the emergence of green technologies. Such events make accurate predictions of future prices problematic. Recent U.S. policy to advance renewable fuels and achieve 15 percent displacement of fuels from petroleum crude oil is an example of a shift in demand that can significantly influence commodity prices. Likewise, significant movement toward the use of natural gas fuel in transportation or the emergence of hybrid and electric vehicles will also lessen demand for petroleum products. Such future technological changes are not included in the methodology.

Using historical price trends to predict future inflation for portland cement may also be inaccurate due to regulatory and legislative initiatives. For example, the House of Representatives approved H.R. 2681, the Cement Sector Regulatory Relief Act of 2011, which addresses a number of federal rulemakings emanating from the Environmental Protection Agency. These rulemakings, if implemented in their current form, could lead to significant job losses in the cement industry and force the closure of up to 20 U.S. cement facilities. U.S. Representative John Sullivan stated during the proceedings that "Lost supplies of cement resulting from closure of cement plants would drive up the cost of infrastructure."[22] Another instance is the proposed EPA regulation of concrete components. Fly ash, a by-product of coal production, is frequently used as a portland cement binder. While it has a positive effect on the greenhouse gas footprint of concrete, fly ash may soon be outlawed as a binder element due to

[22] Rep. John Sullivan (R-OK). Congressional Record. October 5, 2011. H6575.

environmental and storage concerns. Such a ban would alter the price of production, and consequently the market, for concrete.[23]

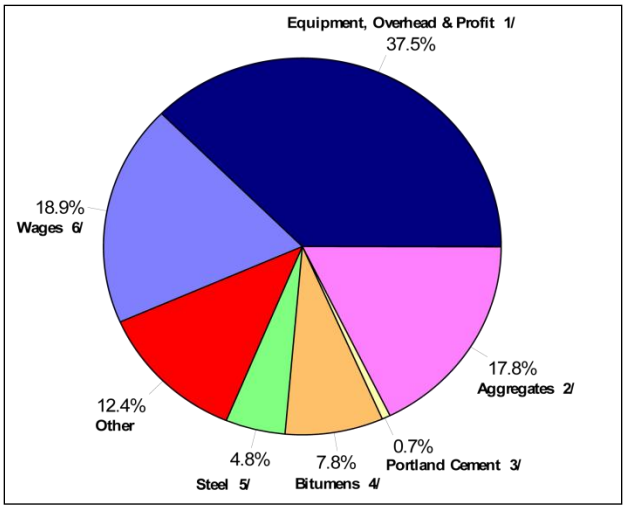
4. Bill of Goods, Asphalt Innovation, and Other Considerations

If an LCCA assumes various inputs used in highway construction inflate at different rates, then the analysis will require knowledge of the amount of each input. In fact, there is significant uncertainty as to the makeup of this "bill of goods," both now and in the future. The CSH paper, which the concrete industry commissioned, advocates that LCCA inflate asphalt and concrete differently from other inputs. However, this methodology is subject to several shortcomings. The following subsections discuss several of these shortcomings.

Estimating Current Inputs to Highway Construction

Every highway project is different and consumes a different mix of inputs from labor to equipment to fuel to materials. While the CSH report would have the reader focus on materials, in fact, wages, equipment, overhead, and profits dominate the costs of highway construction. As shown in Exhibit 5, these items accounted for 57 percent of the costs of federal-aid highway construction in 2004. In contrast, asphalt cement (bitumen) and portland cement combined accounted for less than 9 percent of costs.

Exhibit 5: Cost Distribution on Federal-Aid Highway Construction over $1 Million (2004)[24]



1/Equipment includes fuel and lubricants. Overhead includes contractors' on-site expenses such as mobilization, office, rental, licenses, insurance, etc.; 2/ Aggregates consist of sand, gravel, slag, crushed stone, etc.; 3/ For both roadway and structures; 4/ For various types of bituminous surfaces and bases; 5/ Includes structural, reinforcing, culvert and miscellaneous steel; 6/ Gross earnings of contractors' employees.

Developing a "bill of goods" to maintain a road is actually a very uncertain process. For example, the CSH report does not describe how the maintenance estimates in their report were developed other than to note they are "Expenditures by pavement type for 10 miles in North Carolina." They then assigned 34.4 percent of the costs to "liquid binder." They assume that the exact same costs occur every 10 years. Not only is every 10 years unusually frequent (see Exhibit 6 below, which indicates that only seven out of 38 states reported initial asphalt

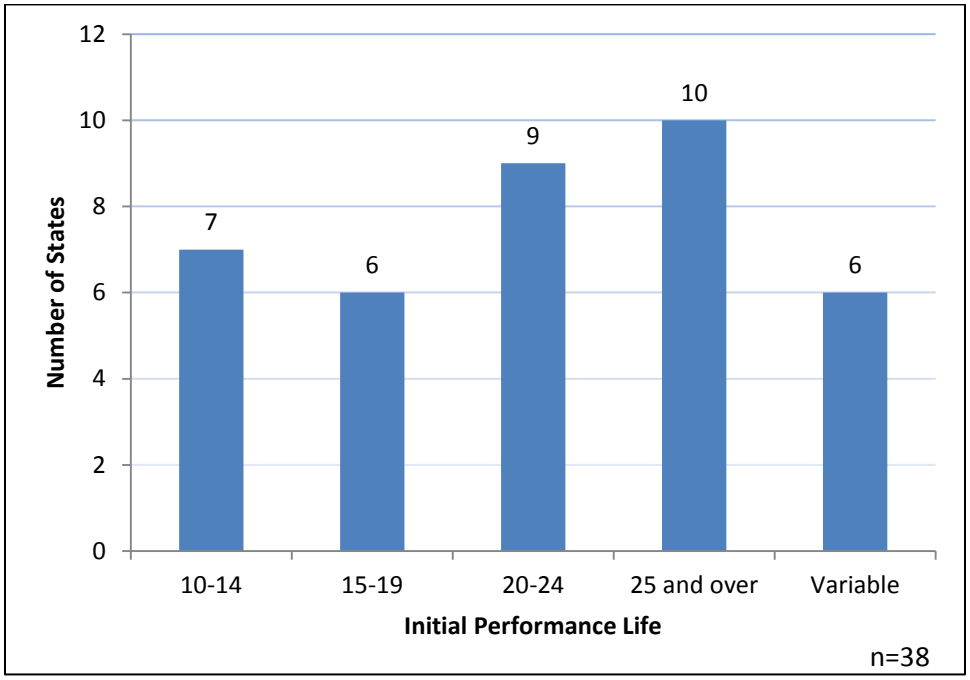
[23] Ideker, Jason. "New fly ash regulations threaten sustainable concrete." Oregon State University. August 4, 2010. http://www.sustainablebusinessoregon.com/columns/2010/08/new_fly_ash_regulations_threaten_sustainable_concrete.html

[24] http://www.fhwa.dot.gov/policy/ohim/hs04/pdf/costpie.pdf

performance lives of fewer than 15 years), but CSH assumes no recycling of asphalt materials, a commonplace procedure. For example, by the mid-2000s, asphalt pavement had become the most recycled material in America and the U.S. recycled more than 81 percent of all asphalt back into highway use.[25]

In a recently completed survey of asphalt pavement producers in the U.S. conducted by the National Asphalt Pavement Association (NAPA) for FHWA, it is estimated that in 2010 the asphalt pavement industry recycled more than 99 percent of asphalt pavement back into highway use. This saved about 19 million barrels of asphalt binder. The asphalt pavement industry also recycled about 1.1 million tons of waste shingles (from manufacturers and tear-offs) back into asphalt pavements. This represents about 10 percent of the waste shingles produced annually and saved about 1.5 million barrels of asphalt binder.[26]

Exhibit 6: Initial Performance Life of Asphalt Pavement as Reported by State DOTs[27]



The FHWA Recycled Materials Policy recognizes the importance of recycling roadway materials, noting that "recycling of aggregates and other highway construction materials makes sound economic, environmental, and engineering sense."[28] Under the policy, recycled materials are given first consideration in materials selection, and FHWA actively promotes asphalt pavement recycling.[29] "Reclaimed Asphalt Pavement in Asphalt Mixtures: State of The

[25] http://business.highbeam.com/industry-reports/chemicals/asphalt-paving-mixtures-blocks
[26] Hansen, Kent and David Newcomb. "Asphalt Pavement Mix Production Survey on Reclaimed Asphalt Pavement, Reclaimed Asphalt Shingles, and Warm-mix Asphalt Usage: 2009-2010." National Asphalt Pavement Association. November 2011.
[27] Rangaraju, Prasada, Serji Amirkhanian, and Zeynep Guven. "Life Cycle Cost Analysis for Pavement Type Selection." Clemson University, for the South Carolina Department of Transportation. April 25, 2008. Page 35.
[28] FHWA Recycled Materials Policy. http://www.fhwa.dot.gov/legsregs/directives/policy/recmatpolicy.htm
[29] "Asphalt Pavement Recycling with Reclaimed Asphalt Pavement (RAP)." FHWA. http://www.fhwa.dot.gov/pavement/recycling/rap/index.cfm

Practice," issued by FHWA in April 2011, offers best practices for State DOTs and others to advance the use of RAP.[30]

Matching Materials and Other Inputs to Inflation Data

The analysis must also link each item used in road construction to an inflation index. However, there is not an exact match from products to indices, which the Bureau of Labor Statistics compiles on an industry-specific basis. For example, the CSH report compares concrete, a finished product, to liquid asphalt, the binder used in the manufacture of asphalt pavements. Liquid asphalt is about 5 percent by weight of the total material used in the manufacture of asphalt pavements. Aggregate, a key ingredient in both materials, is not cited in the CSH analysis. By comparing liquid asphalt (PCU324121324121), a component in a mixture, and ready-mixed concrete (PCU327320327320), a finished mixture, CSH has made a comparison that is not valid.

Choosing Items to Inflate

The CSH study examines relative past inflation rates for concrete, asphalt, lumber and steel and chooses to inflate costs for concrete and asphalt. Meanwhile, the CSH study assumed that all other items inflate with the general rate of inflation for consumer prices. The study does not examine inflation rates for other items used in significant quantities, such as labor, fuel and lubricants. Many of these items have inflation rates that have differed significantly from the CPI.

Bill of Goods in the Future

Predicting the mix of goods and services required to maintain a road in the future is even more difficult. Technologies evolve and materials and procedures change. For example, at present, recycling of a significant portion of asphalt pavements has become accepted practice[31] and FHWA guidelines favor a substantial increase in the use of recycled materials over the next few years.[32] However, an LCCA conducted 15 to 20 years ago could not have anticipated this change. Predicting the general costs of road maintenance is a difficult exercise. Estimating what the exact amounts of each input will be in the future and their timing is even more challenging.

Not only is asphalt often recycled, but also a variety of other materials are now recycled into asphalt pavements. For example, state DOTs began using rubberized asphalt, which incorporates crumb rubber into its aggregate mix, in the early 1990s. It was especially notable for incorporating scrap tires into its mix design. By the middle of the first decade of the 2000s, more than 40 states used rubberized asphalt, particularly Florida, Arizona, Texas, and California. Recycled asphalt shingles is another type of material used in road construction which has seen significant growth in recent years. Note that when alternate materials replace asphalt cement, the LCCA should substitute an appropriate price index for that material. Therefore, disposal costs are substantially lower than in the past.

Warm-mix asphalt is gaining in popularity as a pavement alternative. Due to its lower mixing and laying temperatures, warm-mix asphalt results in lower levels of fuel consumption, an item with recent high inflation. Warm-mix also is adaptable enough to be applied in cold weather.

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[30] "Reclaimed Asphalt Pavement in Asphalt Mixtures: State of The Practice." FHWA. http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/index.cfm

[31] Copeland, Audrey, Cecil Jones, and John Bukowski. "Reclaiming Roads." Better Roads. Vol. 73, No. 5. March/April 2010. http://www.fhwa.dot.gov/publications/publicroads/10mar/06.cfm

[32] FHWA Recycled Materials Policy. http://www.fhwa.dot.gov/legsregs/directives/policy/recmatpolicy.htm

The CSH analysis also assumes that concrete road maintenance will consist of patching with concrete. In fact, since concrete roads are more susceptible to cracking and weathering,[33] concrete roads are often resurfaced with asphalt. In this case, the LCCA would have similar future maintenance costs.

Salvage Value

The CSH report also ignores the issue of the salvage value of asphalt. Asphalt pavements are becoming more durable and can be recycled in place and the asphalt and aggregate reused. This is not the case with cement and concrete roads. These roads will have a much lower salvage value and higher disposal costs, and the LCCA should consider this. Asphalt is easier to remove and is 100 percent recyclable. A highway contractor can now excavate an entire road surface and remix it for use in new surfaces.[34]

Delay Costs

Asphalt pavement projects are typically completed more rapidly than concrete projects of a similar scope.[35] This minimizes user-disruption economic costs as well as fuel, equipment and labor costs. This consideration should inform transportation planners as they weigh the LCCA comparisons of asphalt and concrete.

5. Relevant Regulatory and Legislative Actions

Several federal sources inform the current debate over the use of a material-specific escalation or discount rate within life-cycle cost analyses. This section briefly covers the initiatives by the concrete pavement industry to influence the ongoing debates on material-specific escalation or discount rates, life-cycle cost analyses, and pavement choice and introduces existing and proposed laws and regulations that affect treatment of LCCAs on the federal level.

Concrete Pavement Industry LCCA Initiative

The concrete pavement industry is currently conducting a national lobbying and marketing campaign lead by Mercury LLC, a public relations and strategy firm, on behalf of its client the Portland Cement Association (PCA), [36] to make concrete the preferred building material in heavy construction by introducing the material-specific discount rate to public sector life-cycle cost analyses. The primary result of this campaign was the introduction of the Fiscal Accountability and Transparency in Infrastructure Spending Act in the U.S. Senate and House of Representatives and the inclusion of material-specific discount rate language in the Financial Services and General Government Appropriations Bill for fiscal year 2012. Mercury LLC has also conducted outreach at the state level, particularly in Alabama and Virginia.

Overall, the concrete industry campaign has targeted 142 governors and members of Congress, officials within the executive branch and various departments, including Transportation and Energy, fiscally conservative advocacy groups, regional and state leadership networks, and numerous transportation and infrastructure organizations.[37] Their campaign also includes an

[33] http://business.highbeam.com/industry-reports/chemicals/asphalt-paving-mixtures-blocks
[34] http://business.highbeam.com/industry-reports/chemicals/asphalt-paving-mixtures-blocks
[35] http://wcfcourier.com/news/local/govt-and-politics/article_46a8d8f9-8f8f-5904-9120-5f08ff82972a.html
[36] http://www.opensecrets.org/lobby/clientsum.php?id=D000000442&year=2011
[37] "Campaign Strategic Update." Mercury. July 21, 2011.

active social networking effort and over 30 articles in newspapers, political publications, blogs, billboards and other media.

Evolution of Language in the Consolidated Appropriations Act, 2012

On June 23, 2011, the House Appropriations Committee approved the Financial Services and General Government Appropriations Bill for fiscal year 2012 (H.R. 2434). This appropriations bill was accompanied by a Committee Report that contained a request for the Office of Management and Budget (OMB) to revise Circular A-94 to include the use of material-specific discount rates.[38] Page 25 of the report contains the following request regarding the use of material-specific discount rates:

> "In light of increased efforts to identify government-wide efficiencies and properly anticipate the cost of major infrastructure projects, the Committee instructs OMB to examine and revise Circular A-94 as necessary and appropriate to improve the guidance provided to agencies in conducting benefit-cost analysis. The Committee expects OMB's review and modernization of Circular A-94 to emphasize the importance of incorporating life-cycle cost analysis. Moreover, this analysis should be as accurate, complete and reflective of the real costs and lifespans of materials as possible, ***including the use of material-specific discount rates and maintenance scheduled cost***. OMB is directed to report to the Committee within 180 days of enactment of this Act on the status of reviewing Circular A-94." (emphasis added)

Several modifications to the proposed language were instituted following discussions with stakeholders including the National Asphalt Pavement Association. Although the modified language retains the material-specific discount rate language, it now instructs OMB to review Circular A-94 instead of mandating revisions to it. This modified language is included as part of H.R. 3671, the Consolidated Appropriations Act, 2012. The new language explains that OMB's review of circular A-94 should:

> "…***include an examination of the potential to incorporate life-cycle cost analysis***. Moreover, this analysis should be as accurate, complete and reflective of the real costs and lifespans of materials as possible, including the use of material-specific discount rates and maintenance scheduled cost. OMB is directed to report to the Committee within 180 days of enactment of this Act on the status of reviewing Circular A-94. ***OMB should include appropriate experts in the field of life-cycle cost analysis, as well as appropriate experts and research centers***." (modified language in bolded italics)

The Fiscal Accountability and Transparency in Infrastructure Spending Act

S. 615, otherwise known as the Fiscal Accountability and Transparency in Infrastructure Spending Act of 2011, was introduced by Senator David Vitter in March 2011. A companion bill, H.R. 2602, was introduced in July 2011. If passed, this legislation would mandate that OMB develop a new federal LCCA model that would be applied to all major infrastructure projects. It would also mandate the use of the specific design standards for pavements. The

[38] Committee Report, Financial Services and General Government Appropriations Bill for FY 2012. http://appropriations.house.gov/UploadedFiles/FY_2012_FIN-SERVICES_FULL_COMMITTEE_REPORT.pdf. Page 25.

legislation is not specific on the LCCA model except requiring a 50-year evaluation period.[39] S. 615 has been referred to the Senate Committee on Homeland Security and Governmental Affairs, while H.R. 2602 has been referred to the House Committee on Transportation and Infrastructure.

The Moving Ahead for Progress in the 21st Century Act (MAP-21)

S. 1813, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was unanimously recommended with amendments by the Senate Committee on Environment and Public Works in November 2011. This two-year highway reauthorization bill requires a future study of life-cycle cost analyses and discount rates. In response to S. 615/H.R. 2602 and at the request of NAPA, S. 1813 authorizes the Comptroller General, head of the Government Accountability Office (GAO), to examine the best practice for calculating life-cycle costs. This study will include, at a minimum, a literature review and a survey of current practices among state DOTs. The project will culminate in a report due within one year of the passage of S. 1813 that will include a summary of the latest life-cycle cost research, recommendations on the period of analysis, design period, the use of material life and maintenance cost data, and discount rates.[40]

Conclusion

An ongoing debate exists over how to conduct life-cycle cost analyses for transportation planning. One aspect of this debate is the use of material-specific escalation or discount rates and whether or not it would affect pavement choice and neutrality. This paper has provided an economic analysis of an LCCA method proposed by the Concrete Sustainability Hub at the Massachusetts Institute of Technology and reviewed other issues surrounding the material-specific escalation and discount rate from an economics perspective. These issues include the accepted practices of economists and planners; feasibility of accurately predicting future material-specific escalation, discount rates, and costs; the contribution of pavement inputs to the overall construction bill of goods; and recent technological and engineering advances in the asphalt industry.

The main findings of this report are as follows:

- The material-specific discount rate is not endorsed as viable by the economics community; predicting future inflation based on historical figures is a flawed technique, and predicting future inflation and costs is impractical beyond the short term;
- The contribution of the cost of materials to the overall bill of goods is marginal compared to wages, overhead, profit, and equipment, which should be considered before undertaking material-specific rates for LCCA; and
- The CSH analysis does not include recent asphalt innovations that would measurably alter its cost component.

In conclusion, this paper recommends that material-specific discount rates be excluded from life-cycle cost analyses and encourages the overall LCCA review process proposed in S. 1813 and H.R. 3671.

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[39] Fiscal Accountability and Transparency in Infrastructure Spending Act of 2011. http://www.govtrack.us/congress/billtext.xpd?bill=h112-2602

[40] Moving Ahead for Progress in the 21st Century Act. http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=20f89548-8b2e-4498-89f7-c9f4ff22484f. Pages 468-470.

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