KENTUCKY TRANSPORTATION CENTER
176 Raymond Building, University of Kentucky
859. 257. 4513   www.ktc.uky.edu

Cost Benefit Analysis: Applications and Future Opportunities

KTC's Mission

We provide services to the transportation community through research, technology transfer, and education. We create and participate in partnerships to promote safe and effective transportation systems.

Research Report
KTC-16-04/SPR16-517-1F

Cost Benefit Analysis: Applications and Future Opportunities

By

Bryan Gibson, Ph.D.
Kentucky Transportation Center

and

Candice Wallace, Ph.D.
Kentucky Transportation Center

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, KY

in cooperation with the
Kentucky Transportation Cabinet

June 2016

1. **Report No.** KTC-16-04/SPR16-517-1F	2. **Government Accession No.**	3. **Recipient's Catalog No**	
4. **Title and Subtitle** Cost Benefit Analysis: Applications and Future Opportunities		5. **Report Date** June 2016	
		6. **Performing Organization Code**	
7. **Author(s):** Bryan Gibson and Candice Wallace		8. **Performing Organization Report No.** KTC-16-04/SPR16-517-1F	
9. **Performing Organization Name and Address** Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0281		10. **Work Unit No. (TRAIS)**	
		11. **Contract or Grant No.** SPR 16-517	
12. **Sponsoring Agency Name and Address** Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622		13. **Type of Report and Period Covered**	
		14. **Sponsoring Agency Code**	
15. **Supplementary Notes**			

16. **Abstract**

Cost Benefit Analysis (CBA or Benefit Cost Analysis — BCA) is an evaluation tool that state transportation agencies can use to compare infrastructure project options across transportation modes and gauge if the discounted value of benefits exceed the costs. CBA lets policymakers compare alternative project proposals to a baseline scenario, or status quo case, under which no investments are made. CBA is used to select which proposal is the most sensible investment — ideally, the project that maximizes benefits while minimizing costs should be chosen. As the use of CBA to evaluate projects and grant applications (e.g., TIGER Discretionary Grants) continues to grow, state transportation agencies must gain knowledge of CBA methodologies, especially if they want to remain competitive for federal funding. This study documents historical trends in CBA from literature and past studies, provides background on how CBA's are performed, and describes the purpose and basic function of CBAs. The researchers investigated CBA applications and programs that the Kentucky Transportation Cabinet (KYTC) could potentially use to prioritize projects and identify other investment opportunities. This report serves as a primer on the basic elements of CBA, describes what costs and benefits are typically incorporated into analysis, and gives an overview of the formulas that are used to derive costs and benefits. In the transportation context, most benefits are derived from travel time savings and crash reductions. Typical costs include construction and subsequent maintenance. Researchers developed a simple workbook application that KYTC personnel can use run a CBA. The workbook calculates present value of costs and benefits and makes both NPV and BCR available to the user.

| 17. **Key Words** Cost Benefit Analysis, NPV, BCR, travel time, crash reduction, economic analysis, transportation infrastructure | | 18. **Distribution Statement** Unlimited | |
| 19. **Security Classification (report)** Unclassified | 20. **Security Classification (this page)** Unclassified | 21. **No. of Pages** 47 | 19. **Security Classification (report)** |

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

EXECUTIVE SUMMARY

Cost Benefit Analysis (CBA or Benefit Cost Analysis — BCA) is a tool that state transportation agencies can use to perform economic comparisons of infrastructure improvement projects across transportation modes to determine if a project is a justified investment. CBA lets policymakers compare alternative project proposals to a baseline scenario, or status quo case, under which no investments are made. Alternative proposals can also be contrasted with one another. CBA is used to select which proposal is most sensible — ideally, the project that maximizes benefits while minimizing costs should be chosen. To facilitate comparison between projects, CBA accounts for costs and benefits of projects and discounts those in present value terms.

CBA has increasingly been applied to the evaluation of transportation infrastructure projects. Some federal grant programs, such as Transportation Investments Generating Economic Recovery (TIGER) Discretionary Grants, require that proposers submit CBA to demonstrate a project's expected cost-to-benefit ratio. Despite the increased use of CBA, there are no universal standards that guide their performance. While most CBAs include similar parameters, there are a number of programs and methodologies used to conduct them. Additionally, when calculating a CBA there is some level of subjective judgment that is exercised to determine the costs and benefits associated with the project being analyzed. This study investigated CBA applications and programs that the Kentucky Transportation Cabinet (KYTC) could potentially use to prioritize projects and identify other investment opportunities.

The study reviews literature and past studies on CBA and provides background on how CBAs are performed. This report serves as a primer on the basic elements of CBA, describes what costs and benefits are typically incorporated into analysis, and gives an overview of the formulas that are used to derive costs and benefits. Individuals with limited background and understanding of CBA should be able to quickly grasp the main concepts after reading this document.

In the transportation context, CBA has several limitations, such as omitting costs or key benefits. Measuring changes in certain factors like travel time savings and safety improvements that reduce the number of crashes are not easily converted into a single quantifiable (i.e., monetized) metric. We also distinguish between CBA and economic impact analysis — an economic impact analysis differs from CBA in that it measures the dollar value of impacts such as jobs created by a specific project. Further, the report explores the various inputs required for CBA and the costs and benefits typically associated with transportation projects. We provide examples of each (e.g., construction and maintenance costs, emissions reductions, safety improvements (crash reduction), and vehicle miles travelled). CBA outputs are also discussed such as Net Present Value and Benefit-Cost Ratio. A number of applications that are used to perform CBAs are discussed, with screenshots of some of these programs included so readers can understand their templates. After evaluating the options currently available on the market, the research team decided the best course of action was to create a modified Excel workbook that KYTC can use to execute CBA. This workbook is based on Caltrans' Life-Cycle Benefit-Cost Analysis Model. It is a standalone document that accompanies this report.

CHAPTER ONE: INTRODUCTION

1.1 Study Overview

Cost Benefit Analysis (CBA or Benefit Cost Analysis — BCA) is a tool that state transportation agencies can use to perform economic comparisons of infrastructure improvement projects across transportation modes to determine if a project is a justified investment. It can inform long-term planning processes by letting policymakers compare the costs and benefits associated with a range of alternative projects. Often, such analysis is not part of the decision-making process but if capabilities existed it could become an integral part of that process. Additionally, some grant opportunities require a CBA as part of the application. Since detailed CBA analyses that present accurate and defensible results are an important part of many application packages, reviewing and detailing CBA methods is beneficial. A number of programs and methodologies have been developed to execute CBAs. As a result, there are no consistent, clear guidelines or best practices for CBA.

When prioritizing and selecting projects, return on investment is a key factor to consider. CBA gives agencies a way to calculate the benefits and costs of projects. Once the costs and benefits have been estimated, projects may be analyzed individually or, more often, alternative proposals are compared to one another. CBA can illuminate whether a project is justified from an economic perspective and thus is a worthwhile investment. CBA is useful for evaluating transportation projects that meet the following criteria:

1. "The potential project expenditure is significant enough to justify spending resources on forecasting, measuring and evaluating the expected benefits and impacts.
2. The project motivation is to improve the transportation system's efficiency at serving travel and access-related needs, rather than to meet some legal requirement or social goal.
3. Environmental or social impacts that are outside of the transportation system efficiency measurement are either: (a) negligible in magnitude, (b) measurable in ways that can be used within the benefit-cost framework, or (c) to be considered by some other form of project appraisal outside of the benefit-cost analysis."[1]

Some key questions that CBA can help answer/address are (Lawrence et al., 2014):

- Should a project be undertaken?
- When should a project be undertaken?
- Which projects and/or project alternatives should be funded?
- Evaluation of project performance.

CBA can be used to determine which among a range of project alternatives will produce the most economic benefit. CBA can also help develop project and grant priorities. For example, CBA is a required component of Transportation Investment Generating Economic Recovery (TIGER) grants. [2] By developing benefit and cost estimates, policymakers gain a clearer picture of how to

---

[1] http://bca.transportationeconomics.org/home/when-to-use-benefit-cost-analysis
[2] "The Transportation Investment Generating Economic Recovery, or TIGER Discretionary Grant program, provides a unique opportunity for the DOT to invest in road, rail, transit and port projects that promise to achieve

allocate funds if return on investment is a key factor to consider when prioritizing projects. If direct comparison tools are lacking for projects such as those across different modes, CBA can be utilized.

1.2 Research Objectives

This study investigates CBA applications and programs the Kentucky Transportation Cabinet (KYTC) can use to assist with project prioritization and other opportunities. To develop accurate and supportable CBA for projects and grant proposals, it is important to analyze all CBA methods and practices. Based on the scope and data available for projects, methodology and desired outputs may vary. This background information can assist the KYTC in selecting tools to develop realistic cost and benefit estimates that will withstand scrutiny and meet the basic requirements previously detailed.

1.3 Structure of the Report

Chapter 2 is a literature review that discusses, among other things, past studies on CBA, including a study that details the impact of CBA on TIGER grant awards. Chapter 3 introduces CBA, which is followed by a discussion of costs and benefits. TIGER Grant guidelines are used to exemplify valuations of common costs and benefits. Following this, the research team reports on what steps are needed to perform a CBA by leveraging guidance from the Minnesota Department of Transportation and several other sources. Metrics used to compare costs and benefits across projects, such as net present value, are enumerated. Lastly, differences between CBA and economic impact analysis are noted. Chapter 4 reviews various CBA programs that KYTC can use to inform its CBAs, including models developed by the Federal Highway Administration (FHWA) and California's Department of Transportation. Chapter 5 presents concluding suggestions and information regarding the Excel workbook developed for KYTC.

CHAPTER TWO: LITERATURE REVIEW

Historically, CBA has not been widely applied to transportation projects. Barriers to using it have included data needs, resource use, and political factors (Government Accountability Office, 2005). However, as pressure has increased to maximize the benefits of public funding, CBA been used with increasing regularity to justify project selections (Section 1909 Commission Staff, 2007). Rapid growth in the adoption of CBA by federal agencies can be traced to executive orders issued during the Reagan and Clinton administrations (Adler & Posner, 1999). Executive Order 12866, issued by President Clinton, mandated that agencies perform a CBA to scrutinize any regulation or action that affects the economy by $100 million or more each year:

> In deciding whether and how to regulate, agencies should assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative

---

national objectives. Since 2009, Congress has dedicated nearly $4.6 billion for seven rounds of TIGER to fund projects that have a significant impact on the Nation, a region, or a metropolitan area."
https://www.transportation.gov/tiger/about

measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires another regulatory approach (Executive Order, 12866).

President Obama issued Executive Order 13563 to reaffirm the Executive Order 12866's basic framework:

As stated in that Executive Order and to the extent permitted by law, each agency must, among other things: (1) propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); (2) tailor its regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations; (3) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); (4) to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and (5) identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public (Executive Order, 13563).

CBA has been used in a number of contexts, such as the Environmental Protection Agency (EPA), where it has increased the agency's transparency with respect to project impacts and prioritization. As the private sector becomes more involved in the delivery of government-funded projects there will be a need to routinely perform CBAs to evaluate their anticipated public benefits.

Limitations of Cost Benefit Analysis

Agencies must consider a number of factors and limitations when they conduct a CBA. It can be challenging to accurately estimate the value of costs and benefits associated with a project (Guo et al., 2008). Status-quo base cases must be developed with extreme care — if these are incorrect, subsequent calculations will also be inaccurate. Agencies should avoid bundled CBAs, which evaluate the costs and benefits across multiple projects using a single analysis. The benefits and costs for each project may not be transparent (i.e., they may be hidden by other projects. When estimating benefits and costs, the potential for omission always exists. A prime example of this is neglecting to count benefits and costs that may accrue beyond an agency's jurisdiction. Calculations must avoid double-counting benefits that may already be captured (such as economic benefits within reductions in congestion) as well.

Travel time savings and crash reductions (safety improvements) are the benefits most frequently realized from transportation projects (Kulkarni et al., 2004). However, it can be difficult to measure

the changes in these two factors. "With regard to estimating the change in the pre-project impact levels, many factors besides the project improvement impact such parameters as travel time and accident frequency, and assessing the effect of such project improvement is often difficult" (Kulkarni et al., 2004 p. 151). For example, variability in travel times may be omitted from CBAs despite unreliability in travel times imposing significant costs on motorists (Peer, Koopmans, & Verhoef, 2012). A number of scholars have indicated that variable costs can be an important factor, accounting for 10 to 15 percent of travel time costs (Eliasson, 2006; Fosgerau et al., 2008). Peer et al. (2012) used both an expected constant travel time for a particular road over a certain time period and travel times based on factors that are unique to a certain day such as weather. They argued that mean travel time can be used to predict variable travel times and that longer delays are related to higher variability. Benefits like improved rideability may also be difficult to measure by a CBA because they are not easily quantified.

A single project is sometimes framed as combinations of several smaller interrelated projects, which makes developing a comprehensive CBA problematic (Lawrence et al., 2014). Inaccurate or missing data, an inconsistent or methodologically unsound framework, or the absence of tools to facilitate analysis can also pose significant obstacles when performing a CBA. These issues can lead to omitted values, double counting, inaccurate discounting, and other errors that undermine a CBA's usefulness. Questions have been raised about how to value time savings versus human lives in the context of transportation safety projects (Hauer, 2011). By discounting the value of deaths prevented by safety improvements, Hauer argues that CBA can produce results biased against projects that emphasize safety. Policymakers should also keep in mind that a CBA is a decision tool — it does not favor outcomes on moral grounds (Adler & Posner, 1999). Many agencies do not perform CBAs because there are few resources available to do so once the challenges of mandatory planning, environmental analysis, and other assessments have been tackled. Political influence can dampen the influence of CBAs as well, which is a result of competing constituencies and interest groups lobbying for specific projects irrespective of their costs and benefits.

CBA has limitations when applied to large-scale projects, such as statewide highway plans (Kulkarni et al., 2004). But it has been used to measure the impacts of significant corridor projects (Balducci, 2012), intercity bus service (Guo et al., 2008), and winter maintenance approaches (Veneziano et al., 2010) through road weather management (RWM) programs (Lawrence et al., 2014). Because transportation projects often generate impacts outside of the local area in which they are constructed, properly delineating the area that should be included in a CBA is critical (Bartin et al., 2012). The geographic area analysis that is focused on significantly influences results. For example, traffic levels can affect how specific projects are valued. As such, projects focused on rural areas may yield fewer calculated benefits; policymakers may use this information to argue projects in areas with low traffic do not merit funding because projects in more populated areas will produce greater returns. When examining a statewide plan, there are a large number and variety of projects that improve various facets of the transportation system. Projects in different regions may also have differences in construction costs, which can affect a CBA. Geographic variability is likely to be more problematic for states with a large footprint.

Advantages of Cost Benefit Analysis

Despite its potential limitations, from a budgetary perspective CBA is a more reliable way to rank maintenance and rehabilitation projects than approaches such as a worst-first ranking (Menendez et al., 2013). Problems arise over the ability of the organization, particularly smaller organizations, to conduct a CBA and the data needed for inputs. Incomplete data can have significant impacts on the sensitivity of CBA (Williges & Mahdavi, 2008). CBA may be inappropriate if projects have to meet legal requirements that a typical CBA is unable to capture, such as safety, addressing equity concerns, and maintaining or renovating existing infrastructure (often a base case scenario). Because a CBA is not a dynamic analysis, there can be questions of optimal timing when selecting infrastructure projects (Godinho & Dias, 2012). Some researchers have raised questions about when CBAs are executed during project development. If they are completed too late in the planning process or require so much information that comprehensive planning has already taken place, they may not be helpful to transportation agencies (Beukers et al., 2012).

Another potential issue with CBA relates to their treatment of the distribution of benefits among various population and income groups (Brent, 1996). Traditionally, stakeholders that may either reap benefits or suffer costs include people who use infrastructure, the agency responsible for the project, and the community (Sallman et al., 2012; see Table 1). Martens (2011, p. 961) proposed that an equity analysis should accompany a CBA. The equity analysis should ask three questions:

> 1) Which goods and bads or *benefits and costs* should be at the focus of the equity analysis?
> 2) How should 'members of society' be conceptualized, i.e. which *population groups* should be distinguished?
> 3) What constitutes a 'morally proper distribution', i.e. which yardstick or *distributive principle* should be used to determine whether a particular distribution is fair?

Evaluating a CBA from an equity perspective decomposes the benefits and costs of a project, and it reveals how costs and benefits are distributed among various populations (e.g., pollution affects different age groups differently). Once there has been a decision about what costs and benefits to focus on, the analysis can divide the population into appropriate demographic segments. For example, straight benefits could be divided by income or other measures, mobility benefits divided by car ownership and income, and individual benefits by criteria that are relevant to each benefit and cost under consideration. Several factors can be used to determine what an acceptable distribution of benefits and costs looks like. Benefits and costs can be equally distributed among all demographics. An equity perspective would discourage saddling particular demographics with either disproportionate costs or benefits. Equalizing benefits and costs can be considered where benefits and costs are distributed in an effort to narrow existing societal differences. This can also be considered a compensatory approach that redistributes wealth (Schofield, 1987). If policymakers want to include these additional parameters, then it is customary to supplement CBA results with an equity analysis, although the latter is separate from the basic CBA results (Levinson, 2002).

CBA has been used as criteria for awarding TIGER grants. Homan et al. (2014) explored what role CBAs played in awarding of the first round of TIGER grants. The multi-layered review process

consisted of evaluation, economic analysis, and control and calibration review teams. Evaluating the proposals of awardees and non-awardees along several analytical axes, the authors found that some aspects of the CBA, such as quality and expected benefits, were insignificant factors. Projects that funded transit were found to be significant (more likely to receive funding) along with projects that showed additional shared funding. However, the most important factor was whether the project was forwarded to an additional evaluation team, referred to as a Control and Calibration Team (p.48).

> Ultimately, the single most important factor was whether a special Control and Calibration Team had forwarded a project to the RT (Review Team). This team relied on other considerations besides the published primary and secondary evaluation criteria used by the Evaluation Team. We found that the outcome of the BCA and likelihood of net social benefits were significantly lower for projects forwarded by the Control and Calibration Team vis-a-vis than those forwarded by the Evaluation Team. When analyzing only the projects forwarded by the Evaluation Team we found that the quality (outcome) of the BCA was significantly better for projects that received a grant. At the margin, this might indicate that the RT did consider the quality of a BCA somewhat in deciding whether to award a project when the Evaluation Team forwarded projects based on the accepted criteria.

While this analysis of early TIGER grant awards did not indicate that CBA was a significant factor, it is important to note that if CBA included with a proposal did not hold up under scrutiny with the Economic Analysis Team, then that information was transmitted to the Review Team along with recommendations from the Evaluation Team.

CHAPTER THREE: COST BENEFIT ANALYSIS BACKGROUND

3.1 Introduction to Cost Benefit Analysis

In a transportation context, CBA is used to calculate project benefits and costs to decide whether a project can be financially justified. They are also used to compare alternative scenarios and/or projects.[3] The Minnesota Department of Transportation's (MNDOT) Planning and Programming Section describes CBA in the following manner:

> A benefit-cost analysis is a systematic evaluation of the economic advantages (benefits) and disadvantages (costs) of a set of investment alternatives. Typically, a "Base Case" is compared to one or more Alternatives (which have some significant improvement compared to the Base Case). The analysis evaluates incremental differences between the Base Case and the Alternative(s). In other words, a benefit-cost analysis tries to answer the question: What additional benefits will result if this Alternative is undertaken, and what additional costs are needed to bring it about?[4]

---

[3] http://bca.transportationeconomics.org/
[4] http://www.dot.state.mn.us/planning/program/benefitcost.html#section2

The Transportation Economics Committee of the Transportation Research Board (TRB) defines CBA as a tool for economic evaluation that "uses *monetized* (measured in monetary units) values to compare total incremental benefits with total incremental costs."[5] CBA accounts for changes in benefits and costs compared to the status-quo across the project's lifecycle. This provides initial information as to whether the project should be undertaken at all (benefits>costs). Once this first measure has been completed, a CBA can discriminate among alternative project options along the same roadway or evaluate the costs and benefits of competing projects located on different roadways. According to the Transportation Economics Committee, CBA is most applicable for projects that:

- Are large enough to justify the price of a thorough analysis
- Improve transportation systems rather than altering them to meet legal requirements or some other measure
- Have environmental costs which are insignificant or can be assigned monetary values to include in the analysis.

To analyze all years of a project's lifecycle, a discount rate is used to derive benefits and costs. The discount rate measures the "marginal social opportunity cost of funds allocated to public investment" (Zhuang et al., 2007, p. 1).

Generally, benefits accrue over a number of years while most costs are incurred up front during the initial construction. Smaller annual maintenance costs accumulate over the life of the asset. CBA assigns benefits dollar values and discounts them in order to calculate the cost-benefit ratio. "The primary transportation-related elements that can be monetized are travel time costs, vehicle operating costs, safety costs, ongoing maintenance costs, and remaining capital value (a combination of capital expenditure and salvage value)." [6] CBA is conducted at various points during project development and can supplement other project development measures, such as public input. Additionally, CBA is not used strictly for infrastructure analysis. It can measure the costs and benefits of projects related to management and operations (Sallman et al., 2012).

When conducting CBA, the selection and valuation of appropriate benefits and costs is critical to the process. Failing to identify all relevant costs and benefits may produce inaccurate results. The FHWA lists common benefits and costs that are often investigated when conducting CBA (Table 1)[7].

---

[5] http://bca.transportationeconomics.org/home/when-to-use-benefit-cost-analysis
[6] http://www.dot.state.mn.us/planning/program/benefitcost.html#section2
[7] http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm

Table 1: FHWA Benefits and Costs to Consider

Agency Costs	Design and Engineering
	Land Acquisition
	Construction
	Reconstruction/Rehabilitation
	Preservation/Routine Maintenance
	Mitigation
Users (work zones)	Delay
	Crashes
	Vehicle Operating Costs
Users (operations)	Travel Time and Delay
	Crashes
	Vehicle Operating Costs
Externalities	Emissions
	Noise
	Other

TRB's Transportation Economics Committee also lists a number of benefits and costs to evaluate (summarized in Table 2).[8]

Table 2: Transportation Economics Committee Benefits and Costs

Benefits
Travel time
Vehicle cost savings
Safety improvements (crash reduction)
Emissions reductions
Parking savings (if project reduces vehicle ownership/use)
Costs
Initial costs (acquisition, planning, design, engineering, and construction)
Continuing costs (operations, maintenance)
Rehabilitation costs
End of project costs (residual value, salvage value)

Figure 1 (Balducci 2012, p. 2-2, Figure 2-2) illustrates a more complex accounting of benefits and costs in a corridor analysis.

---

[8] http://bca.transportationeconomics.org/home

Figure 1: Costs and Benefits Framework
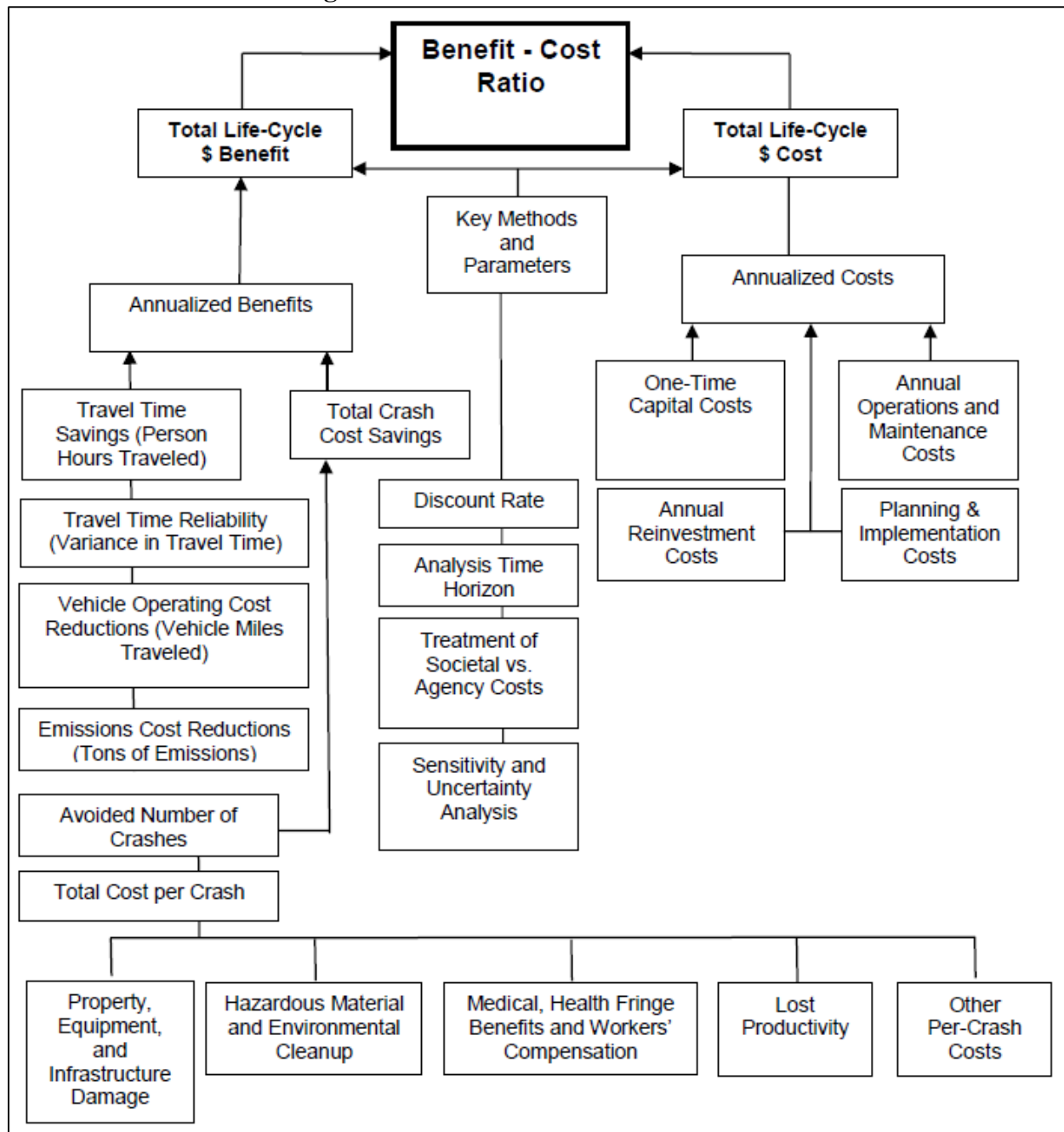
3.2 Benefits

Sullivan et al. (2008) listed the four benefits most commonly realized from transportation projects. These are: travel time savings, a reduction in vehicle operating costs, improved safety, and reduced emissions. Williges and Mahdavi (2008) noted that outside of travel time savings, operating costs, and safety, other benefits are often bracketed as externalities because they are not part of travel decision making. Assigning values and developing accurate data and measures for these potential benefits is often difficult, and many times they are not included in CBA. Many of the benefits and

costs that should be considered are easily identifiable. For example, a reduction in crashes (and/or crash severity) benefits users by shrinking travel times, reducing vehicle operating costs, and preventing injuries and fatalities (which can be assigned a monetary value). Minnesota DOT notes that travel time savings are often the greatest project benefit, generally expressed in terms of vehicle-hours travelled. Section 1909 Commission Staff (2007) described the valuation of travel time as follows (p.5):

> 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.

During CBA, estimates of travel times prior to and after project implementation demonstrate the total change in travel time which can be attributed to a specific project alternative. More exactly, the annual benefits that stem from a reduction in vehicle-hours travelled equals the total annual hours saved multiplied by the hourly value of time, which varies based on the type of travel and mode of travel. Projects are designed to reduce congestion (e.g., adding a lane), reduce travel time, and potentially reduce vehicle costs. TIGER Grants have an accompanying Benefit-Cost Resource Guides[9] with updated values of travel time in 2013 dollars.[10] These are shown below in Table 3.

Table 3: Travel Time Values

Type	Surface Modes (excluding High Speed Rail)	Air and High Speed Rail
Local		
Personal	$12.42	
Business	$25.23	
All (weighted averages 95.4% person, 4.6% business)	$12.98	
Intercity		
Personal	$17.39	$33.05
Business	$24.44	$60.74
All (weighted averages 78.6% personal, 21.4% business for surface; 59.6% personal, 40.4% business for air and high speed rail)	$18.90	$44.24

Vehicle operating costs can result from changing travel distance, the number of stops, and altering roadway conditions. At a micro level, analysis can focus on the type of vehicle, speed, changes in speed, grade and curve of route travelled, and road surface condition. Safety improvements can be measured by valuing crashes (severity), the changes which result from improvements, and trends in accident costs. Crash elements investigated often include property damage, traffic delay, lost

---

[9] https://www.transportation.gov/sites/dot.gov/files/docs/TIGER%20BCA%20Resource%20Guide%202014.pdf.

wages, pain, and emergency services. Table 4 summarizes the values assigned for loss of life and injuries of different scenarios found in the TIGER Benefit-Cost Resource Guide.

Table 4: Crash Values

Value of Statistical Life (VSL)	$9.2 million per fatality	
Value of Injuries		
Severity	**Fraction of VSL**	**Value**
Minor	0.003	$27,600
Moderate	0.047	$432,400
Serious	0.105	$966,000
Severe	0.266	$2,447,200
Critical	0.593	$5,455,600
Property Damage Only	**$3,927 per vehicle**	

A cutback in emissions is another potential benefit of transportation projects. If a proposed project reduces travel time and miles travelled, emissions will decline, yielding health and environmental benefits. However, the linkage between different types of emissions and their levels is less clear. Once a CBA estimates the changes in traffic activity that will result from a project, the implications for emissions can be assessed, and changes in emissions can be monetized based on recommended values. Emission values from the TIGER Benefit-Cost Resource Guide are shown in Table 5.

Table 5: Emissions Values

Emission	Dollars per metric ton
Carbon dioxide	$39*
Volatile Organic Compounds	$1,999
Nitrogen Oxides	$7,877
Particulate Matter	$360,383
Sulfur Dioxide	$46,561
*Social cost of carbon (3%) is present value of marginal future climate damage	

Additional benefits to consider when developing a CBA include: induced travel changes resulting from a project (changes in route, mode, travel time, new trips), changes in travel time reliability (measure and value needed), the negative impact of construction on overall benefits (additional costs due to congestion, diversion, and so forth during construction), noise, and parking impacts of certain projects. Many of these benefits are more difficult to estimate or only apply to certain types of projects.

3.3 Costs

Agency, or project, cost is the amount of money needed to complete a specified project (Tables 1 and 2). Initial costs are incurred from the design and construction phases. If resources already in use — such as engineering staff — are diverted to a project, a CBA should include the opportunity cost of those resources. Sunk costs (i.e., resources that are already owned and lack any opportunity cost) should be excluded from calculations. After construction is finished on a project, there are continuing costs, which may encompass traffic management, tolling operations, maintenance, and rehabilitation (e.g., resurfacing or major repairs that general maintenance would not cover). When

the project reaches the end of its lifecycle, a residual or salvage value may exist. This value will vary among projects and is partially offset by final costs associated with project closeout.

Costs must include those related to construction and future maintenance (Minnesota DOT, 2012). As such, capital, major rehabilitation, and annual maintenance costs should be factored into CBAs. Costs generally appear straightforward, including initial construction costs and maintenance costs over the life of the project. However, other considerations when determining costs are (Sullivan et al., 2008, p. 284):

- Discounting of future costs (and benefits), including selection of the discount rate
- Dealing with opportunity costs
- Dealing with inflation, and the distinction between economic and financial analyses
- Proper treatment of transfer payments and avoidance of double counting
- Avoidance of sunk costs
- Dealing with joint costs
- Dealing with uncertainty and the role of sensitivity analysis

Additional variables may influence benefits and costs, but are difficult to value. These include changes in travel patterns due to the project, noise pollution or abatement, environmental impacts to habitats and water quality, economic and other impacts on surrounding community, and traffic impacts during construction (e.g., increased congestion or diversions). Benefits that are less certain may be documented by interviewing and surveying affected population demographics.

Also difficult to calculate are the residual value of the asset that remains after its lifecycle has ended and the impact of externalities on people who do not benefit from the project. Economic Development Research Group (2010) defines residual value as: "The value of an investment as a benefit after: (1) depreciating the investment to the end of the BCA analysis period, and then (2) discounting the depreciated nominal value" (p. 23). Subtracting cumulative depreciation over the life of the asset and applying the discount rate yields its residual value. Positive and negative externalities can result from projects. Valuing these is often difficult, and may not be possible in some cases (e.g., emissions). Environmental impacts such as emissions may be calculated based on EPA data. In cases where no dollar amount can be assigned, qualitative perceptions of externalities may integrated into CBA.

3.4 Cost Benefit Analysis Methodologies

Generally, transportation projects are designed to meet objectives such as increased road capacity, crash reductions, or some other goal. Many projects have multiple objectives, and these will need to be accounted for by CBA. Constraints may include policy and legal impediments to the proposed project. When developing a CBA, the first step is to identify the costs and benefits of the base case, which is the minimal option wherein operations continue without any major capital investment. The base case scenario is then compared to different project options (e.g., rehabilitating or entirely reconstructing a deteriorating road), specifically, the costs and benefits that would be realized under each scenario. The period for analysis includes the alternatives' lifecycles, ensuring that the CBA captures all benefits and costs. Then, dollar amounts are assigned to the benefits and costs and discounted appropriately. If an analyst is uncertain about the specific impacts of a project (and

therefore its costs and benefits), the likelihood of CBA generating an error increases, which makes the prospect of doing comparisons shaky.

We review and summarize several sources that describe the application of CBA to transportation, including the FHWA's *Economic Analysis Primer on Benefit-Cost Analysis* and the Minnesota DOT's *Benefit-Cost Analysis for Transportation Projects*, below.

The FHWA lists the major steps in the CBA process[11]:

1. Establish objectives
2. Identify constraints and specify assumptions
3. Define base case and identify alternatives
4. Set analysis period
5. Define level of effort for screening alternatives
6. Analyze traffic effects
7. Estimate benefits and costs relative to base case
8. Evaluate risk
9. Compare net benefits and rank alternatives
10. Make recommendations

Guo et al. (2008, p. 4-5) synthesized a novel approach to CBA based on several sources:

1. Define the base case and the options
2. Identify the scope of the CBA
3. Identify investment impacts within the scope
4. Measure the impacts and convert them into dollar values
5. Calculate the net present value for the options proposed
6. Conduct sensitivity and/or risk analyses
7. Make funding decisions based on the information gathered

Although a number of other sources provide guidance on CBA, they usually mirror the approaches noted. There appears to be consensus among researchers that the most basic steps of CBA involve defining the base case and proposed alternative, listing and valuing benefits and costs, conducting net present value calculations, and producing recommendations.
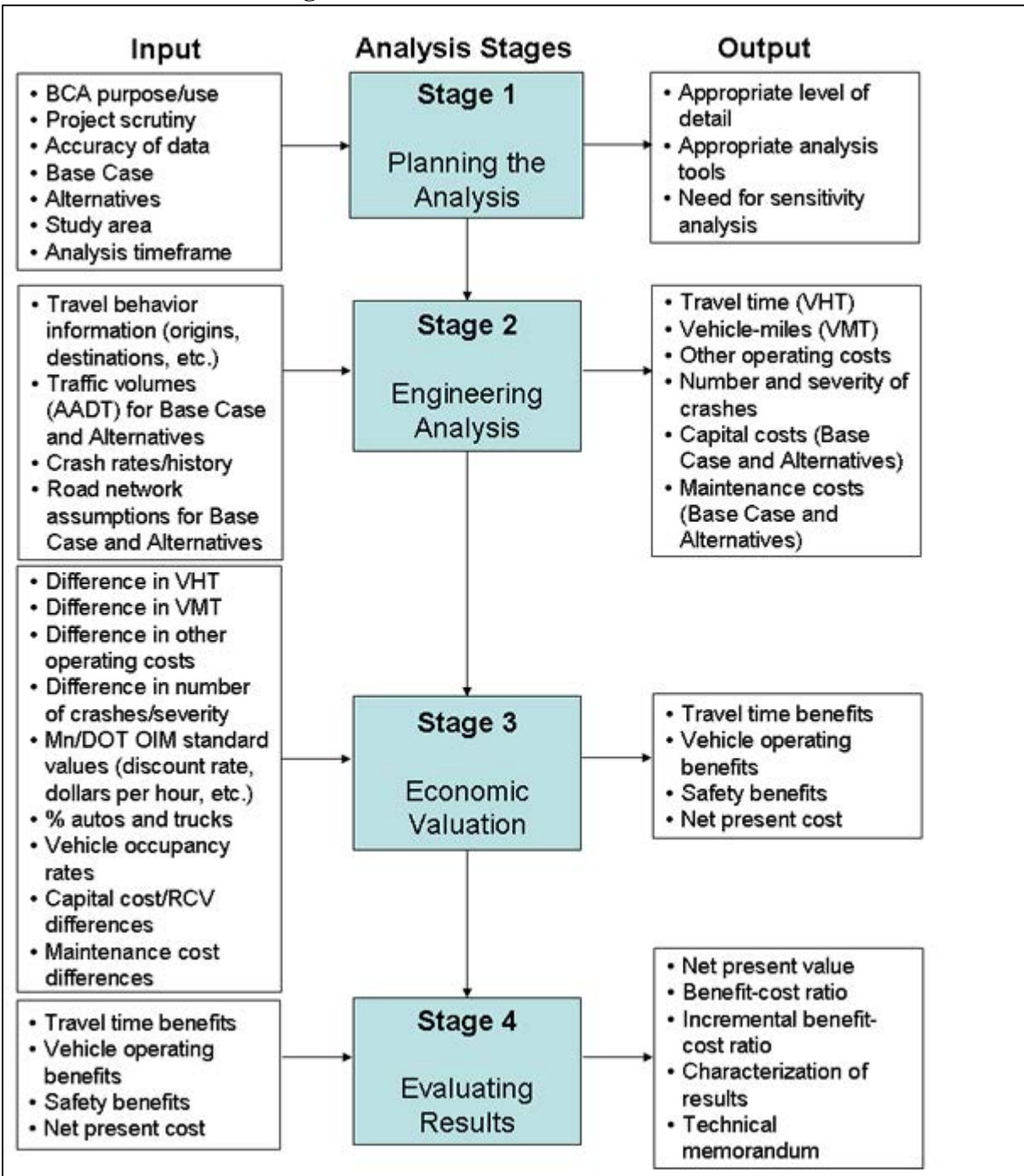
Minnesota DOT has developed a blueprint for conducting CBA on highway projects.[12] Many aspects of their CBA process align with the FHWA's. The four steps of CBA are: 1) planning and defining the scope of the analysis, 2) analyzing the alternatives, 3) calculating benefits and costs to present value, and 4) evaluating results. Several figures illustrate how to perform these calculations.

Figure 2 captures the inputs and outputs for CBA in relation to the four steps.

---

[11] http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm
[12] For a discussion of benefits and costs associated with transit projects see Guo et al. (2008) p. 9-12.

Figure 2: Minnesota DOT CBA Process[13]

Input	Analysis Stages	Output
• BCA purpose/use • Project scrutiny • Accuracy of data • Base Case • Alternatives • Study area • Analysis timeframe	**Stage 1** Planning the Analysis	• Appropriate level of detail • Appropriate analysis tools • Need for sensitivity analysis
• Travel behavior information (origins, destinations, etc.) • Traffic volumes (AADT) for Base Case and Alternatives • Crash rates/history • Road network assumptions for Base Case and Alternatives	**Stage 2** Engineering Analysis	• Travel time (VHT) • Vehicle-miles (VMT) • Other operating costs • Number and severity of crashes • Capital costs (Base Case and Alternatives) • Maintenance costs (Base Case and Alternatives)
• Difference in VHT • Difference in VMT • Difference in other operating costs • Difference in number of crashes/severity • Mn/DOT OIM standard values (discount rate, dollars per hour, etc.) • % autos and trucks • Vehicle occupancy rates • Capital cost/RCV differences • Maintenance cost differences	**Stage 3** Economic Valuation	• Travel time benefits • Vehicle operating benefits • Safety benefits • Net present cost
• Travel time benefits • Vehicle operating benefits • Safety benefits • Net present cost	**Stage 4** Evaluating Results	• Net present value • Benefit-cost ratio • Incremental benefit-cost ratio • Characterization of results • Technical memorandum

Each stage includes several sub-tasks. As part of the initial scope and project planning, the purpose of the analysis needs to be defined. Data availability must be assessed because it will determine

---

[13] Source: Minnesota DOT, http://www.dot.state.mn.us/planning/program/benefitcost.html

the level of detail that is feasible. Initial work should define the base case and alternatives it will be compared to and the timeframe (construction, benefits lifecycle) the analysis should cover. Once these decisions have been made, the salient data must be collected. The next step is to analyze the alternatives relative to one another and the base case. This analysis should focus on benefits that arise from changes in travel times, vehicle operations, and safety, and the costs including construction, maintenance, and minor rehabilitation. Deriving present value calculations requires monetization of costs and benefits. Minnesota DOT's guidance suggests quantifying highway user benefits (e.g. vehicle miles travelled, vehicle hours travelled, safety) and leveraging the resulting calculations to make comparisons among the alternatives and base case. Once the benefits and costs of the alternatives for the specified period of analysis have been identified, the next step is to aggregate and convert dollar amounts using present value calculations (formula and details are discussed later). Figure 3 is an example the Minnesota DOT provides that relates to benefits derived from vehicle hours per day. Figure 4 summarizes the total benefits that users might derive from a highway project including vehicle miles travelled, vehicle hours travelled, and safety.

Figure 3: Minnesota DOT Example Benefit Calculation

Column:		A	B	C	D	E
		DAILY VHT [a] (veh-hours/day)		DIFFERENCE IN VHT (veh-hours/day)	Annual Savings in Constant Dollars [b]	Present Value of Savings (dollars) [c]
	Year	Base Condition	Alternative			
2011	1	2,643,108	2,635,761	7,348	$28,432,953	$22,348,044
2012	2	2,687,035	2,678,788	8,247	$31,914,451	$24,236,203
2013	3	2,731,691	2,722,517	9,175	$35,502,929	$26,049,598
2014	4	2,777,090	2,766,960	10,130	$39,200,965	$27,790,302
2015	5	2,823,243	2,812,128	11,115	$43,011,196	$29,460,334
2016	6	2,870,164	2,858,034	12,129	$46,936,313	$31,061,668
2017	7	2,917,864	2,904,689	13,174	$50,979,070	$32,596,229
2018	8	2,966,356	2,952,106	14,250	$55,142,275	$34,065,893
2019	9	3,015,655	3,000,297	15,358	$59,428,800	$35,472,493
2020	10	3,065,773	3,049,275	16,498	$63,841,579	$36,817,816
2021	11	3,116,724	3,099,052	17,672	$68,383,607	$38,103,604
2022	12	3,168,521	3,149,642	18,880	$73,057,945	$39,331,558
2023	13	3,221,180	3,201,057	20,123	$77,867,720	$40,503,338
2024	14	3,274,714	3,253,312	21,402	$82,816,126	$41,620,560
2025	15	3,329,137	3,306,420	22,717	$87,906,424	$42,684,802
2026	16	3,384,465	3,360,395	24,070	$93,141,947	$43,697,603
2027	17	3,440,712	3,415,251	25,461	$98,526,098	$44,660,465
2028	18	3,497,894	3,471,002	26,892	$104,062,352	$45,574,849
2029	19	3,556,026	3,527,664	28,363	$109,754,260	$46,442,185
2030	20	3,615,125	3,585,250	29,875	$115,605,448	$47,263,862

Total Benefits During Project Life (2011 - 2030)	$729,781,406

(a) All daily VHT data was derived using a transportation forecast model of this region.
(b) Using the composite cost per hour (includes both auto and truck).
(c) Present value of savings during the life of the project in terms of 2004 dollars.

Figure 4: Minnesota DOT Total User Benefits

	Year	PRESENT VALUE OF USER BENEFITS [c]			Present Value of Total User Benefits [c]
		VMT Benefits [a]	VHT Benefits [a]	Accident Reduction Savings [b] [c]	
2011	1	$5,373,985	$22,348,044	$4,079,014	$ 31,801,043
2012	2	$5,222,634	$24,236,203	$3,774,352	$ 33,233,189
2013	3	$5,075,546	$26,049,598	$3,485,631	$ 34,610,775
2014	4	$4,932,600	$27,790,302	$3,212,120	$ 35,935,022
2015	5	$4,793,680	$29,460,334	$2,953,122	$ 37,207,136
2016	6	$4,658,672	$31,061,668	$2,707,967	$ 38,428,308
2017	7	$4,527,467	$32,596,229	$2,476,016	$ 39,599,712
2018	8	$4,399,957	$34,065,893	$2,256,656	$ 40,722,506
2019	9	$4,276,038	$35,472,493	$2,049,300	$ 41,797,832
2020	10	$4,155,609	$36,817,816	$1,853,388	$ 42,826,813
2021	11	$4,038,572	$38,103,604	$1,668,382	$ 43,810,559
2022	12	$3,924,831	$39,331,558	$1,493,770	$ 44,750,159
2023	13	$3,814,294	$40,503,338	$1,329,059	$ 45,646,690
2024	14	$3,706,869	$41,620,560	$1,173,779	$ 46,501,208
2025	15	$3,602,470	$42,684,802	$1,027,482	$ 47,314,754
2026	16	$3,501,011	$43,697,603	$889,737	$ 48,088,352
2027	17	$3,402,410	$44,660,465	$760,133	$ 48,823,008
2028	18	$3,306,585	$45,574,849	$638,277	$ 49,519,712
2029	19	$3,213,460	$46,442,185	$523,794	$ 50,179,438
2030	20	$3,122,957	$47,263,862	$416,323	$ 50,803,142
2011-2030		$83,049,648	$729,781,406	$38,768,303	$ 851,599,358

(a) All daily VMT and VHT data was derived using a transportation forecast model of this region.

(b) Statewide crash data for each facility type was gathered from Mn/DOT sources for a three year period from 1999-2001. This data was used to find a crash rate per 100 million vehicle miles and severity distribution, These two factors were used to estimate crash data benefits for 2011 and 2030 (Positive benefits are obtained because the Alternative shifted VMT to facilities with lower crash rates and severity distribution as compared to the Base Case).

(c) Present value of savings during the life of the project in terms of 2004 dollars.

Next, the base case is compared to the alternatives by calculating how they differ from one another in terms of highway user metrics. To facilitate comparisons, those differences are converted to dollar amounts, which in turn are adjusted to present value. The total user benefits for each scenario equals the sum of individual benefits calculations. Cost calculations allocate expenditures across the project's life and/or period of analysis for construction and associated maintenance. Whatever value remains at the end of the period of analysis is the remaining capital value. This is calculated by determining the percentage of remaining useful life at the last year of the analysis. Figure 5 illustrates one method for calculating total project costs.

Figure 5: Minnesota DOT Example Cost Calculation

Year		Capital Cost [a]		Maintenance Cost [b]		Remaining Capital Value [c]		Present Value of Net Annual Costs [d][e][f]
		Base Case	Alternative	Base Case	Alternative	Base Case	Alternative	
2008	-	$0	$94,115,754	$0	$0	$0	$0	$94,115,754
2009	-	$0	$90,933,096	$0	$0	$0	$0	$90,933,096
2010	-	$0	$87,858,064	$0	$0	$0	$0	$87,858,064
2011	1	$0	$0	$391,887	$218,226	$0	$0	-$173,662
2012	2	$0	$0	$378,635	$210,846	$0	$0	-$167,789
2013	3	$0	$0	$384,120	$203,716	$0	$0	-$180,404
2014	4	$0	$0	$353,460	$196,827	$0	$0	-$156,633
2015	5	$0	$0	$341,507	$190,171	$0	$0	-$151,336
2016	6	$0	$0	$329,959	$183,740	$0	$0	-$146,218
2017	7	$0	$0	$470,084	$177,527	$0	$0	-$292,557
2018	8	$0	$0	$448,041	$171,523	$0	$0	-$276,518
2019	9	$0	$0	$297,604	$165,723	$0	$0	-$131,881
2020	10	$7,497,177	$0	$37,080	$160,119	$0	$0	-$7,374,138
2021	11	$7,243,649	$0	$27,075	$154,704	$0	$0	-$7,116,019
2022	12	$0	$0	$268,421	$149,473	$0	$0	-$118,949
2023	13	$0	$0	$259,344	$144,416	$0	$0	-$114,926
2024	14	$0	$0	$250,574	$139,534	$0	$0	-$111,040
2025	15	$0	$0	$242,101	$134,816	$0	$0	-$107,285
2026	16	$0	$0	$503,821	$130,257	$0	$0	-$373,564
2027	17	$0	$0	$226,004	$125,852	$0	$0	-$100,152
2028	18	$0	$0	$218,361	$121,596	$0	$0	-$96,765
2029	19	$0	$0	$364,368	$117,484	$0	$0	-$246,883
2030	20	$0	$0	$203,842	$113,511	$9,673,099	$91,944,562	-$82,361,793
2011-2030		$14,740,826	$272,906,915	$5,996,288	$3,210,064	$9,673,099	$91,944,562	$ 173,108,403

(a) Assumes construction in 2020-2021 for Base Case and 2008-2010 for Alt. Initial capital costs were brought back to 2004 to determine present value.

(b) Annual costs consist of roadway and bridge maintenance. For the Base Condition, major maintenance costs are added to routine maintenance costs in scheduled years (Minnesota only).

(c) Assumes base year for remaining capital value as 2030. Remaining value in constant dollars was brought back from 2030 to 2004 to determine present value.

(d) Present value of costs during the life of the project in terms of 2004 dollars.

(e) Net cost is the difference between the Base Case and the Alternative.

(f) Remaining capital value was considered a reduction of cost in this analysis and was subtracted from construction and maintenance costs to obtain a net cost.

Results can be evaluated using several approaches. Net present value (NPV), Benefit-Cost Ratio, and Incremental Benefit-Cost Ratio are often used to contrast the alternatives from an economic perspective. Payback period and internal rate of return can be used as well. NPV discounts all benefits and costs and then subtracts costs from benefits. The following equation can be used to calculate the present value of benefit and cost flows. Results are then summed for multiple benefits and/or costs:

$$PV = \frac{B_n}{(1+d)^{(n-o)}}$$

Where:　　　　PV = present value
B = benefit (cost)
N = year benefit (cost) is incurred
o = year to which discounting is occurring

23

$$d = \text{discount rate}^{14}$$

Thus, $\boldsymbol{NPV = \Sigma PV_b - PV_c}$

Where:
PV$_b$ = present value of benefits
PV$_c$ = present value of costs

If benefits are greater than costs, the NPV is positive. This would suggest a project may be worth investigating further and potentially undertaken. When a state transportation agency compares project alternatives, in general it should move forward with the project having the highest NPV. But there is a caveat to this statement. As the FHWA notes, "Policy issues, perceived risk, and funding availability may lead to the selection of an alternative with a lower, positive NPV." That is, other variables — which are not factored into CBA — may dictate project selection. The FHWA also observes that benefit-cost ratio (BCR) is another measure that can be used. It is applicable if there are funding issues that must be considered. To calculate BCR, the benefits are discounted in the numerator and the agency investment cost discounted in the denominator.

$$BCR = \frac{\Sigma PV_b}{\Sigma PV_c}$$

After calculations are completed, a project recommendation can be made. If multiple alternatives are being considered, the Incremental Benefit-Cost Ratio can be used. The Incremental Benefit-Cost Ratio compares the change in present value between two alternatives. Alternative project scenarios are ordered from least to most expensive. The first round of analysis compares only the first two options. These options are termed the defender and challenger, with the challenger being the more expensive alternative. The Incremental Benefit-Cost Ratio formula is applied to contrast projects:

$$IBCR = \frac{(\Sigma PV_{b,d} - \Sigma PV_{b,f})}{(\Sigma PV_{c,d} - \Sigma PV_{c,f})}$$

Where:
IBCR = Incremental Benefit-Cost Ratio
PV$_{b,d}$ = present value of defender benefits
PV$_{b,f}$ = present value of challenger benefits
PV$_{c,d}$ = present value of defender costs
PV$_{c,f}$ = present value of challenger costs

The difference in the projects' net benefits is divided by the difference in their net costs. If the IBCR is greater than or equal to 1.0, it means the benefits of the *challenger* are equal to or greater than its increase in costs. If this occurs in the next round of analysis, the current *challenger* becomes the *defender* and is compared to another project. If the IBCR is less than 1.0, the current *defender* is retained, and the new *challenger* is the next alternative on the project list. Comparisons

---

[14] TIGER grants use a 7 percent rate from OMB Circulars A-4 and A-94; an alternative analysis is also allowed with 3 percent. The Congressional Budget Office and General Accounting Office use the rate of marketable Treasury securities with maturities similar to the length of the project in question (Zhuang et al. 2007).

of challengers and defenders are made until all Alternatives have been considered. The surviving defender is the most economically efficient.[15]

Often, state transportation agencies select their preferred evaluation tool; multiple tools can be used if agency staff think they will improve comparisons. The Transportation Economics Committee lists several additional measures that can be used to evaluate proposed projects. The Internal Rate of Return (IRR) is the discount rate that results in the net present value of project cash flows equal to zero. Projects with a high IRR are considered to have greater value. The Payback Period is the amount of time required for the cumulative benefits to equal cumulative costs (both discounted to present value). Last, Cost Effectiveness compares discounted benefits of alternative projects with the assumption of budgetary constraints. This measure can also be used to quantify the discounted costs needed to reach a specified benefit.

TIGER Discretionary Grants are an example of a federal grant program that emphasizes CBA. The U.S. DOT's 2013 Notice of Funding Availability for TIGER grants noted:

> Each applicant should provide evidence that the expected benefits of the project justify the costs (recognizing that some costs and benefits are difficult to quantify). If it is clear that the benefits do not justify the costs, the Department will not award a TIGER Discretionary Grant to the project.

CBAs submitted as part of a TIGER proposal should include the following components:

- Project Summary
- Monetized estimates of benefits and costs
- Replicable Methodology
- Demonstration of independent utility[16]

Figure 6 provides an example of a simple CBA calculation used in a TIGER grant proposal. It shows information from the CBA and the results.

---

[15] http://www.dot.state.mn.us/planning/program/benefitcost.html
[16] Information from webinar presented by the Office of Assistant Secretary for Transportation Policy in the U.S. Department of Transportation.

Figure 6: Example Cost Benefit Analysis Calculation[17]

Calendar Year	Project Year	Affected Drivers	Travel Time Saved (hours)[1]	Total Value of Time Saved ($2013)[2]	Initial Costs ($2013)	Operations & Maintenance Costs ($2013)	Undiscounted Net Benefits	Discounted at 7%
2015	1				$38,500,000	$6,000,000	-$44,500,000	-$41,588,785
2016	2	80,000	1,040,000	19,656,000		$700,000	$18,956,000	$16,556,905
2017	3	95,000	1,235,000	23,341,500		$700,000	$22,641,500	$18,482,208
2018	4	100,000	1,300,000	24,570,000		$700,000	$23,870,000	$18,210,309
2019	5	102,000	1,326,000	25,061,400		$700,000	$24,361,400	$17,369,342
2020	6	109,000	1,417,000	26,781,300		$700,000	$26,081,300	$17,379,071
NPV								$46,409,050
1. Number of drivers times three minutes a day (3/60 hours) over 260 workdays								
2. Hours at $18.90 per hour for All Purpose inter-city travel ($2013)								
3. Includes costs from delays to users during construction								

As the TIGER CBA guidance notes, one strategy to effectively communicate the results of a CBA to wider audiences that are not well-versed in the technical aspects of CBAs is to build a project matrix that summarizes the findings. Figure 7 is an example from TIGER CBA guidance.

Figure 7: CBA Project Matrix[18]

Current Status/Baseline & Problem to be Addressed	Change to Baseline/ Alternatives	Type of Impacts	Population Affected by Impacts	Economic Benefit	Summary of Results	Page Reference in BCA
Stop light at lightly used (non-peak) rural intersection / excess waiting time and safety hazard	Replace with roundabout /signal phasing improvement	Reduce wait time for vehicles (non-peak) & reduce accidents (peak)	Number of drivers with reduced wait time & number of accidents/fatalities & injuries per year	Monetized value of reduced travel times, emissions, and accident costs	Estimated dollar value of time savings, reduced pollution, and safety benefits	pp. 15-18 and p.19

Programs such as the Transportation Infrastructure Finance and Innovation Act (TIFIA) require a CBA to qualify for federal credit assistance.[19] The FHWA notes that at a minimum "a project's public and private benefits would be required to exceed the sum of its public and private costs."[20] Thus, CBA is used to demonstrate whether a project surpasses that threshold.

It is often challenging to distinguish between economic impact studies[21] and CBAs. According to TIGER grant guidance, CBA measures benefits and costs to society by assigning dollar values. An economic impact analysis, conversely, measures the dollar value of a specific project's impacts (e.g., number of jobs created). It is typically a locally focused analysis that evaluates a project's effects on economic activity rather than measuring overall social improvement:

> Economic impacts are the effects a project or policy has on the economy of a designated project area, measured in terms of the change in business sales, jobs,

---

[17] TIGER BCA Guidance, U.S. Department of Transportation.
[18] TIGER BCA Guidance, U.S. Department of Transportation.
[19] TIFIA provides credit assistance for surface transportation projects.
[20] http://www.fhwa.dot.gov/ipd/tifia/technical_resources/federal_credit_policy_paper/ch3.aspx
[21] See Kreis, Howell, and O'Connell (2006) for an examination of several options for assessing economic impacts of proposed transportation investment in Kentucky.

value added, income, or tax revenue. These effects are sometimes referred to as "economic development impacts." Whereas Benefit-Cost Analysis is an exercise to determine an action's social welfare effects (compared to costs), Economic Impact Analysis is an exercise to determine how a project or policy affects the amount and type of economic activity in a region.[22]

One way to differentiate economic impact analysis from CBA is by thinking about the questions they attempt to answer:

- CBA: is society better off by undertaking the project versus doing nothing?
- Economic Impacts: how will the economy change due to a project? [23]

Sallman et al. (2012, Table 2-3) looked at several examples of benefits and noted whether CBA or economic impact analysis explicitly consider them. Table 6 has been reproduced from their piece:

Table 6: Comparison of CBA and Economic Impact Analysis

Type of Benefit	Direct Benefit	Indirect Benefit	Induced Benefit
Example of Benefit	Reduction in corridor travel times.	New businesses are attracted to the corridor by the improved corridor performance.	Employees of the new businesses spend their incomes at other regional businesses.
Considered in CBA	Yes	No	No
Considered in Economic Impact Analysis	Yes	Yes	Yes

An example of economic impacts runs as follows: building a new road will entice businesses to relocate near it; as businesses move into the area, new jobs are created and tax revenues increase; in turn, local residents will enjoy the better transit access which connects them to their new jobs.

CBA is a widely-accepted method of comparing projects options. Data requirements are contingent on the project in question and which benefits and costs are identified for the project. Identifying a comprehensive list of these and costing them appropriately will ensure a CBA is valid. Multiple evaluation criteria can be used to evaluate projects. The information they generate gives decision makers project-specific information they can use to select and implement projects that will provide the greatest benefit levels to the constituencies affected.

CHAPTER FOUR: COST BENEFIT ANALYSIS APPROACHES

The FHWA made several efforts to develop CBA tools in the 1990s. While there are no longer active links to these models online, briefly reviewing their capabilities contextualizes the development of similar tools today. The Sketch-Planning Analysis Spreadsheet Model (SPASM) was one of these early models;[24] it was a spreadsheet for use in multimodal analysis at the sketch

---

[22] http://bca.transportationeconomics.org/home/bca-vs-economic-impact-analysis
[23] http://bca.transportationeconomics.org/home/bca-vs-economic-impact-analysis
[24] For more on SPASM, see Findley et al. (2007) p. 7-9.

planning detail level. SPASM was a precursor to the Surface Transportation Efficiency Analysis Model (STEAM), which assessed multimodal transportation alternatives and approaches to travel demand. It used travel demand models and outputs to analyze projects such as corridor plans (Coley, 2012). STEAM focused on regional multimodal analysis. Benefits considered in STEAM included travel time, vehicle costs, emissions, noise, and energy consumption, whereas the costs focused on were the initial capital costs and operating and maintenance costs. Other impacts were also factored in, such as congestion and job impacts. Results were presented as net present value calculations or benefit-cost ratios.

Given the widespread use of CBA in transportation and other sectors, there are a number of current applications that can be used to perform CBA. This research involved summarizing and commenting on a number of these applications; they are listed below. Also provided are any costs and relevant links. Additionally, the Transportation Economics Committee of TRB describes these models and provides an example of each.[25] These models can aid policymakers interested in comparing project alternatives by giving them a more representative look at the benefits and costs associated with each choice. Used appropriately, these models will lead to improved, cost efficient project selection and safer, improved travel outcomes for users.

Highway Economic Requirements System (HERS-ST) (Free)
Available at: https://www.fhwa.dot.gov/infrastructure/asstmgmt/hersrprep.cfm

The Highway Economic Requirements System — State Version (HERS-ST) is an FHWA software program that is an extension of the national-level model used to predict the level of investment required to meet specified highway performance measures.

> HERS-ST is an engineering/economic analysis (EEA) tool that uses engineering standards to identify highway deficiencies, and then applies economic criteria to select the most cost-effective mix of improvements for system-wide implementation. HERS-ST is designed to evaluate the implications of alternative programs and policies on the conditions, performance, and user cost levels associated with highway systems. The model will provide cost estimates for achieving economically optimal program structures, as well as predict system condition and user cost levels resulting from a given level of investment.[26]

HERS-ST is linked to the Highway Performance Monitoring System (HPMS). It can be used to estimate the highway performance that would be expected from different levels of investment. The program can consider capital projects focused on addressing issues on the highway system such as capacity and condition. HERS-ST can select improvement scenarios where the benefits exceed the costs. Scenarios can be developed using different criteria:

- Given a specified level of funding, determine the best project combinations from an economic perspective
- Determine the minimum level of spending to achieve performance measures

---

[25] http://bca.transportationeconomics.org/models
[26] https://www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.cfm

- Identify the project combinations and spending levels needed to undertake all projects that meet a certain economic target such as a benefit cost ratio

HERS-ST uses interview screens to assist with data entry and verification. Inputs from the HPMS format are accepted for highway sections. After data are input, the model identifies future condition and capacity issues and alternatives, corrects for these, and performs a CBA for each. Examining different scenarios and the numerous ways of displaying results offers the user greater flexibility when conducting analyses, which can include an incremental benefit-cost approach. Benefits that can be evaluated include travel time, vehicle operating costs, reduction in crashes, emissions, agency costs for maintenance and operation, and residual values. Costs are limited to right-of-way acquisition and construction costs. Funding constraints or specified performance measures can be used to drive the analysis. A user's guide and examples of the software in action can be found on the HERS-ST website.[27]

Figure 8: HERS-ST Screenshot

BCA.NET (Free)
Available at: http://bca.decisiontek.com/
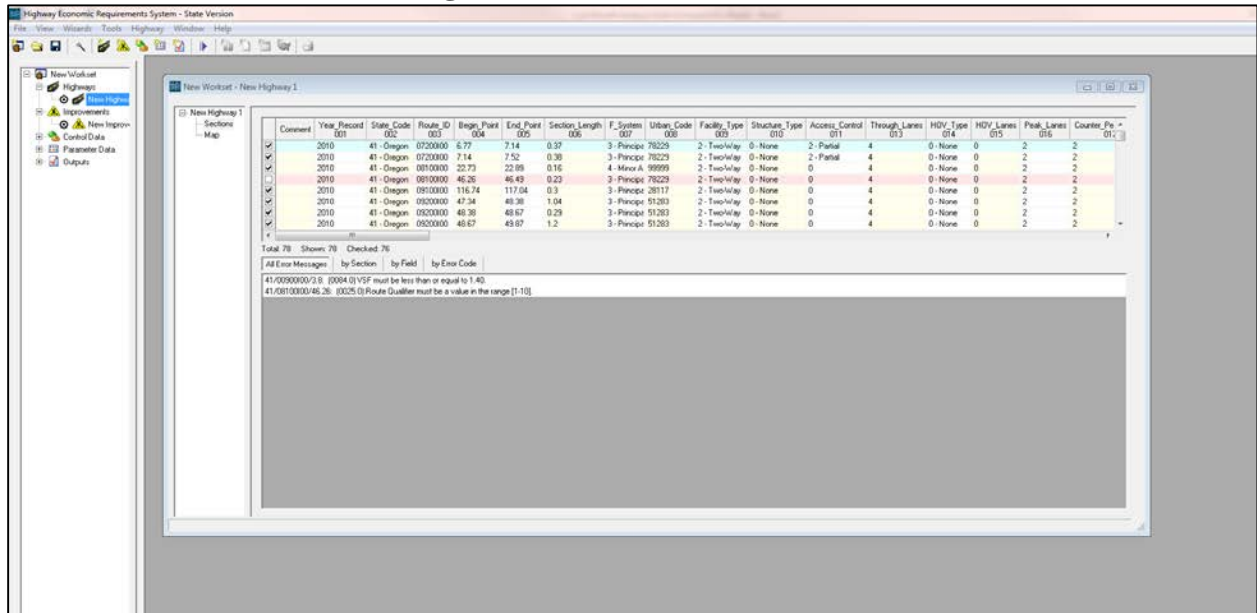
BCA.Net is home to the FHWA's benefit-cost analysis tool, which can support the highway project decision-making process. BCA.NET is a web-based application that lets users compare alternative approaches for managing and improving highways. BCA.NET is supported by the FHWA Asset Management Evaluation and Economic Investment Team:

> The BCA.Net system enables users to: manage the data for an analysis; select from a wide array of sample data values; develop cases corresponding to alternative strategies for improving and managing highway facilities; evaluate and compare

---

[27] See also: http://www.gao.gov/products/GAO-01-299

the benefits and costs of the alternative strategies; and, provide summary indicators for informing investment decisions.[28]

BCA.NET input options include capital cost, physical characteristics, performance impacts, and forecasted travel demand. Design, project timing, and project alternatives can also be factored into analysis. BCA.NET is most appropriate for small- to medium-sized highway capacity projects that involve significant resources, but which do not necessarily alter traffic patterns (Coley, 2012). During analysis, the user can specify needed maintenance during the project's lifecycle. BCA.NET then calculates the present value of benefits and costs, which gives the user several measures to compare alternatives, including net present value, internal rate of return, and benefit-cost ratio. BCA.NET is free and, because of its web-based format, does not require software installation. A workshop is available to interested users that provides information on Highway Investment Analysis, including the BCA.NET tool. Workshop sessions are held at various points throughout the year.

Figure 9: BCA.NET Screenshot

TREDIS Multimodal Benefit-Cost Analysis Tool (Free)
Available at: http://www.tredis.com/mbca

The TREDIS Multimodal Benefit-Cost Analysis (MBCA) is a web-based program that compares the benefits and costs of transportation projects. It includes passenger and freight transport across all modes. MBCA meets USDOT requirements and can be used to support grant applications in addition to executing project assessments.

MBCA lets users conduct multimodal analysis that covers air, water, rail, and highway. Even non-motorized methods of transportation are included (e.g., pedestrian and bicycle).

> MBCA is unique in that it covers both passenger and freight transportation spanning all modes – highway, rail, air, and marine – and it also includes pedestrian and bicycle modes. It is designed to be consistent with USDOT guidelines, making it useful for multimodal project assessments, grant applications, and education

---

[28] http://bca.transportationeconomics.org/models/bca-net

programs. MBCA is set up with standard U.S. and Canadian values for user benefit, which are not tied to any specific study area. (Lawrence et al., 2014, p. 3-3)

TREDIS notes that the MBCA tool is useful for three project types: 1) single mode projects with one or more alternatives, 2) single mode projects that impact other modes, and 3) multimodal projects that cross modes (e.g., combination transit/highway corridor project). MBCA inputs include project costs and timelines and common benefits, such as changes in congestion, safety, and travel distance. MBCA accounts for benefits that accrue directly to users as well as externalities, such as emissions and business productivity. TREDIS offers additional tools that may come with a cost.

Figure 10: TREDIS MBCA Screenshots

Figure 11: TREDIS MBCA Results

BENEFIT-COST RESULTS - BY MODE (NATIONAL PERSPECTIVE) (5a)

Analysis Year: 2020
Constant $ Year: 2015
Base Alternative: Base
Project Alternative: Project
Annual CO_2 Cost Increase: 3%

Project: Highway
Region: National
Period: All Periods
Perspective: National Perspective

Present Value of Benefit Stream ($m 2015 Const Dollars)

Mode	(A) Traveler Money Benefit		(B) Value of Traveler Non-Money Benefit			(C) Logistics Productivity ($)	(D) Mkt Access / Other Prod. ($)	(E) Social & Environ Value
	(A1) Vehicle Operating Costs	(A2) Business Time + Rel Cost	(B1) Personal Time + Rel Value	(B2) Safety Value	(B3) Consumer Surplus Value			
Passenger Car - Business	0	0	0	0	0	0	--	0
Passenger Car - Commute	0	--	0	0	0	0	--	0
Passenger Car - Personal	0	--	0	0	0	0	--	0
Totals	0	0	0	0	0	0	0	0

Present Value of Cost Stream ($m 2015 Const Dollars)

Facility Type	Startup Costs	Annual O&M Costs	Residual Value	Net Total Costs
Road	0	0	0	0
Rail	0	0	0	0
Air	0	0	0	0
Marine	0	0	0	0
Total for All Facilities	0	0	0	0

Efficiency Measures

Benefit Measure	Benefit Definition	Present Value of Benefit Stream	Present Value of Cost Stream	Net Present Value (Benefits - Costs)	Benefit-Cost Ratio
Traveler Benefit	A+B	0	0	0	N/A
Full User Benefit	A+B+C	0	0	0	N/A
Total Societal Benefit	A+B+C+D+E	0	0	0	N/A

Wider Measures

Impact Measure	Impact Definition	Present Value of Impact Stream	Present Value of Cost Stream	Net Present Value (Impacts - Costs)	Impact/Cost Ratio
Add'l Gross Regional Product	GRP	0	0	0	N/A
GRP plus Traveler non-$ Benefit	GRP+B	0	0	0	N/A
GRP plus Total non-$ Benefit	GRP+B+E	0	0	0	N/A

MicroBENCOST ($50)
Available at: http://mctrans.ce.ufl.edu/

MicroBENCOST was created by the National Cooperative Highway Research Program (NCHRP) to perform CBA. Developed in the early 1990s, the program is a DOS application, but also runs with Windows. It is distributed by the Texas Transportation Institute and the McTrans Center at the University of Florida:

> MicroBENCOST is a computer program for analyzing benefits and costs of a wide range of highway improvements. It also can allocate corridor traffic and calculate forecasted traffic volumes. The program is capable of analyzing seven categories of projects: added-capacity, bypass, intersection/interchange, pavement rehabilitation, bridge, safety, and highway-railroad grade crossing.

> In general, the program compares the motorist costs in the existing situation, the "without improvement" alternative, to the motorist costs if the improvement is completed, the "with improvement" alternative. In all cases, the "without improvement" alternative includes an existing route and an optional alternate route. Except for new location projects, the "with improvement" alternative includes a proposed route that replaces the existing route and an optional alternate route. For new location projects, the "with improvement" alternative includes an existing route, a proposed route, and an optional alternate route. The proposed route does not replace the existing route in a bypass project although it may take some of the traffic off the existing route. [29]

Users can examine highway improvement projects with MicroBENCOST. Benefits that may be factored into analysis are travel time, vehicle costs, and accidents. Impacts to vehicles can be estimated across nine different passenger types and nine different truck types. Cost analysis is based on initial project cost, residual value at the end of the analysis period, and rehabilitation/maintenance costs. Results are in the form of NPV calculations, internal rate of return, or benefit cost ratios.

StratBENCOST ($55)
Available at: http://mctrans.ce.ufl.edu/
Also available at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=498

StratBENCOST combines aspects of HERS and MicroBENCOST into CBA. It was developed as part of NCHRP Project 2-18(4). StratBENCOST's lifecycle analysis can run 30 years, and the user can specify when benefits start to accumulate. The program can analyze two project types: a road segment with no significant traffic diversions or an investment with larger network implications that diverts traffic. StratBENCOST lets users compare up to 20 alternatives against the base case. The program also generates random variables if the user inputs a median or tenth and ninetieth percentiles. It can also generate probability distributions using Monte Carlo simulations to show a range of values. StratBENCOST calculates benefits like travel times, vehicle costs, accidents, and

---

[29] http://mctrans.ce.ufl.edu/store/description.asp?itemID=166

emissions; costs include capital, right-of-way, maintenance, and lifecycle, among others. The program calculates NPV, IRR, BCR, and total benefits or total costs:

> StratBENCOST32 is designed as a decision support tool for state and local transportation agencies engaged in multi-year strategic planning and budgeting for highways. StratBENCOST32 consists of two models, one for network analysis and one for single segment analysis. Each model incorporates risk analysis techniques to account explicitly for the inherent uncertainty in the methodology and the data underlying the analysis. The conceptual basis for each model is described below.
> *Network Benefit Cost Analysis Model* - Few highway projects can be accurately evaluated without studying their effect on the network of highways and other roads around them, particularly in dense urban settings. Sophisticated network analysis models have been developed to analyze the effects a new roadway improvement will have on a developed network. StratBENCOST32 utilizes the aggregate results of these models that include daily vehicle miles of travel and vehicle hours of travel to develop economic criteria. Standard roadway characteristics are applied to each roadway type, simplifying the analysis.
> *Single Segment Benefit Cost Analysis Model* - Many highway projects do not significantly affect highways around them, particularly in sparsely populated or rural areas. This strategic level-planning model analyzes these situations in a manner that is similar to project modeling, without the same level of detailed data input.[30]

California Life-Cycle Benefit-Cost Analysis Model (Cal-B/C) (Free)
Available at: http://www.dot.ca.gov/hq/tpp/offices/eab/LCBC_Analysis_Model.html

Cal-B/C is an excel spreadsheet used to perform CBA for highway and transit projects. Booz-Allen Hamilton developed it for the California Department of Transportation (Caltrans). Cal-B/C was developed "in the mid-1990s to facilitate the assessment of many projects in a short time frame using a standardized approach" (Williges & Mahdavi, 2008, p. 79). Projects based in California have minimal data input requirements due to prepopulated default values. If agencies in other states decide to use the tool, these values can be overridden as desired.

> The Economic Analysis Branch (of California DOT) routinely conducts life-cycle benefit/cost analysis for proposed state highway and public transit projects. Such analysis is performed using Cal-B/C, a PC-based spreadsheet model developed by the Branch and outside consultants. Cal-B/C can be used to analyze many types of highway construction and operational improvement projects, as well as some Intelligent Transportation System (ITS) and transit projects.[31]

Cal-B/C analyzes prospective corridor projects against existing transportation infrastructure, including highways and transit as well as Intelligent Transportation Systems (ITS). The types of projects that Cal-B/C can evaluate are listed below in Table 7 (Findley et al., 2007, p.4).

---

[30] http://mctrans.ce.ufl.edu/store/description.asp?itemID=524
[31] http://www.dot.ca.gov/hq/tpp/offices/eab/LCBC_Analysis_Model.html

Table 7: Cal-B/C Projects

Highway Capacity Expansion	Transit Capacity Expansion	Operational Improvements	Transportation Management Systems
General Highway HOV Lane Passing Lane Interchange Bypass Pavements	Passenger Rail Light Rail Bus	Auxiliary Lane Freeway Connector HOV Connector HOV Drop Ramp Off-Ramp Widening On-Ramp Widening	Ramp Metering Signal Coordination Incident Management Traveler Information Arterial Signal Management

The spreadsheet contains 10 work sheets and a cover sheet. Users enter information in the first four sheets. Color coding identifies where data are needed, with green denoting user input and red indicating default. The inputs required for highway projects include (Williges & Mahdavi, 2008, p. 81):

- Number of general and HOV lanes
- Estimated free-flow speed
- Length of highway segment
- Average daily traffic (ADT) and hourly HOV traffic
- Three-year collision data for the facility
- Statewide average collision rates

Benefits that may be derived with Cal-B/C are travel time, vehicle costs, and accident and emission reductions, while the costs it computes are focused on a total life investment along with operating and rehabilitation costs. Costs are needed for various components depending on the type of project including (Williges & Mahdavi, 2008, p. 83):

- Right-of-way
- Construction
- Mitigation
- Project supports
- Maintenance and operation
- Rehabilitation

The program captures benefits for current traffic as well as any benefits that are brought about by an alternative project. The period of analysis can run for 20 years, and it generates results in the form of NPV, benefit-cost ratio, internal rate of return, and payback period. Default values for fuel, wages, and other variables are California-specific, but can be modified.

Figure 12: Cal-B/C Screenshots

Tool for Operations Benefit/Cost (TOPS-BC) (Free)
Available at: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm

TOPS-BC is a sketch-planning tool the FHWA developed. It supports CBA for Transportation System Management and Operations (TSM&O) strategies. TOPS-BC was developed with input from practitioners and is spreadsheet-based. It analyzes the impact of selecting different TSM&O approaches, identifies the appropriate methodology for CBA based on the type of analysis desired, and estimates lifecycle costs and benefits.

TOPS-BC provides:

- The ability to analyze many TSM&O strategies and to investigate the expected range of impacts associated with previous deployments
- A screening mechanism to help identify appropriate tools and methodologies for conducting a B/C analysis based on analysis needs
- A framework and default cost data to estimate the life-cycle costs (including capital, replacement, and continuing O&M costs) of various TSM&O strategies
- A framework and suggested impact values for conducting simple sketch planning level B/C analysis for selected TSM&O strategies[32]

All of TOPS-BC's capabilities are included in one workbook, and color coded tabs assist users in selecting the appropriate function. Default data, output, and user input are defined within each sheet, also using color coded cells.

---

[32] http://ops.fhwa.dot.gov/publications/fhwahop13041/fhwahop13041.pdf

Figure 13: TOPS-BC Screenshots

Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) Model (Free)
Available at: http://www.nctr.usf.edu/abstracts/abs77805.htm

TRIMMS measures the social benefits created by transportation demand projects, with a focus on emissions, safety, and fuel usage. Because it assesses cost effectiveness via sensitivity analysis,

TRIMMS can be used to support transportation demand management, which is necessary to comply with FHWA Congestion and Air Quality Improvement Program requirements.

TRIMMS© is a spreadsheet application that estimates the impacts of a broad range of transportation demand management initiatives and provides program cost effectiveness measures, such as net program benefits and benefit to cost ratio indicators. TRIMMS© evaluates strategies directly affecting the cost of travel, like public transportation subsidies, parking pricing, pay-as-you-go pricing, and other financial incentives. TRIMMS© also evaluates the impact of strategies affecting access and travel times and a host of employer- based program support strategies, such as flexible working hours, telecommuting and guaranteed ride home programs (Concas & Winters, 2009, p. v).

Figure 14: TRIMMS Model Screenshot

ANALYSIS INFORMATION

Agency Name	0
Analysis Title	0
Analyst	0
Analysis Type	Area-Wide
Date	1/0/1900
Region	0
Total Affected Employment	0
Total Program Cost	$ -
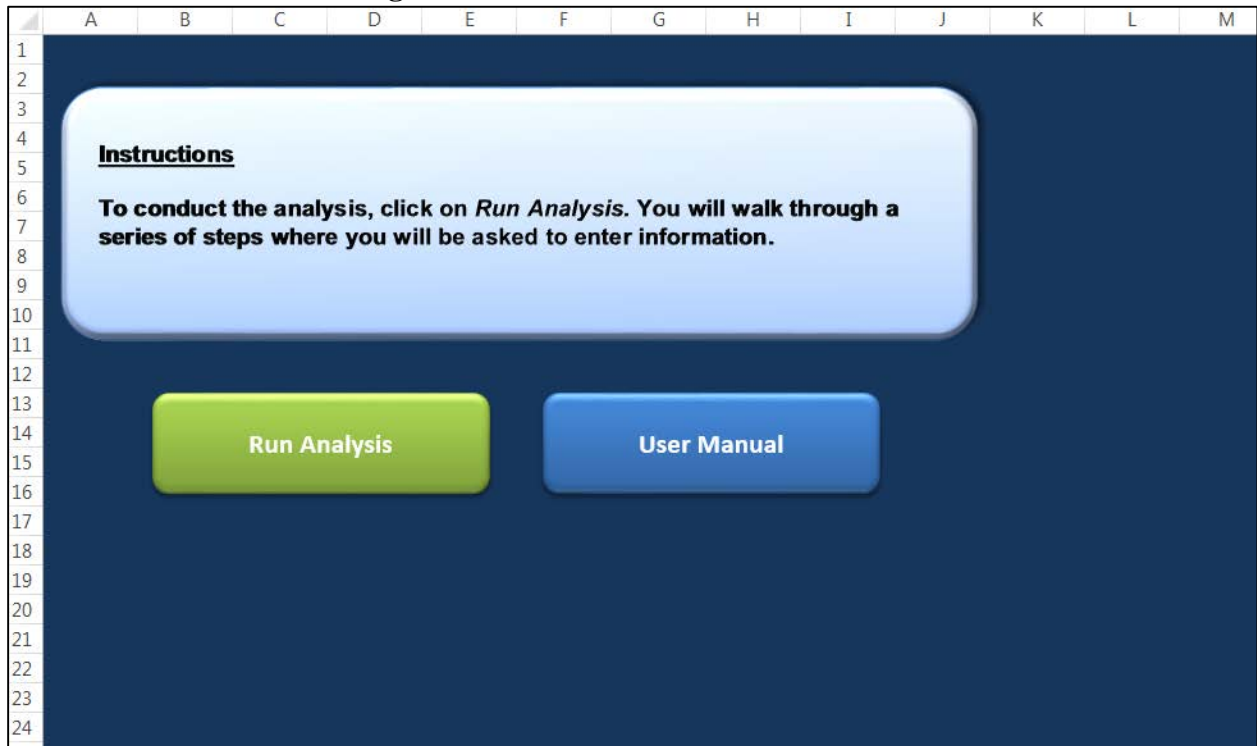
POLICY EVALUATED

	Site Access Improvements
	Transit Service Improvements
	Financial Incentives
	Pay-as-you-go Programs
	Parking Pricing
	Support Programs

Back to Introduction

Save Results

Print Results

Sensitivity Analysis

Model Reset

Model Parameters

Model Elasticities

MODE SHARE IMPACTS

Mode Share (%)	Baseline	Final	% Change
Auto-Drive Alone	79.12	#DIV/0!	
Auto-Rideshare	12.24	#DIV/0!	
Vanpool	0.45	#DIV/0!	
Public Transit	4.15	#DIV/0!	
Cycling	0.45	#DIV/0!	
Walking	2.70	#DIV/0!	
Other	0.89	#DIV/0!	
Total	*100.00*	*#DIV/0!*	*#DIV/0!*

TRAVEL IMPACTS

Unit	Peak	Off-Peak	Total
Baseline Trips	0	0	0
Final Trips	0	0	0
Trip Reduction	0	0	0
% Trip Reduction			
Baseline VMT	0	0	0
Final VMT	0	0	0
VMT Reduction	0	0	0
% VMT Reduction			

CHANGE IN SOCIAL COSTS ($, Daily) (negative value is a reduction)

	Peak	Off-Peak	Total
Air Pollution	0.00	0.00	0.00
Congestion	0.00	0.00	0.00
Excess Fuel Consumption	0.00	0.00	0.00
Global Climate Change	0.00	0.00	0.00
Health and Safety	0.00	0.00	0.00
Noise Pollution	0.00	0.00	0.00
Total	*0.00*	*0.00*	*0.00*

PROGRAM BENEFITS

	Total	Peak	Off-Peak
Total Annual Benefits (A)	$ -	$ -	$ -
Total Annualized Cost (B)	#NUM!	#NUM!	#NUM!
Net Benefit (A-B)	$ -	$ -	$ -
Benefit to Cost Ratio (A/B)	#NUM!	#NUM!	#NUM!

CHANGE IN EMISSIONS (Amount, Daily) (negative value is a reduction)

Pollutant	lbs/day			metric tons/day			Percent Reduction over Baseline		
	Peak	Off Peak	Total	Peak	Off Peak	Total	Peak	Off Peak	Total
Volatile Organic Compounds (VOCs)	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!
Carbon Monoxide (CO)	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!
Nitrogen Oxide (NO$_X$)	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!
Carbon Dioxide (CO$_2$)	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!

CHAPTER FIVE: IMPLEMENTATION AND CONCLUSION

This study documented historical trends in CBA as well as its purpose and basic functions. CBA is an evaluation tool used to compare alternative project options and gauge if the discounted value of benefits exceed the costs. Several metrics are used to make this judgment, such as NPV, Benefit-Cost Ratio, and Incremental Benefit-Cost Ratio. CBA compares cumulative, discounted costs and benefits over the lifecycle of the infrastructure projects being compared. Most CBAs follow similar procedures. CBAs typically begin by defining the base case and identifying project alternatives and setting scope of the analysis. From here, an analysis will determine project impacts (and convert to dollar values where necessary), discount costs and benefits, compare net benefits, and, based on these findings, put forward recommendations. In the transportation context, most benefits are derived from travel time savings and crash reductions. Typical costs include construction and subsequent maintenance. The calculations required for a CBA are relatively straightforward, but users should keep some issues in mind when deciding whether performing one is appropriate. First, CBAs are well-suited to large projects, projects that are designed to improve efficiency and not meet other goals, and where environmental and social impacts are either negligible or measurable. They are a preferred method for ranking alternative projects and are more methodologically robust than worst-first rankings.

CBA is not appropriate to study the costs and benefits of large-scale initiatives that combine multiple smaller projects in a single package. While CBA can trenchantly assess *individual projects*, it is an acceptable means of examining a number of projects collectively. Similarly, CBA should not be used if the goal of a project is to comply with a legal requirement. CBAs are of

limited use if potential costs or benefits are omitted, or if measuring certain elements such as travel time savings or safety improvements proves difficult or impossible. Incomplete data can also hinder analysis. CBA differs from economic impact analysis, which is an important distinction to make. Economic impacts analyses measures the dollar value of a project (e.g., number of jobs created), while CBA measures benefits and costs from a broader social perspective.

The increasing popularity of CBA stems partially from the federal government which, through a series of executive orders, mandates that projects using public funds should focus on maximizing benefits. As the use of CBA to evaluate projects and grant applications (e.g., TIGER Discretionary Grants) continues to grow, it will be important for state transportation agencies to have knowledge of CBA methodologies, especially if they want to remain competitive for federal funding. Several state DOTs already have CBA guidance in place or have developed templates to facilitate project analysis. Having information on the costs of benefits of proposed projects can assist the Cabinet with project selection and bring a renewed focus to cost efficiency by selecting projects that will significantly benefit citizens of the Commonwealth. Several programs that can be used to perform CBA were discussed to identify applications that KYTC could readily mobilize to execute CBAs. Most of the programs discussed are either free or inexpensive. Some of the applications provide detailed guidance and instruction to users, either through online documentation or through a downloadable spreadsheet that contains directions.

To facilitate implementation of a CBA tool at KYTC, the research team studied each of the CBA programs and spreadsheets detailed in Chapter 4. They identified applications with a user-friendly approach to CBA which policymakers could become familiar with quickly and that would yield a rapid CBA for projects. The Cal-B/C model is appealing because it is spreadsheet-based and lets users input data easily. Many of the default settings are unique to California; thus, without modifications this model would not be useful. The three applications that hold the most promise are HERS-ST, BCA.NET, and TREDIS MBCA. HERS-ST is mainly an extension of the national model for performance measures, but it is linked to the HPMS. It evaluates project combinations based on specified funding levels *and* the amount of funding needed to comply with specific requirements. BCA.NET is a web-based CBA tool developed by FHWA. It requires users to input project cost, characteristics, and travel demand. FHWA notes that BCA.NET is most appropriate for small- or medium-sized highway capacity projects. TREDIS MBCA is a free web-based CBA program that can handle multiple modes. Users input project costs, timelines, and benefits, which can include congestion reduction, safety improvements, and others. TREDIS has other tools available that can be used to perform an economic impact analysis.

Building off of this research, the team developed a simple workbook application that KYTC personnel can use run a CBA. The workbook contains instructions and calculations tabs. To simplify calculations and reduce the number of user inputs, it considers a limited number of costs (construction and maintenance) and benefits (travel time and crash reduction savings). Required user inputs are: base and alternative construction costs, vehicle travel time savings, whether the project is local or intercity, the number of drivers affected, and the anticipated crash reductions (by severity of injury). The workbook calculates present value of costs and benefits using a seven percent discount rate and makes both NPV and BCR available to the user. While this workbook is straightforward, it is a tool that can quickly produce a CBA with a small number of inputs.

REFERENCES

Adler, Matthew, & Eric Posner. (1999). Rethinking Cost-Benefit Analysis. *The Yale Law Journal, 109*(2), 165-247.

Balducci, Patrick. (2012). *Integrated Corridor Management Initiative: Demonstration Phase Evaluation- San Diego Benefit-Cost Analysis Test Plan.* U.S. Department of Transportation Research and Innovative Technology Administration, FHWA-JPO-13-042.

Bartin, Bekir, Kaan Ozbay, & Nusrat Jahan. (2012). *Benefit Cost Analysis of Highway Investment Projects Using Regional Transportation Planning Models.* Transportation Research Board Annual Conference: Washington, D.C.

Beukers, Els, Luca Bertolini, & Marco Te Brommelstroet. (2012). Why Cost Benefit Analysis is perceived as a problematic tool for assessment of transport plans: A process perspective. *Transportation Research Part A,* 46. 68-78.

Brent, R.J. (1996). *Applied Cost–Benefit Analysis*. Edward Elgar Publishing: Cheltenham.

Coley, Nathaniel. (2012). *Spotlight on Benefit-Cost Analysis.* Federal Highways Administration Publication, FHWA-HRT-12-003.

Concas, Sisinnio & Philip Winters. (2009). *Quantifying the Net Social Benefits of Vehicle Trip Reductions: Guidance for Customizing the TRIMMS Model*. National Center for Transit Research, Center for Urban Transportation Research, University of South Florida, Research Report BD 549 WO 52.

Economic Development Research Group. (2010). *Benefit-Cost Assessment Guidance for Evaluating Proposed Highway Tolling and Pricing Options for Oregon*. Prepared for the Oregon Department of Transportation. Retrieved from:
http://www.oregon.gov/ODOT/TD/TP/docs/tolling/benefit.pdf.

Eliasson, J. (2006). *Forecasting travel time variability*. Proceedings of the European Transport Conference 2006: Strasbourg, France.

Federal Highway Administration's *Economic Analysis Primer on Benefit-Cost Analysis*. Retrieved from: http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm.

Findley, Daniel, John Stone, Shannon Fain, & Robery Foyle. (2007). *NCDOT Benefit/Cost Analysis for Planning Highway Projects*. North Carolina State University Research Report for the North Carolina Department of Transportation, FHWA/NC/2006-43.

Fosgerau, M., Hjorth, K., Brems, C., Fukuda, D. (2008). *Travel time variability – definition and valuation.* DTU Transport: Copenhagen, Denmark.

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

Guo, Jessica, Jie Zheng, Qi Gong, & Kevin White. (2008). *Benefit-Cost Analysis for Evaluating Inter-City Transit Investment*. Midwest Regional University Transportation Center (University of Wisconsin-Madison), MRUTC 08-03.

Hauer, Ezra. (2011). Computing what the public wants: Some issues in road safety cost-benefit analysis. *Accident Analysis and Prevention, 43*, 151-164.

Homan, Anthony, Teresa Adams, & Alex Marach. (2014). A Statistical Analysis of the Role of Benefit-Cost Analysis in Awarding TIGER Grants. *Public Works Management and Policy, 19*(1), 37-50.

Kreis, Doug, Brian Howell, & Len O'Connell. (2006). *Early Stage Benefit Cost Analysis for Estimating Economic Impacts.* Kentucky Transportation Center Research Report, KTC-06-11/SPR306-05-1F.

Kulkarni, Ram, Deb Miller, Rosemary Ingram, Chi-Wah Wong, & Julie Lorenz. (2004). Need-Based Project Prioritization: Alternative to Cost-Benefit Analysis. *Journal of Transportation Engineering, 103*, 150-158.

Lawrence, Michael, Paul Nguyen, Jonathan Skolnick, Jim Hunt, & Roemer Alfelor. (2014). *Road Weather Management Benefit Cost Analysis Compendium.* Federal Highway Administration Research Report, FHWA-HOP-14-033.

Levinson, D. (2002). Identifying winners and losers in transportation. *Transportation Research Record: Journal of the Transportation Research Board*, *1812*, 179–185.

Martens, Karel. (2011). Substance precedes methodology: on cost benefit analysis and equity. *Transportation,* 38, 959-974.

Menendez, Jose Rafael, Salar Zabihi Siabil, Paul Narciso, & Nasir Gharaibeh. (2013). Prioritizing Infrastructure Maintenance and Rehabilitation Activities Under Various Budgetary Scenarios: Evaluation of Worst-First and Benefit-Cost Analysis Approaches. *Transportation Research Record: Journal of the Transportation Research Board*, *2361*, 56-62.

Minnesota Department of Transportation. *Benefit-Cost Analysis for Transportation Projects*. Retrieved from: http://www.dot.state.mn.us/planning/program/benefitcost.html.

Peer, Stefanie, Carl Koopmans, & Erik Verhoef. (2012). Prediction of travel time variability for cost-benefit analysis. *Transportation Research Part A, 46*, 79-903.

Sallman, Doug, Erin Flanigan, Krista Jeannotte, Chris Hedden, & Dorothy Morallos. (2012). *Operations Benefit/Cost Analysis Desk Reference.* Federal Highway Administration Report, FHWA—OP-12-028.

Schofield, J.A. (1987). *Cost–Benefit Analysis in Urban and Regional Planning.* Allen & Unwin: London.

Section 1909 Commission Staff. (2007). *Benefit-Cost Analysis in Public Sector Infrastructure Investment Decisions.* Paper prepared for the National Surface Transportation Policy and Revenue Study Commission, U.S. Department of Transportation.

Sullivan, Edward, Joy Dahlgren, Glen Weisbrod, & Kazem Attaran. (2008). Web-Based Guide to Transportation Benefit-Cost Analysis. *Journal of Transportation Engineering, 134*(7), 282-286.

Transportation Economics Committee. Transportation Research Board. *Benefit-Cost Analysis.* Retrieved from: http://bca.transportationeconomics.org/home.

Veneziano, David, Laura Fay, Zhirui Ye, Dan Williams, & Xianming Shi. (2010). *Development of a Toolkit for Cost-Benefit Analysis of Specific Winter Maintenance Practices, Equipment, and Operations*. Wisconsin Department of Transportation Report prepared by Western Transportation Institute, WisDOT 0092-09-08.

Williges, Chris, & Mahmoud Mahdavi. (2008). Transportation Benefit-Cost Analysis: Lessons from Cal-B/C. *Transportation Research Record, 2079*, 79-87.

Zhuang, Juzhong, Zhihong Liang, Tun Lin, & Franklin De Guzman. (2007). *Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey.* Asian Development Bank, Economics and Research Department Working Paper Series 94.