Commission Briefing Paper 4K-05

Benefit-Cost Analysis in Public Sector Infrastructure Investment Decisions

Prepared by: Section 1909 Commission Staff
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Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 1909 of SAFETEA-LU. The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909, and will serve as background material in developing the analyses to be presented in the final report of the Commission.

This paper presents information on the role of economic analysis in public sector infrastructure investment decisions and how its use can be expanded to help target scarce resources to their highest value transportation uses. The emphasis of this paper will be on the use of benefit-cost analysis (including financial analysis), in which the monetary value of travel time savings, reduced crashes, and other transportation benefits of a project or program are compared to the costs of building, operating, and maintaining it. Methods for measuring how such transportation benefits and costs impact the broader economy in the form of economic development are the subject of another briefing paper on economic impact analysis (Paper 4K-06).

Background and Key Findings

Benefit-cost analysis (BCA) is an economic analysis tool that can inform decision-makers on whether the direct benefits to society of a project or program will justify the resources invested in it. This paper makes several findings:

- BCA is often confused with financial analysis and economic impact analysis (EIA). Financial analysis focuses only on those benefits and costs of a project that are realized in the form of cash, but will not generally capture non-cash social benefits and costs. EIA measures the impact of a project's benefits and costs on the economy in the form of jobs created, business and sales growth, land values, and other economic development.
- Most public agencies do not routinely apply formal BCA to surface transportation projects, especially highway projects. BCA is not required by statute or regulation for most projects. Impediments to the greater use of BCA include other statutory demands on planning resources, political resistance, and technical and data issues.
- Significant progress is being made in the development of BCA guidance, data, and tools.
- Some States and local agencies have begun to make greater use of BCA and other economic analysis tools to evaluate surface transportation projects. As budgets become tighter and the public demands to know that resources are being invested wisely, use of such economic analysis tools may grow even further.

- BCA is an important complement to financial analysis in public-private partnerships because it can help to measure the appropriate level of public funding needed to realize the non-cash social benefits of the partnership project.

Definition of Benefit-Cost Analysis (BCA)

BCA is an economic analysis tool for measuring and comparing the social benefits and costs of transportation projects or programs. The analysis is based on a multi-year period that typically incorporates much or all of the operational lifespan of the project being evaluated. The analyst quantifies the costs (e.g., the resources expended to build, maintain, and operate the project) and the direct benefits of the operational project (e.g., travel time savings of system users) and, to the extent possible, puts them into dollar terms. Only costs and benefits of the project that are incremental to a "no action" base case are quantified. The analyst then converts these dollar amounts, whether realized initially or 30 years in the future, into "present value" amounts using a discount rate. The discount rate measures the annual opportunity cost of money, which is equivalent in concept to an interest rate that would have been earned on the invested funds had they not been expended on the project. Discounting causes dollars realized in the future to have lower present value than current dollars. For instance, at a 5% discount rate, $1 million in benefits received 30 years from now would be worth $231,277 today, whereas $1 million received one year from today would be worth $952,381 in present value.

Once the analyst has calculated the present values of a project's lifecycle benefits and costs relative to the "no action" base case, the two sums can be compared using a variety of measures to see if the present value of the benefits exceeds the present value of the costs. Projects with positive net benefits are generally worth pursuing from an economic standpoint, although political, social, budgetary, and other factors may cause decision-makers to reject a project even if it has positive net benefits. In the situation of constrained budgets, the projects with the highest ratios of benefits to costs can be selected first to enable the greatest public benefit for each invested budgetary dollar. Alternatively, the costs and benefits can be used to calculate an internal rate of return for the project, and only projects whose internal rates of return exceed a pre-established "hurdle rate" can be considered eligible for funding.

Distinction between BCA and Financial Analysis

BCA measures the value of direct benefits and costs of a project or program even if those effects do not actually take the form of cash flows when the project is underway. In other words, if a project saves travel time, the value of that travel time is assigned a monetary value even if the beneficiary does not compensate the owner of the transportation project through a fee. Public agencies investing resources for the public at large are typically the practitioners of BCA.

Financial analysis, on the other hand, is a special subset of BCA that focuses only on those benefits and costs of a project that take the form of cash transactions realized by the project's owner. Rather than the total amount of time a transportation investment might save the public, a financial analysis would focus on how much of the value of this time saving could be captured in toll revenues. This amount will be only a portion of the value of total time savings. Similarly, to the extent that there are costs associated with the investment that the project owner would not have to pay (either directly or indirectly), the dollar value of these costs would not be included in

the financial analysis. In summary, the financial analysis does not capture the complete range of a project's benefits and costs, as does BCA.

In the case of private sector investments, financial analysis may be the only form of benefit-cost assessment conducted. Public sector agencies would typically use financial analysis to determine how to pay for a project already approved for funding on the basis of a BCA or other project justification. Financial analyses are sometimes described as discounted cash flow analyses or rate of return analyses.

While a financial analysis is more limited in scope that a BCA, one advantage of private sector financial participation in a transportation infrastructure project is that at least a financial analysis will be conducted, whereas there is no assurance that a BCA will be conducted. The fact that a private sector investor will insist on conducting a financial analysis before investing gives some assurance that the project is worthwhile, whereas a purely publicly funded project may have no economic analysis of benefits and costs conducted at all.

The distinction between BCA and financial analysis is particularly important with regard to tolls, fares, taxes, and other user charges for transportation projects. While central to financial analyses, user charges are not "benefits" of a project as measured by BCA. Rather, these charges represent a means by which some of the value of the user benefits of a transportation project (as measured by the value of travel time savings or improved safety) can be transferred in the form of cash payments to the public or private agency that operates the facility. When conducting a BCA, adding toll or tax revenues to the value of travel time savings, safety improvements, and reduced vehicle operating cost would be double-counting benefits.

On the other hand, user charges can influence the demand for a transportation facility. Fewer travelers are likely to use a toll facility if there are alternative, non-toll facilities nearby. The BCA must factor in this user reaction to tolls in so far as it affects the overall performance (e.g., travel speed and congestion level) of the facility, even though the tolls themselves do not constitute an additional benefit to the travel time saving (see Federal Highway Administration, *Economic Analysis Primer*).

Distinction Between BCA and Economic Impact Analysis

BCA focuses on the monetary values of direct benefits and costs to society, regardless of who in society receives or incurs them or the final form the benefits and costs will ultimately take once they filter through the economy. If issues of final impact or distributional equity of a transportation project are of interest—as they often are—the results of the BCA for that project may be used as input to an Economic Impact Analysis (EIA).

It is easiest to make the distinction between BCA and EIA with an example. Assume that a surface transportation project is being built to expedite travel times and improve the economic well being of a region. BCA would be used to calculate the value of faster commuting times to users of the surface transportation project (as well as other direct traveler benefits). These faster commuting times, however, might induce more people to purchase houses in the area served by the project, which is now more accessible to employment centers. This new demand would drive up the prices of real estate in the area to levels higher than they would have been without the

project. New home buyers would, in effect, transfer part of the value of their travel time savings caused by the project to existing property owners in the form of higher purchase prices than they would have paid had the improvement not been built.

BCA would attempt to capture only the value of the direct transportation benefits—in the example above, time savings. To also count the indirect change in property values resulting from the time saving would double count its value. EIA, on the other hand, would attempt to calculate only the value of indirect benefits, such as changes in property values, wages, sales, etc., that result from the improved commuting time, but would not include the direct value of the saved commuting time. A frequent error in the conduct of both BCA and EIA is the mixing of direct and indirect benefits and costs—particularly benefits—leading to over-estimates of a project's true net benefits.

Generally speaking, economists hold that in a perfectly competitive economy, the marketplace will convert the direct benefits and costs of transportation improvements (measured using BCA) into an equivalent, but not additive, value of wider, indirect economic impacts (measured using EIA). Accordingly, a thorough BCA should capture most or all of the net value of a project to society. Because economies are never perfectly competitive, however, BCA and EIA values typically diverge in practice. New transportation projects can contribute to productivity and competitive effects that may cause the indirect benefits of a project to exceed its direct benefits by some degree, particularly in areas poorly served by existing infrastructure. Estimates of the size of this discrepancy vary, with one estimate showing that indirect benefits may exceed direct benefits by 6% in a typical project (Standing Advisory Committee on Trunk Road Assessment, *Transport and the Economy*, Para. 4.70).

Typical Benefits and Costs Measured in BCA

BCA typically incorporates those benefits and costs of interest to the entity making the investment decision. For a public sector agency, these benefits and costs usually incorporate a full range of direct impacts to the agency and the public (see Table 1).

Table 1. Benefits and Costs Typically Considered in Benefit-Cost Analysis

Agency Costs Over Project Lifecycle	**User Costs at Construction Work Zones**	**User Benefits Associated with Facility Operation**	**Externalities to Non-Users**
Design and engineering Land acquisition Construction/Capital Reconstruction Rehabilitation Preservation Routine maintenance Residual & salvage values (benefits)	Delay Crashes Detours Vehicle operating costs (VOC)	Travel time saving Improved reliability Reduced crashes Reduced VOC Freight inventory cost reductions Transit benefits including more trips, comfort, and option values	Air pollutant emissions Noise Other direct impacts

Economists assign dollar values to project benefits and costs using a variety of methods. Project costs are generally engineering estimates. All capital costs should be accounted for, including allowances for contingencies and administrative expenses such as internal staff planning and overhead costs. Expenses associated with a project's financing, such as depreciation and interest payments, are not included in the BCA. The equivalent value of such expenses is already captured in the BCA through the application of the discount rate to the agency cost of the project. Only in the case of a financial analysis, particularly one conducted by a private sector owner/operator subject to taxes and able to deduct depreciation and interest charges, would depreciation and interest be relevant to the evaluation.

User costs associated with traveling through or detouring around construction projects can be very significant, particularly with respect to delays at highway work zones. In some regions, these costs have become so large that construction may be limited to night or non-peak travel times. These costs are often ignored in the BCA, even though they are real costs to the traveler.

The principal benefit of most surface transportation projects is reduction in travel time. An hour of travel associated with a business trip or commerce is usually valued at the average traveler's wage plus overhead—representing the cost to the traveler's employer. Personal travel time (either for commuting or leisure) is usually valued as a percentage of average personal wage based on estimates of what travelers would be willing to pay to reduce their travel time. The U.S. DOT currently uses the following values for an hour of local surface travel time: $21.20 for business; $10.60 for non-business; and $11.20 for a weighted average of the two.

Improved reliability of travel time (as opposed to reductions in average travel time) can also be an important benefit of some transportation projects, but it has proven more difficult to measure, in part because improvements to travel time reliability are often closely tied to reductions in average travel time. It is likely that current valuations of travel time implicitly include a component for reliability. Most BCA efforts to date have not attempted to assign a separate value to reliability improvements, but this may change as new research develops methods to measure and value reliability independently of average time savings.

Many surface transportation projects also have ramifications for safety, leading to reductions in the number and severity of crashes. Assigning monetary values to such changes is complicated by the incidence of injuries and fatalities in some crashes. The value of an avoided fatality (also called the value of a statistical life) is usually established based on the amount of money that large numbers of people would be willing to pay to reduce the statistical chance that one among them would experience a fatality. Based on this methodology, the U.S. DOT currently uses a valuation of $3 million per statistical life. Injury valuations are generally set as a percentage of the value of statistical life, depending on their severity.

Vehicle operating costs (e.g., fuel, tires, routine maintenance) are empirically measured, but exclude fixed depreciation and finance costs that are not directly affected by the project being evaluated. Freight inventory cost savings reflect, at a minimum, the reduced cost of capital tied up in freight in transit, and may, in some cases, reflect significant cost savings associated with improved reliability of delivery times and avoided production stoppages.

Transit improvements can convey benefits to users that are not fully captured by other benefit measures, including mobility for low income and disabled persons, and increased trip frequency and comfort. Non-users may receive a direct benefit from transit through reduced highway congestion or through transit's availability as a transportation option or insurance in the event that motorists temporarily lose access to automobiles. Other benefits are frequently cited (see TCRP Report 78, *Estimating the Benefits and Costs of Public Transit Projects*).

Externalities are those costs or benefits that fall on parties other than the parties that cause them. Externalities to non-users of the project, such as emissions and noise, are often not addressed in BCA, in part because they are very difficult to quantify. To the extent possible, however, they should be quantified either directly (in terms of their direct impact on non-users) or in the estimated cost to mitigate them, particularly if such actions are required as a condition to build the project (e.g., the cost of context-sensitive design features or noise barriers). Where impacts cannot be monetized, they should be addressed in the BCA in a qualitative sense.

There is a broad range of so-called externalities of surface transportation projects that are, in fact, indirect effects not tied principally to the transportation project itself. These indirect effects are more appropriately treated using EIA. One such indirect effect frequently attributed to highway projects is low-density development, or "sprawl." Whereas low-density development may be abetted or mitigated by surface transportation projects, land-use planning and zoning decisions play a much more significant role in its occurrence (see Paper 4D-8).

Application of BCA to U.S. Surface Transportation Investments

The systematic use of BCA in the planning and implementation of surface transportation projects could yield significant benefits to society by ensuring that scarce resources are invested in projects whose benefits will more than compensate society for those resources. Moreover, BCA can be used to identify those projects whose benefits most exceed their costs, ensuring that society gets the greatest return for each dollar invested.

The U.S. DOT, the American Association of State Highway and Transportation Officials (AASHTO), and other organizations have long promoted the use of BCA and other economic analysis tools for evaluating surface transportation infrastructure projects and programs. In practice, however, most States and local government agencies do not routinely apply formal BCA to surface transportation projects, especially highway projects. More often they apply financial analyses to ensure the projects can be funded from available revenue sources (e.g., gasoline tax receipts), particularly if bond financing is used. Private sector companies that own and operate the Nation's freight rail system make use of sophisticated financial analysis methods to evaluate rail investments. Similarly, Amtrak routinely applies financial analysis to its investment decisions. The U.S. Army Corps of Engineers has a longstanding practice of applying BCA to water transportation projects such as shipping channels and inland waterways.

At the request of Congress, the Government Accountability Office (GAO) recently conducted two studies to identify the key processes for surface transportation infrastructure planning and decision-making, with a particular emphasis on the role of economic analysis methods. These studies are *Highway and Transit Investments: Options for Improving Information on Projects'*

Benefits and Costs and Increasing Accountability for Results (GAO-05-172); and *Surface Transportation: Many Factors Affect Investment Decisions* (GAO-04-744).

The GAO reports that "the increased use of economic analytical tools, such as benefit-cost analysis, could improve the information available to decision makers and ultimately lead to better-informed transportation investment decision making" (GAO-05-172, p. 6). As of now, however, "For the highway projects we studied, we found that project documents contained little, if any, economic analyses on the various alternatives" (ibid, p. 24). The GAO notes that "when comparing alternatives for proposed projects, economic analyses were more likely to be conducted for transit projects than highway projects" (ibid, p. 24).

The GAO found several reasons why BCA is not more widely used in U.S. public sector surface transportation decision-making. These reasons can be grouped into the following major categories: statutory and funding issues; political concerns; and technical and data limitations. Each of these categories is discussed in more detail below, along with potential solutions.

Statutory and Funding Issues Impeding Broader Use of BCA

The Federal Transit Administration's (FTA) New Starts Program is a federally funded discretionary grant program. The FTA requires a project sponsor applying for New Starts grant to calculate the project's cost-effectiveness. The required analysis lends an important economic component to the FTA's evaluation of the project, although it is technically not a BCA because TEA-21 prohibits the FTA from requiring that sponsors place dollar values on transit mobility improvements (GAO-05-172, pp. 44-45).

The federal-aid highway program is a federally funded formula grant program. Title 23 of the U.S. Code, Section 145, gives States and larger urbanized areas the authority to select which projects shall be federally funded (GAO-05-172, p. 44). While Title 23 requires States and Metropolitan Planning Organizations (MPOs) to use planning processes that promote an "efficient" surface transportation system, and while FHWA and FTA impose planning requirements on States and MPOs, FHWA and FTA do not require the preparation of cost-benefit analyses as part of the planning process. Neither the FHWA nor the FTA has the authority to tie funding levels to the performance of the infrastructure, which might otherwise create the need for systematic appraisals of project performance.

A State or local government is free, of course, to implement BCA on its own initiative, but is often reluctant to do so given the significant volume of other transportation planning and environmental analyses that are required by Federal statutes. Transportation planning requirements are covered under 23 U.S.C. 134 and 135 and 49 U.S.C. 5303-5306 (strengthened by ISTEA and TEA-21). In addition, transportation projects must comply with the requirements of the National Environmental Policy Act (NEPA) of 1969 involving a comprehensive range of social, economic, and environmental analyses, and transportation projects in air quality non-attainment or maintenance areas must meet Conformity requirements of the Clean Air Act.

The GAO also reported that statutorily-created "separations between federal programs and funds give state, regional, and local agencies little incentive to systematically compare the trade-offs between investing in different transportation alternatives to meet passenger and freight travel

needs because funding can be tied to certain programs or types of projects, according to several experts" (GAO-05-172, p. 45). In fact, there is much more flexibility in the use of highway funds for transit and other transportation projects than is commonly realized. Eligibility restrictions, however, are particularly relevant to fixed-guideway projects funded under the FTA New Starts program, as well as limiting the use of Federal funds for most intercity rail projects.

The FTA also offers preference to New Starts projects that carry a higher local funding share than the minimum required under statute. Some local officials report that there is a greater incentive to perform economic analysis when there is a need to raise more local revenue to meet the higher match (GAO-05-172, p. 25).

Political Resistance to BCA

Political issues frequently complicate efforts to apply BCA to projects. In some cases, a project may be important for a particular interest group even though it is not efficient from an economic standpoint. The use of BCA in such instances is not attractive to the agency promoting a project. Educational efforts could mitigate this aversion by stressing that it is completely defensible to select projects that are less than optimal from an economic standpoint if they meet compelling policy objectives. BCA informs the decision-making process; it does not control it.

In most States, which have both rural and urban constituencies, State agencies are often concerned that BCA will favor urban projects over rural projects, because more users and more traffic congestion are in urban areas. A potential solution to this problem involves setting aside separate pools of funds to urban and rural areas for equity reasons. This is already addressed to some extent in current Federal surface transportation allocation formulae.

The GAO notes that MPOs may seek consensus among constituent members by distributing funds for transportation projects throughout a metropolitan area for equity reasons rather than transportation efficiency considerations (GAO-04-744, p. 34). In addition, MPOs may prefer projects that generate local benefits, rather than national benefits, or which benefit the public rather than private entities. BCA methods that assign equal values to benefits regardless of recipients could conflict with local preferences. However, a BCA can incorporate equity effects by weighting costs and benefits to different parties differently. Efforts to improve coordination among State and local planning groups and private sector parties will yield a better platform for BCA applications, particularly for large intermodal projects.

Technical and Data Impediments to BCA

Other major hurdles to the wider application of BCA are technical and data issues, typically involving problems with the application of BCA to projects. These issues include:

- Inaccurate or missing data: Analysts often struggle to obtain the necessary data required to conduct an economic analysis that may extend 30 or more years into the future. Data needs include accurate estimates of capital and maintenance costs, future traffic flows, hours of travel time saved by a project and the value of those hours, impacts of the project on safety, etc. Enhancements to data quality continue to be made (including recent work on the valuation of travel time reliability). Improved risk analysis techniques enable explicit handling of the uncertainty associated with analysis inputs and results.

- Inconsistent methodologies and practice of BCA: Most decision-makers and many transportation professionals have limited understanding of economic analysis techniques. Confusion about the roles and limitations of BCA, financial analysis, EIA, and other methods often leads to errors such as the combining of direct and indirect benefits and costs; double counting of benefits; confusion of benefits and costs (as when labor costs are treated as job creation benefits); omitted benefits and costs (especially when non-local capital contributions are neglected); poorly specified base cases and improvement cases; inappropriate discount rates; failure to address risk; and other problems that undermine confidence in the methods. However, AASHTO, the U.S. DOT, the GAO, the Transportation Research Board (TRB), and other organizations are making progress in providing guidance on appropriate economic analysis methods.
- Lack of models and tools to support BCA: Transportation professionals often cite the lack of analytical tools as an impediment to the wider use of BCA. During the last two decades, however, a growing number of tools have been developed by AASHTO and TRB (e.g., spreadsheet tools based on its *User Benefit Analysis for Highways Manual*); FHWA (e.g., the program-level Highway Economic Requirements System and the ITS Deployment Analysis System); FTA (e.g., the SUMMIT model); the World Bank (HDM-4); and others. The consulting community has produced a variety of sophisticated BCA tools for various States and MPOs. Use of these tools, particularly the more recent ones, enables BCA to be conducted by agency staff without contracting it out, thereby mitigating another criticism—that BCA is too expensive to conduct.
- Several of the tools cited in the preceding bullet are appropriate for small to medium scale projects involving one mode that do not have major regional traffic impacts. BCA of large projects, with regional traffic impacts, requires input provided by travel demand models. Travel demand models can capture the changes to regional travel time and vehicle miles caused by a large project. However, there are few universally accepted guidelines or standards of practice for these models (GAO-04-744, pp. 23-24). Also, the travel demand models currently in use are not strong in measuring time-of-day travel shifts (peak spreading), freight and commercial traffic patterns, or changes in land use. U.S. DOT's Office of Transportation Policy examined these issues in its November 2005 Expert Forum on Road Pricing and Travel Demand Modeling.
- The GAO notes that BCA results are rarely reviewed in light of actual project outcomes. Before-and-after evaluations, now being required by the FTA for New Starts projects, offer the opportunity to calibrate and improve BCA tools and data.
- BCA normally looks at aggregate net benefits rather than benefits to different groups, though costs and benefits can be disaggregated for different groups if desired.

Outlook for Greater Use of BCA

While some states (e.g., California, Florida, Michigan, Minnesota, Oregon, and Washington) have increased their use of BCA and other economic analysis techniques to evaluate surface transportation projects, many states still make minimal use of these techniques. Recent controversies over congressionally earmarked projects in SAFETEA-LU appear to have undermined public confidence in traditional project selection methods. Efforts to raise more money from the public to pay for needed transportation infrastructure may falter unless the efficacy of investments can be demonstrated by greater use of economic analysis of proposed investments. The public may also sense that returns to public investments in surface

transportation infrastructure have been declining, a perception borne out by careful analysis conducted for the FHWA (Mamuneas and Nadiri, 2003).

The discussion in the previous section of this paper highlighted issues that have impeded the broader use of BCA and also suggested ways of overcoming the impediments, many of which are already underway. These remedies involve reducing political barriers to BCA applications through education concerning the strengths and limitations of BCA; better regional coordination of large projects so as to capture all benefits; increased quality of BCA data, guidance, and tools; improved application of travel demand models to BCA data needs; and the conduct of before-and-after studies to evaluate and improve the performance of economic analysis methods.

A particularly important driver for the increased use of economic analysis methods will be the growing role of the private sector in providing surface transportation infrastructure through public-private partnerships. Private sector investors will apply financial analysis to potential projects to determine expected future cash flows. In many cases, however, the project may also generate public benefits that are not captured in revenue transactions. Through the conduct of BCA, the cooperating public agency is in a much better position to understand the magnitude of non-revenue generating benefits and the level of public participation that would be required to realize these benefits jointly through the partnership.

In closing, BCA and other economic analysis tools have much to offer to the decision-making process. It is important to remember, however, that these tools contribute information to the decision-making process but do not constrain it. It neither will nor should be the case that decisions about projects are made solely on economic grounds.

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