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Benefit-Cost Analysis with Nevada Characteristics

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil and Environmental Engineering

by

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ABSTRACT

The efficient allocation of funding for transportation projects is crucial for Nevada's roadway system. Well-established prioritization frameworks are needed in order to accomplish the allocation of funding for projects that will provide the most benefit for its users. In Nevada, the Nevada Department of Transportation's (NDOT's) Performance Analysis Division conducts benefit-cost analysis (BCA) on all capacity projects equal to or exceeding $25 million. In recent years NDOT has used the California Life-Cycle Benefit-Cost Analysis Model (Cal-B/C) as part of their prioritization process. The Cal-B/C Model was developed by the California Department of Transportation (Caltrans). The default economic parameters in this model along with the economic parameters assigned by NDOT were used to run analysis on two projects in the state. This was completed to see how suitable Cal-B/C's parameters would be for use in Nevada since Cal-B/C's parameters are specific for California. This thesis also provides recommendations on updating the current economic parameters to better model Nevada's situation since certain parameters assigned by NDOT were still based on California data. Through a review of existing methodologies used across the country new parameter recommendations were made.

Furthermore, an investigation of available BCA software was also conducted to determine if other programs apart from Cal-B/C can meet NDOT's analysis needs. The two projects selected for the case study were then analyzed using Cal-B/C, BCA.net, and the American Association of State Highway and Transportation Officials (AASHTO) Redbook Wizard. The results of the analysis showed that substantial differences in

results did exist when the different models were used. Cal-B/C results were the highest followed by BCA.net. The results from the AASHTO Redbook were not favorable in either analysis. The different methodologies used by the software and the level of detailed information can be attributed to the differences in results. NDOT should continue to use Cal-B/C for general transportation projects where localized benefits will be obtained but NDOT should consider using software such as BCA.net and the Surface Transportation Efficiency Analysis Model (STEAM) for projects having regional level impacts.

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1 INTRODUCTION

The efficient allocation of funding for transportation projects is crucial for Nevada's roadway system. Tasked with the responsibility of evaluating a multitude of transportation projects suitable for implementation, transportation agencies need to incorporate a well-established prioritization framework to rank projects based on those that will provide the most benefit for its users. To accomplish this, the Nevada Department of Transportation's (NDOT's) Performance Analysis Division conducts benefit-cost analysis (BCA) on all capacity projects equal to or exceeding $25 million. Defined as the systematic process for calculating and comparing benefits and costs of a project, BCA is used to determine if a project is economically justifiable (1).

NDOT currently uses the California Life-Cycle Benefit-Cost Analysis Model (Cal-B/C) as part of their prioritization process. The Cal-B/C Model was developed by the California Department of Transportation (Caltrans). The Performance Analysis Division provides economic values to be used in place of Cal-B/C's default values, these values can be found in NDOT's *2014 Performance Management Report* (2). Such values include travel time costs, vehicle operating costs, crash costs, and emission health cost parameters (2). The emission health cost parameters found in the "Discussion of the Calculations Costs and Benefits" section of the *2014 Performance Management Report* are based on California data (2). Analyzing the accuracy of these values for Nevada's application is important in this study since California and Nevada exhibit different characteristics that would greatly influence vehicle emissions. As of 2011 California had 13.3 times more vehicle miles of travel than Nevada (3) which would infer a greater concern for emissions in California. Therefore, it is important to investigate how significant the difference in results is when Cal-B/C's default values versus the currently recommended parameters for Nevada are used.

Furthermore, this thesis also provides recommendations on updating the economic parameters to better model Nevada's situation based on a review of different methodologies used across the country. An investigation of available BCA software was also conducted to determine if other programs apart from Cal-B/C can meet NDOT's analysis needs. The parameter values recommended in this thesis were then applied to two projects in the state. The two projects selected for the case study were analyzed using Cal-B/C, BCA.net, and the AASHTO Redbook Wizard. The analysis completed using the two software packages demonstrated differences in results for the projects analyzed. These differences can be attributed to the methodologies used by each software along with the level of detailed information needed for each of the tools. Ultimately, this thesis aims to provide Nevada with better fitting parameters for future use in BCA analysis and also recommends the use of alternative BCA software in the analysis of projects. Providing Nevada with an improved standardized method of conducting these analyses will improve the efficient allocation of funding for transportation projects in the state.

1.1 Background

The process of conducting BCA was first proposed by Jules Dupuit in 1844 (2). This process was first applied to the engineering field in 1936 when the U.S. Corps of Engineers implemented BCA for projects improving waterway systems (4). In the transportation field, BCA was first considered in the 1970s with the American Association of State Highway and Transportation Officials (AASHTO) publication of *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, also referred to as the "AASHTO Redbook" (5). Even with the introduction of the Redbook, the concept of BCA for use in transportation did not gain popularity until the mid to late 1990s with the emersion of different computer-based models (5). With the establishment of legislation, such as the Transportation Equity Act for the 21st Century (TEA-21) and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the use of BCA further increased (5).

BCA produces various results, of which the benefit-cost ratio (BCR) is the most commonly used. The BCR is used to interpret the level of economic efficiency a project can sustain. Hence, BCRs greater than one are considered efficient investments and BCRs less than one are considered inefficient (6). Another measure obtained from BCAs includes the Net Present Value, also referred to as the Net Benefit, which includes all project benefits subtracted by costs. As stated in the Operations Benefit/Cost Analysis Desk Reference (6), the use of the Net Present Value (NPV) is applied when ranking projects with similar BCRs. Project selection should not only focus on BCR and NPV, but should also combine non-monetized benefits in the final project ranking decision (6) .

It is important to note that BCA should not be confused with Economic Impact analysis (EIA). As mentioned by the Transportation Benefit Cost Analysis website and in the Operations Benefit/Cost Analysis Desk Reference (1, 6), BCAs provide results of benefits affecting society, while EIAs focus on economic indicators such as changes in businesses, jobs, and added value. In other words, a BCA considers the direct benefit from the project being analyzed while an EIA considers the indirect impacts (6). Direct and indirect benefits as measured by both BCA and EIA are summarized in Table 1.

Table 1 Summary of Benefit-Cost Analysis vs. Economic Impact Analysis

Benefit-Cost Analysis	Economic Impact Analysis
• Travel Time • Crash Reductions • Operating Costs • Enviromental Benefit	• Business Sales • Jobs • Added Value • Income • Tax Revenues

Note: Adapted from Transportation Benefit Cost Analysis website and Operations Benefit/Cost Analysis Desk Reference (1, 6)

1.2 Problem Statement and Research Objective

In reviewing various studies, it has been found that transportation agencies across the country employ different methods and economic values for conducting BCAs (7). Variation within the methods and values implemented can make the process of conducting BCAs inconsistent. This research investigates current parameters used by Cal-B/C and compares them against those in use by Nevada. Based on the review of the results and investigation of values used by other sources, updated parameters more fitting for Nevada's situation are recommended. This thesis also reviewed different BCA software to compare against Cal-B/C and see if another software would be best suited for Nevada's prioritization process.

1.3 Tasks Performed

The tasks performed for this research included the review of various methods employed by transportation agencies for conducting BCAs, a review of available BCA software, calibration of economic parameters for use in Nevada, and application of the recommended economic parameters on two projects found in the state.

1.4 Document Organization

This thesis is composed of five chapters. Chapter 1 provides an introduction of the research conducted thus far along with a background of BCA, problem statement and research objective, and tasks performed in this study. Chapter 2 includes a detailed literature review consisting of BCA methods being applied across the country along with a review of software packages currently available for the BCA of transportation projects. Chapter 3 provides an overview of the BCA process that should be conducted for transportation projects along with a detailed discussion of the various economic values available. The recommendations in terms of economic parameters for use in Nevada along with the analysis of the two case studies is found in Chapter 4. Lastly, Chapter 5 provides the final recommendations and conclusions drawn from the study.

2 LITERATURE REVIEW

This literature review provides an overview of the methods and software in use throughout the United States for BCA of transportation projects. From this review, economic parameters for Nevada are recommended. Additionally, the review of the software was useful in determining if the usage of Cal-B/C for analysis of transportation projects should continue or if a better tool exists accommodating Nevada's needs.

2.1 Benefit-Cost Analysis across the United States

A study conducted by the National Cooperative Highway Research Program (NCHRP) (7) investigated how transportation agencies across the United States apply economic analysis in their highway investment decision-making process. *NCHRP Synthesis 424* found that most state departments of transportation (DOTs) conduct economic analysis for certain investments (7). A survey was conducted as part of the study which was sent to each state's DOT. A total of 23 responses were received of which 87 percent (20 states) stated they used economic analysis in their decision-making process. The states using economic analysis reported using this process in the following stages of projects (7):

- Planning
- Programming and Budgeting
- Resource Allocation Following Budget Approval
- Project Design and Development
- Project Construction Options

NCHRP Synthesis 424 also identified limitations in how BCA methods are applied. Some of these limitations included: the way projects are scoped, benefits difficult to quantify being eliminated, lack of complete and accurate data, and double-counting of benefits (7).

The following sections present the literature review conducted for the present study. First an overview of the guidelines and policies in place by the federal government are described followed by the methodologies in place by California, Florida, Iowa, Minnesota, Nevada, North Carolina, the Ohio-Kentucky-Indiana Metropolitan Planning Organization (MPO), Oregon, and Washington. A brief explanation of the different method categorization of BCA software along with a review of Cal-B/C, BCA.net, AASHTO Redbook Wizard, and Surface Transportation Efficiency Analysis Model (STEAM) follows.

2.1.1 Federal Level

The U.S. Department of Transportation (USDOT) provides guidance for economic values in terms of statistical value of life and value of time for consideration in transportation projects. In terms of valuing a statistical life (VSL), the USDOT recommends that fatalities be valued at $9.4 million for analysis to be completed in 2015 (8). USDOT updates this value every year based on changes in real income and inflation during the prior year. Equation 1 is used to update the VSL to dollars in the analysis year.

Equation 1: $$VSL_{Year\ X} = VSL_{Base\ Year} * \left(\frac{CPI_X}{CPI_{Base}}\right) * \left(\frac{Year\ X\ Real\ Income}{Base\ Year\ Real\ Income}\right)$$

A fraction of the VSL value is then assigned to each injury severity types based on the Abbreviated Injury Scale (AIS) in order to provide a monetized value for all injury types as shown in Table 2. As provided in the Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grant resource, *TIGER BCA Resource Guide* (9), a matrix to convert from the AIS Scale to the KABCO scale is shown in Table 3. The *TIGER BCA Resource Guide* adapted this matrix from the National Highway Traffic Safety Administration. The resource guide also provides a sample calculation to convert from the AIS to the KABCO scale. AIS was implemented by the Association for the Advancement of Automotive Medicine in 1969 to rank the severity of injuries (10) and the KABCO severity scale is used by police officers to categorize the severity of occupant injuries at the scene of a crash (11).

Table 2 Fractions of VSL by AIS Injury Severity Levels

AIS Level	Severity	Fraction of VSL
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Unsurvivable	1

Source: Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis—2015 Adjustment (8)

Table 3 AIS to KABCO Conversion Matrix

AIS	O *No injury*	C *Possible Injury*	B *Non-incapacitating*	A *Incapacitating*	K *Killed*	U *Injured Severity Unknown*	# Non-fatal Accidents *Unknown if Injured*
0	0.92534	0.23437	0.08347	0.03437	0.00000	0.21538	0.43676
1	0.07257	0.68946	0.76843	0.55449	0.00000	0.62728	0.41739
2	0.00198	0.06391	0.10898	0.20908	0.00000	0.10400	0.08872
3	0.00008	0.01071	0.03191	0.14437	0.00000	0.03858	0.04817
4	0.00000	0.00142	0.00620	0.03986	0.00000	0.00442	0.00617
5	0.00003	0.00013	0.00101	0.01783	0.00000	0.01034	0.00279
Fatality	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
Sum(Prob)	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***

Source: National Highway Traffic Safety Administration, July 2011.

Source: TIGER Benefit-Cost Analysis (BCA) Resource Guide (9)

The USDOT guidance for the valuation of travel time was first established in 1997 and has had two major revisions ever since (12). The guidance provides the values that are to be used by all DOTs when evaluating value of travel time. As stated in the guidance, valuing travel time is critical in the evaluation of benefits since reduction in delay provides major purpose for investments (12). Revisions made to the previous versions include the use of median income wage instead of mean wage. This change was made as it is believed the new approach will provide more reliable estimations reflecting travelers in a diverse population while providing results that are less sensitive to variations in extreme values (12). Business travel, which includes all on-the-clock travel, should be valued at 100 percent of the average median wage for heavy and light truck drivers plus fridge benefits. As for personal travel, 50 percent of the median wage for all occupations is to be used for travelers using a vehicle while time spent waiting outside a vehicle or walking should be valued at 100 percent of the median hourly wage (12).

Mentioned earlier, the *TIGER BCA Resource Guide* provides guidance on how to complete BCA for projects applying for the TIGER Grant. This grant was established by the USDOT and provides funding for a variety of transportation projects having significant impact at the National Level (13). The resource guide outlines the two Federal guidelines mentioned above and also provides recommended values for emission calculations. The emission cost values provided in the *TIGER BCA Resource Guide* were obtained from a study conducted by the National Highway Traffic Safety Administration titled *Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks* (14). More detailed information about the emission cost values is provided in Chapter 3.

In terms of discount rates, the U.S. Office of Management and Budget (OMB) Circular A-94 requires that BCA should use a real discount rate of 7 percent (15). The *TIGER BCA Resource Guide* recommends that in addition to the 7 percent real discount rate, a 3 percent real discount rate should also be applied (9).

2.1.2 State Level

California

In the early 1990s, the Commission on Transportation Investments was formed in California. The commission advised Caltrans to establish BCA as the primary method for comparing projects. Caltrans has one of the largest State Improvement Transportation Programs in the country, with over 100 projects needing evaluation in a short period of time each year (16). Therefore, Caltrans developed an in-house Excel based tool called the California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). First used in 1996, Cal-B/C is based on the 1970's program called the Highway Economic Evaluation Model and was developed based on extensive theoretical reviews (16).

Cal-B/C is aimed at providing a standard method of performing BCA while accelerating the evaluation process (16). The model is able to analyze both highway and transit projects. This thesis will go into extensive detail of this model in further sections since the model is currently being used for BCA analysis in Nevada.

Florida

The Florida Department of Transportation (FDOT) focuses on highway capacity, preservation, and safety projects for their prioritization process (17). BCA in the project prioritization process is specifically used for safety projects where historical crash data along with crash reduction factors (CRFs) are used and applied to an in-house spreadsheet tool. The CRFs are based on project improvement type, crash type, and roadway type. BCA analysis in Florida only focuses on safety benefits since these are one of the principal benefits resulting from transportation improvements (18). The analysis model also provides the 5-year average cost per crash for Florida.

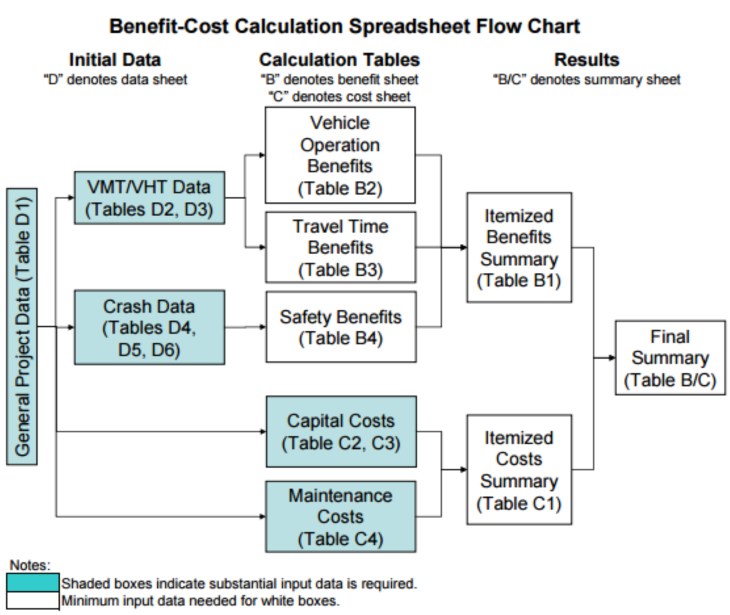
Iowa

Before 2006 Iowa used a two-tiered prioritization process for project selection but a review of the procedure led to the Iowa DOT adopting a BCR procedure which they believed would provide the most benefit to the public (19). Iowa now uses an Excel-based tool in order to determine BCR results. This tool was last updated in May 2015 and focuses on the benefits obtained due to safety improvements (20).

Minnesota

The Minnesota Department of Transportation's (MnDOT's) guidance for conducting BCA is based on the AASHTO Redbook (21). MnDOT does not require a specific software package to be used for BCA, but it does have familiarity using Parson Brinckerhoff's Prioritization Scenario Model (PRISM) which is a web-based tool developed in 2007 (22). The procedure framework described by MnDOT's guidance is shown in Figure 1. As seen in this figure, vehicle miles traveled and vehicle hours traveled data are used to determine benefits in vehicle operation and travel time benefits. Crash data is then added to the benefits obtained for vehicle operation and travel time benefits. The benefits obtained from the three categories are then compared against the capital and ongoing maintenance costs.

Figure 1 MnDOT Procedure for Conducting BCA



Source: Minnesota Department of Transportation Benefit-Cost Analysis for Transportation Projects (21)

Nevada

The Nevada Department of Transportation Conducts BCA analysis within the Performance Analysis Division. The Performance Analysis Division conducts BCA for projects equal to or exceeding $25 million dollars per NRS 408.3195 (2). In recent years, this division has used the Cal-BC analysis tool with economic parameters using some of Nevada's characteristics. Even though Nevada has established the use of specialized parameters instead of the default values provided in Cal-B/C, various other values will be recommended in this thesis based on more recent data.

In terms of safety projects, NDOT is using the *Nevada Project Safety Process* (PSP) which uses BCA analysis to verify if selected safety improvements are economically justifiable (23). The process outlined in the PSP specifies two methods of analyzing crashes based on the AASHTO Highway Safety Manual (HSM) published in 2010. These two methods are the Crash Modification (CMF) Method and the Predictive Method (23). This guide utilizes the economic appraisal process outlined in the HSM in order to quantify the safety benefits of projects. As stated in the PSP, the selection of the methods mentioned above can produce different results since the methodologies for calculating BCRs is different for the two methods (23).

North Carolina

The North Carolina Department of Transportation (NCDOT) used an in-house tool, known as the Benefit Matrix Model, for their economic evaluation of projects. While the program is easily operated and requires minimal data input, it has a number of drawbacks (24). These drawbacks include: travel demand model data cannot be imported directly into the software, lack of automated system to update cost values, documentation of parameters is not easily accessible, and costs are not included in the analysis therefore a BCR is not provided (24). A study reviewing various BCA software was then conducted in order to find a software tool that would address the limitations of the Benefit Matrix Model.

The software reviewed included Cal-B/C, NET-BC, the Benefits Matrix Model, and the AASHTO Redbook Wizard (24). In comparing Cal-B/C and the Redbook Wizard the researchers found that the two software provided consistent results (24). Based on the research it was determined that NCDOT would benefit by using the Redbook Wizard since it is the “national standard for highway benefit analysis” (24) . Therefore the research team worked with ECONorthwest, one of the consultants for the development of the Redbook Wizard, to develop a customizable version for NCDOT. Some of the changes made to the original Redbook Wizard included delay and volume input options, in addition to corrections made to calculations found within the program (24).

Ohio-Kentucky-Indiana Regional Council of Governments

Ohio, Kentucky, and Indiana compromise the Ohio-Kentucky-Indiana Regional Council of Governments (OKI) — a Metropolitan Planning Organization (MPO) in charge of approving approximately $40 million per year for surface transportation projects (25). OKI decided to conduct economic analyses in-house on surface transportation projects and decided to investigate the use of STEAM (26). Prior to the investigation, OKI conducted BCA analyses exclusively on large corridor projects that were outsourced to consultant companies (26). A case study was produced based on the findings from OKI through the use of STEAM. With the use of the software, OKI successfully developed an interface that could be used for future projects (26). Through the entire process, OKI developed location-specific inputs for STEAM and integrated the travel demand model by implementing additional programs to provide a seamless transition between the travel demand model and the requirements for the analysis software.

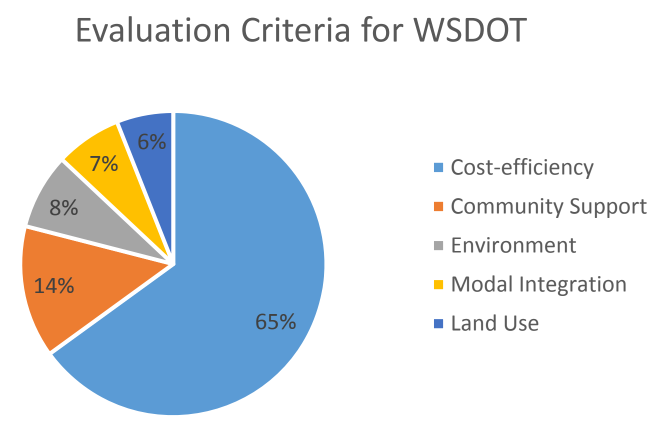
Oregon

Oregon DOT produced a BCA worksheet for use in highway safety projects. The worksheet can provide analysis in terms of targeting crashes by severity or type with the use of CRFs (27).

Washington

The Washington Department of Transportation (WSDOT) uses the WSDOT Mobility Project Prioritization Process (MPPP). The purpose of MPPP is to estimate project cost efficiency based on a BCR. The general prioritization process consists of three components: screening criteria, evaluation, and a mathematical ranging algorithm (28). The prioritization criteria used by WSDOT consists of five main categories in which the cost efficiency accounts for the greatest percentage, at 65 percent.

Figure 2 shows the criteria used by WSDOT based on their weight in the prioritization process (28).



Source: WSDOT Mobility Project Prioritization Process: Benefit/Cost Software User's Guide (28)

Figure 2 Prioritization Criteria Used by WSDOT

Projects evaluated by MPPPs are then evaluated with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS, developed by Hwang and Yoon, is an algorithm that is used to rank alternatives based on those having the shortest distance from the ideal solution (29).

2.2 Software Methods and Packages for Benefit-Cost Analysis

This section provides a description of the categorization of different methods involved in BCA software and is followed by a general review covering basic information about the software packages selected.

2.2.1 Method Categorization

As mentioned in the Operations Desktop Reference, three method categorizations for BCA analysis software packages exist, these include: sketchbook-planning methods, post-processing methods, and multiresolution/multiscenario methods (6). Each of these methods differ in the level of complexity the models present.

Sketchbook-Planning Method

BCA tools found in the sketch-planning method are generally based in a spreadsheet format and provide for quick, simple, and low-cost estimations of benefits and costs. Tools falling under this method rely on available input data and default relationships between strategies (6). Sketchbook-planning tools are especially useful in the early stages of the planning process. According to the Operations Desktop Reference, Cal-B/C is considered a sketchbook-planning tool. Advantages of using sketch-planning methods include the ease of use, limited data required, quick and easy setup and analysis, and customizable options. Disadvantages of sketch-planning methods include the lack of advanced analysis methods, limited measure of effectiveness (MOE) outputs, and the assumption of static conditions for behavior changes during travel (6).

Post-Processing

The BCA.net tool is categorized as a post-processing method. For post-processing methods customized user interfaces and methods are usually found (6). More detailed analysis can be achieved with this method since the functionality of such tools can be customized to fit the user's needs. This method is better suited for mid to late stages of project prioritization. Advantages of the post-processing method include: the capabilities to access various traveler behaviors, access to calibrated data from regional travel demand models, consistency with the planning process in a region, and reuse of the process involved (6). In terms of disadvantages, post-processing methods require extensive effort for development and application of the methods used (6).

Multiresolution/multiscenario

Multiresolution/multiscenario methods provide the most complex approach of the three methods discussed. Therefore, this method is useful in the design phase where very specific data is required (6). The detailed analysis of this method provides a high level of confidence in the results obtained (6).

The next section contains general information on each software package reviewed. The software reviewed included: Cal-B/C, BCA.net, AASHTO Redbook Wizard, and STEAM. Emphasis was placed on Cal-B/C as a result of its current use for BCA by NDOT.

2.2.2 Software Packages Reviewed

California Life-Cycle Benefit Cost Analysis Model

The California Life Cycle Benefit Cost Analysis Model (CAL-B/C) software is setup in an Excel spreadsheet consisting of eleven sheets. Out of the eleven sheets only three need user input, these sheets include the *Project Information, Model Inputs,* and *Results* sheet. A fourth sheet, the *Parameter* sheet, can also be updated to override default parameters used by the program. The following gives an overview of the projects supported by Cal-B/C followed by the required information for the sheets mentioned above.

Table 4 Project Options Available for Cal-B/C

Highway Capacity Expansion	Transit Capacity Expansion
General Highway	Passenger Rail
HOV Lane Addition	Light-Rail (LRT)
HOT Lane Addition	Bus
Passing Lane	Highway-Rail
Intersection	Grade Crossing
Bypass	
Queuing	
Highway Operational Improvement	**Transportation Management Systems (TMS)**
Auxiliary Lane	Ramp Metering
Freeway Connector	Ramp Metering Signal Coordination
HOV Connector	Incident Management
HOV Drop Ramp	Traveler Information
Off-Ramp Widening	Arterial Signal Management
On-Ramp Widening	Transit Vehicle Location (AVL)
HOV-2 to HOV-3 Conversion	Transit Vehicle Signal Priority
HOT Lane Conversion	Bus Rapid Transit (BRT)

Source: California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) User's Guide (Version 4.0) (30)

As can be seen from Table 4, Cal-B/C can analyze many projects but additional projects should be considered in new updates to the model. In the *Project Sheet* users are required to input general information about the project including: project type, construction period, peak hour duration, traffic volumes, crash data, and various other information. If agencies have regional travel demand or simulation data for a particular project, they can override the estimates provided by the program by inputting the detailed data into the *Model Inputs* sheet. This sheet consists of highway speed, volume, number of trips, and crash data information.

In terms of speed and volume, Cal-B/C creates relationships based on the Highway Capacity Manual. Based on the project selected, the software is able to use a combination of input data along with information stored in look-up tables within the *Parameter* tab to calculate the specific benefits. The impacted length of a project can be greater than the length of a project. For example, auxiliary lanes and off-ramps assume a projected distance of 1,500 ft or 0.28 miles being affected while passing lanes assume an additional 3 miles of roadway being affected upstream of the updated segment (31).

The Cal-B/C model analyzes benefits in terms of travel time savings, vehicle operating cost savings, safety benefits, and emission reductions. Default values provided in the software are updated based on the information provided by the Performance Analysis Division for use by NDOT. Over the years, the software has gone through various revisions to expand on project selection types. The latest version of the software, which was last updated in February 2012, can be obtained from the Caltrans website (32). On the website, a copy of the user's guide, three technical supplements, and current economic values used by the model are available for the user. Benefits produced by Cal-B/C are based on a function of speed and volume. As previously stated, Cal-B/C gives the option for regional planning model outputs to be used. For analysis without a regional planning model, future value predictions are estimated based on straight-line interpolation (31). The following sections delve into the methodologies used for the determination of the four benefit categories mentioned earlier.

Value of Time Calculation

Value of time becomes important when dealing with transportation projects since higher speeds are usually achieved creating for a reduction in travel time for users (31). Therefore, it is important to monetize these benefits for consideration in BCA. The first volume of the Cal-B/C technical documents covers in great detail the theoretical background and methodology applied by the software for travel time savings (31). Cost of travel is divided into resource and disutility costs. Resource costs, also referred to as opportunity cost, represent costs where a person gives up an activity or use of time in order to accomplish something while disutility costs represent a negative factor attributed to lost time due to travel (31).

Based on the literature review conducted in the development of Cal-B/C, the developers determined that the USDOT guidance for the value of travel time was the method that should be used. Therefore, personal travel is valued at 50% of the median wage for the state while business travel is valued at 100% plus fridge costs. When calculating travel time savings Cal-B/C assumes the number of travelers will remain the same with and without the project, but induced travel can be included if specific data is available. The model calculates travel time savings as a function of speed, volume, and value of time (31). Benefits in terms of travel time savings are calculated separately for trucks and other vehicles as well as during peak and non-peak periods.

Vehicle Operating Costs

Vehicle operating cost, as the name implies, are costs associated with the usage of a vehicle and are measured in vehicle-miles. Cal-B/C separates vehicle operating costs into fuel and non-fuel costs. The parameters provided in their most recent update are found in Table 5 and have been updated to 2015 dollars (33).

Table 5 Vehicle Operating Values Used by Cal-B/C (2015 USD)

Parameter	Regular-Grade Fuel	Diesel Fuel
Fuel Cost per Gallon	$3.91	$4.15
Non-fuel Cost per Mile Tires	Car ($/mile)	Truck ($/mile)
	$0.32	$0.44

Source: Life-Cycle Benefit-Cost Analysis Economic Parameters 2012 (33)

Emission Costs

In the development of Cal-B/C various studies were reviewed to determine which emission costs should be used. The methodology implemented for Cal-B/C only considers air pollution for health emission costs. The values chosen for the software are based on a study conducted by Donald McCubbin and Mark Delucchi in 1996 named "The Social Cost of the Health Effects of Motor Vehicle Air Pollution" (34). This study provided estimates for the Los Angeles Area and other urban and rural parts of the United States. The study was able to provide emission estimates for the following pollutants: carbon monoxide, nitrogen oxides, particulate matter, sulfur oxides, and volatile organic compounds (31). The values in use by Cal-B/C have been updated to 2015 dollars and are shown in Table 6.

Table 6 Emission Cost Values Used by Cal-B/C (2015 USD)

Pollutant	L.A./South Coast	CA Urban Areas	CA Rural Areas
Carbon Monoxide (CO)	$153	$79	$74
Nitrogen Oxide (NOx)	$62,254	$18,223	$13,589
Particular Matter (PM10)	$510,149	$147,367	$105,021
Sulfur Oxide (SOx)	$191,714	$73,526	$53,090
Volatile Organic Compounds (VOC)	$3,871	$1,275	$1,001
Greenhouse Gases (CO2)	$24		

Source: Life-Cycle Benefit-Cost Analysis Economic Parameters 2012 (33)

Safety Costs

Crash cost values are used for the analysis of safety benefits. The values used by Cal-B/C are based on data from the National Safety Council and are provided in Table 13. The values provided by the National Safety Council were chosen since they were based on a comprehensive method (31).

Table 7 Crash Costs Used by Cal-B/C (2015 USD)

Crash Type	National Safety Council
Fatal (K)	$4,634,848
Disabling Injury (A)	$233,217
Evident Injury (B)	$59,516
Possible Injury (C)	$28,336
Property Damage Only (O)	$10,744

Source: Life-Cycle Benefit-Cost Analysis Economic Parameters 2012 (33)

To summarize, the Cal-B/C software can analyze a variety of projects and provides for an analysis period of 20 years. Minimal information is needed to run an analysis and if a traffic demand model is unavailable the software can provide the estimates needed based on minimal information. Advantages of using Cal-B/C include its ease of use, simple interface, and support of a variety of projects. In terms of disadvantages, Cal-B/C does not contain risk analysis, as some software include, for instances where parameter value uncertainties exist.

BCA.net

Developed by the Federal Highway Administration, BCA.net is web-based. It was developed as a way of providing an easy to use interface where minimal data and technical expertise is needed to run the model (35). The BCA.net user manual describes the following advantages of using the software (35):

- Management of analysis within the interface
- Availability of a selection of sample data
- Development of different scenarios
- Risk Analysis Feature

The risk analysis feature becomes useful when there is uncertainty in analysis parameters. This risk analysis option provides the user with the probability of where the outputs reside.

The manual for the BCA.net program does not give detailed information on what specific methodologies were used for analysis of value of time, environmental costs, crash costs, and vehicle operating costs. What it does go into detail is explaining the simulation process where the risk analysis features is used. In general, there are four probability distribution options to choose from which can be incorporated into the scenario variables. These distributions include uniform, skewed normal, normal, and triangle distributions. The scenario section also produces charts that display the probability distribution, cumulative probability, and the de-cumulative probability. By providing the option of risk analysis within the model, decisions in regards to project selection are better supported (35).

Redbook

AASTHO first published *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements* in 1977 (5). Then in 2003 updates to this manual were made to address BCA for highway improvement projects. From this update an Excel enabled wizard called the Redbook Wizard was made. In 2010, this publication was updated again and is now called the *User and Non-User Benefit Analysis for Highways (36)*. Divided into two parts, the first part contains information about user benefits while the second portion contains information for non-user benefits. The Redbook Wizard that accompanies the updated Redbook follows the methodology described by AASHTO. The wizard has a navigation interface which includes button choices to “jump” to different sections of the model or to go “back” or “next” within the wizard. This wizard interface is useful as it helps new users go step-by-step through running the program without having to worry about omitting critical data for analysis. It is also helpful that the interface displays information and provides hyperlinks referencing sections of the Redbook where users can find more information of the specific parameters being input to the model. The Redbook Wizard can distribute the benefits for up to six user classes. The Redbook Wizard also allows project analysis up to 50 years instead of the 20 years Cal-B/C provides. Advantages of the Redbook Wizard include that it is easy to use as the wizard walks the user through all the inputs of a project. The references provided in the wizard window provide an advantage as well. North Carolina adopted the use of the

Redbook Wizard and made changes to the software to better accommodate the state's characteristics (24).

STEAM

Introduced in 1997 by FHWA, STEAM is useful for region-wide analysis. With STEAM users can use outputs produced by the four-step travel demand mode. The software is structured into four modules which include: user interface module, network analysis module, trip distribution module, and the evaluation summary module (37). As with the BCA.net, STEAM also includes risk analysis. STEAM should be used when region-wide benefits are expected for a project since this software is very detailed. The OKI MPO tested the use of STEAM and observed favorable results (26).

2.3 Summary of Literature Review

As seen in the literature review, various state DOTs use different software for prioritization frameworks of highway projects. A summary of the methods used by the different states discussed in this literature review is provided in Table 8. Based on the review of the software it was determined that Cal-B/C should be compared against BCA.net and the AASHTO Redbook to determine if a significant difference in results exists. This comparison was done through the analysis of two case studies. These case studies are covered in Chapter 4.

Table 8 Summary of Benefit-Cost Analysis across the U.S.

Entity	Summary of Benefit-cost Analysis Methods used
Federal Level	The federal government gives guidance in regards to value of time, value of a statistical life, and what discount rates should be used in BCA analysis.
California	California uses its in-house tool, Cal-B/C, to conduct analysis for project prioritization. The methodology used in Cal-B/C is based on national standard practices (24).
Florida	Florida targets safety projects and uses CRFs to determine BCRs by using an Excel-based tool.
Iowa	Iowa focuses on safety benefits and uses an Excel-based tool for their BCA.
Minnesota	Minnesota DOT is familiar with the use of PRISM for their BCA, but does not require a specific software package be used.
Nevada	Nevada focuses on highway capacity projects and safety projects when conducting BCA. In recent years, NDOT has used Cal-B/C to conduct their analysis.
North Carolina	North Carolina had an in-house economic analysis software but proposed a change to use the AASHTO Redbook Wizard since this software provides more capabilities than the one previously used.
Ohio-Kentucky-Indiana Regional Council of Governments (OKI)	OKI conducted an investigation to determine if STEAM was useful for the analysis of their projects. Through their research, OKI determined that STEAM was useful for economic analysis of their projects.
Oregon	Oregon DOT has a BCA worksheet that is used to analyze safety projects in the state.
Washington	For their prioritization process Washington uses five categories for evaluation, of these the cost efficiency category has the largest weight. BCA is conducted for the evaluation of this category.

3 ECONOMIC PARAMETERS USED IN BENEFIT-COST ANALYSIS

This chapter provides details on different economic values recommended by different sources for use in BCA of transportation projects. A general overview of the BCA process is also discussed as provided by MnDOT's guidance (21).

3.1 General Benefit-Cost Analysis Process

The benefits of a BCA for transportation projects are generally monetized into travel time savings, vehicle operating costs savings, crash reductions, and emission reductions (1, 6, and 21). While costs to be considered in analysis include capital costs, annual maintenance costs, and rehabilitation costs. Capital costs include all costs that are paid at the beginning of a project. These costs fall into preliminary engineering, right-of-way, or construction costs (21). MnDOT lists four major stages in the development and analysis of transportation projects. The four stages presented by MnDOT are as follows:

- Planning of the Analysis
- Engineering Analysis
- Economic Valuation
- Evaluation of Results

The first stage of the BCA process involves three steps as illustrated in Figure 3 .

Figure 3 Steps Involved in Analysis Planning Stage

In the first stage, an initial evaluation of the extents the analysis should take into account is determined. This helps provide the level of detail needed for the study (21). To help determine the level of analysis needed, it is important to know what data and budget are available to conduct the analysis (21). Having the level of understanding involved in the analysis will determine how much data will need to be gathered. A balance of the ideal amount of information needed for a project is crucial since having too much data can create for over analysis while having minimal data will need sensitivity analysis to provide credible results (21). Once the purpose of the project is determined, the base case or least expensive capital cost alternative along with all other alternatives needs to be defined. Once this is complete, the number of years the analysis period will cover along with the number of years for construction will need to be determined (21).

The second stage in the BCA process involves the gathering and calculation of engineering measures for both the base case and all other alternatives. Table 9 depicts the level of data analysis involved in this stage.

Table 9 Summary of Engineering Analysis Stage

Data for Benefits	Data for Costs
•Average Annual Daily Traffic Volumes •Daily Vehicle-hours traveled •Daily Vehicle-miles traveled •Annual Number of Crashes and severity	•Capital Costs •Preliminary Engineering •Right-of-way •Construction •Annual Maintence Cost •Rehabilitation Costs

Note: Figure developed based on data available from MnDOT Benefit-Cost Analysis for Transportation Projects (21)

Data obtained from the engineering analysis normally includes: average annual daily traffic, daily vehicle-hours travelled, daily vehicle-miles traveled, other operational changes, and annual crash data (21). Some suggestions made by MnDOT for method implementation in this stage are that a regional travel demand model or local traffic operations model be used for projects that will have an influence at the regional level. While a local traffic operations model is recommended for projects that should have a small to mid-size effect on traffic, peak hour congestion projects, and minor traffic diversions (21). For localized traffic effects and congestion on projects providing minimal or no traffic diversions, engineering judgment and other tools can be used for the estimation of traffic volumes (21).

The third stage of analysis involves the conversion of the benefits obtained in the engineering analysis to a monetary value. The last stage of the general BCA process as described by MnDOT includes the evaluation of all the benefits and costs to be presented in the form of a BCR and Net Present Value.

3.2 Conversion of Nominal Dollars to Real Dollars

Cost parameters are usually given in values of different years dollars, or the nominal dollar, therefore it is very important for nominal dollars be converted to real dollars which will provide an accurate comparison in the analysis year's dollars. Benefits and costs would not reflect the correct economic value of the project if benefits were not updated according to this. The values found in this thesis have been converted to 2015 dollars based on the Consumer Price Index (CPI) method as shown in Equation 2.

$$\textbf{Equation 2}: Year\ X\ Dollars = \left(\frac{CPI_X}{CPI_{Base}}\right) * (Base\ Year\ Dollars)$$

Historical Consumer Price Index values used were obtained from the Bureau of Labor Statistics (BLS) and are provided in Table 10 (38). The CPI value used in this thesis for the year 2015 is equal to 236.945 which represents the average CPI from January to September 2015.

Table 10 Historical Consumer Price Index Values Obtained from BLS

Table 24. Historical Consumer Price Index for All Urban Consumers (CPI-U): U. S. city average, all items-Continued

(1982-84=100, unless otherwise noted)

Year	Semiannual averages		Annual avg.	Percent change from previous	
	1st half	2nd half		Dec.	Annual avg.
1970	-	-	38.8	5.6	5.7
1971	-	-	40.5	3.3	4.4
1972	-	-	41.8	3.4	3.2
1973	-	-	44.4	8.7	6.2
1974	-	-	49.3	12.3	11.0
1975	-	-	53.8	6.9	9.1
1976	-	-	56.9	4.9	5.8
1977	-	-	60.6	6.7	6.5
1978	-	-	65.2	9.0	7.6
1979	-	-	72.6	13.3	11.3
1980	-	-	82.4	12.5	13.5
1981	-	-	90.9	8.9	10.3
1982	-	-	96.5	3.8	6.2
1983	-	-	99.6	3.8	3.2
1984	102.9	104.9	103.9	3.9	4.3
1985	106.6	108.5	107.6	3.8	3.6
1986	109.1	110.1	109.6	1.1	1.9
1987	112.4	114.9	113.6	4.4	3.6
1988	116.8	119.7	118.3	4.4	4.1
1989	122.7	125.3	124.0	4.6	4.8
1990	128.7	132.6	130.7	6.1	5.4
1991	135.2	137.2	136.2	3.1	4.2
1992	139.2	141.4	140.3	2.9	3.0
1993	143.7	145.3	144.5	2.7	3.0
1994	147.2	149.3	148.2	2.7	2.6
1995	151.5	153.2	152.4	2.5	2.8
1996	155.8	157.9	156.9	3.3	3.0
1997	159.9	161.2	160.5	1.7	2.3
1998	162.3	163.7	163.0	1.6	1.6
1999	165.4	167.8	166.6	2.7	2.2
2000	170.8	173.6	172.2	3.4	3.4
2001	176.6	177.5	177.1	1.6	2.8
2002	178.9	180.9	179.9	2.4	1.6
2003	183.3	184.6	184.0	1.9	2.3
2004	187.6	190.2	188.9	3.3	2.7
2005	193.2	197.4	195.3	3.4	3.4
2006	200.6	202.6	201.6	2.5	3.2
2007	205.709	208.976	207.342	4.1	2.8
2008	214.429	216.177	215.303	.1	3.8
2009	213.139	215.935	214.537	2.7	-.4
2010	217.535	218.576	218.056	1.5	1.6
2011	223.598	226.280	224.939	3.0	3.2
2012	228.850	230.338	229.594	1.7	2.1
2013	232.366	233.548	232.957	1.5	1.5
2014	236.384	237.088	236.736	.8	1.6
2015	236.265	-	-	-	-

- Data not available.
NOTE: Index applies to a month as a whole, not to any specific date.

Source: CPI Detailed Report, Data for September 2015, Bureau of Labor Statistics (38)

3.3 Discount Rates

Discount rates vary between sources, as stated earlier OMB Circular A-94 requires a 7 percent real discount rate be applied to all federal funded projects. On the other hand, other states are using different discount rates for their analysis. For example, MnDOT recommends a discount rate of 1.7 percent be used while Cal-B/C uses a default discount rate of 4 percent (21 and 33). The value for Minnesota was based on a 5-year average of the real interest rate on 30 year treasury bonds (21). At NDOT a discount rate of 7 percent is applied to all BCA bases on the OMB guidance (2).

3.4 Value of Time Cost Parameters

In terms of valuing travel time savings, NDOT is somewhat consistent with the federal guidance and assumes local personal travel should be valued at 50 percent of the local median wage. While business travel is valued at 100 percent of the mean wage for truck/bus drivers plus the addition of fringe benefits (2). The values provided by NDOT were obtained from the Nevada Department of Economic, Training, and Rehabilitation in 2014.

Table 11 displays the values NDOT is currently using, these have been converted to 2015 dollars. The vehicle occupancy rates for the three regions in the state are also shown. The values for the remaining counties were not provided in the *2014 Performance Management Report* (2).

Table 11 Travel Time Values Recommended for Use by Nevada (2015 USD)

Area	Personal Travel	Business Travel	Vehicle Occupancy
Clark County	$11.05	$34.36	1.45
Carson City/Douglas County	$10.49	$33.80	1.43
Washoe County	$11.27	$34.57	1.28

Source: Updates for 2014 Discussion of the Calculation of Costs and Benefits from NDOT (2)

3.5 Vehicle Operating Cost Parameters

Vehicle operating costs provided by NDOT include both fuel and non-fuel costs. The fuel cost for mid-grade gasoline and diesel fuel were obtained from the AAA Daily Fuel Gauge Report based on prices in November 2014 (2). These prices were converted to 2015 dollar values and are found in Table 12 along with the non-fuel costs provided by NDOT.

Table 12 Operating Costs Recommended by NDOT (2015 USD)

Parameter	Regular-Grade Fuel	Diesel Fuel
Fuel Cost per Gallon	$3.54	$3.88
Non-fuel Cost	**Car ($/mile)**	**Truck ($/mile)**
Tires	$0.0101	$0.0244
Depreciation	$0.2638	$0.3405
Maintenance	$0.0471	$0.1094
Insurance	$0.0685	$0.0680
License, Registration, Taxes	$0.0421	$0.0223
Finance Charge	$0.0583	$0.1698
Total Non-fuel Cost	***$0.4899***	***$0.7344***

Source: Updates for 2014 Discussion of the Calculation of Costs and Benefits from NDOT (2)

A comparison of the values used by Cal-B/C and those provided by NDOT is shown in Table 13. The changes in fuel prices are reasonable as California does exhibit higher fuel costs than Nevada. As for non-fuel costs, Nevada has higher estimates than California, in particular a 42 percent and an approximate 50 percent difference was seen between automobile and truck non-fuel costs respectively. California based their values on the 2011 Edition of *Your Driving Costs* which is produced by AAA (32). NDOT data for automobile non-fuel costs was also based on the AAA source. No detail description of how these values were interpreted from the source were provided. Possible differences in results can be due to the assumptions for the average miles driven per year in each state. The cost provided in all editions of *Your Driving Costs* are separated into either 10,000; 15,000; or 20,000 miles driven per year which shows a decrease in vehicle costs as the mileage increases (39). The truck non-fuel costs for California were based on the American Transportation Research Institute while the values for Nevada were based on the "The Real Cost of Trucking in the United States" which is provided from the Trucker Report (32 and 40). The difference in the results for truck non-fuel costs is due to the depreciation that is added to the Nevada costs which the American Transportation Research Institute does not include (41).

Table 13 Comparison of Vehicle Operating Costs (2015 USD)

	California	Nevada
Average Fuel Cost		
Gasoline (automobile)	$3.91	$ 3.54
Diesel (truck)	$4.15	$ 3.88
Non-Fuel Costs		
Automobile	$0.32	$0.49
Truck	$0.44	$0.73

3.6 Emission Cost Parameters

The emission health costs used by Nevada are provided in Table 14. These estimates are based on data from California (2). The values provided over estimate Nevada's pollution characteristics since Nevada does not exhibit the same driving patterns and congestion as California does which affect emission production.

Table 14 Emission Costs Recommended by NDOT (2015 USD)

Emission Type	Cost (Dollars/Ton)
Carbon Monoxide	$135
Particular Matter	$449,157
Nitrogen Oxides	$54,791
Hydrocarbons	$7,868

Source: Updates for 2014 Discussion of the Calculation of Costs and Benefits from NDOT (2)

As had been mentioned in Chapter 2, the *TIGER BCA Resource Guide* (9) also provides recommendations on emission costs. These values are presented in Table 15.

Table 15 Recommended Emission Values from TIGER BCA Resource Guide

Emission Type	Dollars/short ton (2015$)	Dollars/metric ton (2015$)
Carbon Dioxide (CO_2)	varies	varies
Volatile Organic Compounds (VOCS)	$1,847	$2,037
Nitrogen Oxides (NO_x)	$7,280	$8,027
Particulate Matter (PM)	$333,050	$367,188
Sulfur Dioxide (SO_x)	$43,030	$47,441

Source: TIGER BCA Resource Guide (9)

As can be seen from Table 15, the cost values are provided in both short ton and metric ton units since all emissions except for carbon dioxide were reported in short ton. The difference between the two measurements is that a metric ton contains approximately

2,205 lbs. while a short ton contains 2,000 lbs. (9). This variation of carbon dioxide emission is described in the *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (42). This technical update provides the annual social cost of carbon in 2007 nominal dollars and only provides cost in terms of metric tons. Therefore, an analysis conducted in 2015 would use a cost of $46 per metric ton of carbon dioxide emissions. Since the Federal Interagency Social Cost of Carbon (SCC) guidance states carbon dioxide emissions change over time, they are to be discounted at 2.5 percent, 3 percent, and 5 percent and the benefits from these should then be added to the non-carbon net benefits (9). Results in Table 14 and Table 15 are different since the values provided in Table 14 are based on California data which used a 1990s study covering the Los Angeles area and other urban and rural areas across the United States (34) while the data provided in Table 15 is based on emissions of average fuel economy for vehicles being manufactured between 2017 and 2025 (14).

3.7 Safety Cost Parameters

NDOT provided the crash cost values assigned to each crash type which were adapted from the HSM. Table 16 shows these recommended values adjusted to 2015 dollars.

Table 16 Nevada Crash Cost Assumptions (2015 USD)

Crash Type	Cost (2015$)
Fatality	$5,431,122
Injury (Average A, B, and C)	$152,123
Property Damage Only (PDO)	$9,803

Source: Updates for 2014 Discussion of the Calculation of Costs and Benefits from NDOT (2)

The various sources reviewed showed a difference in crash cost estimates. Table 17 shows the values converted from the AIS scale to the KABCO scale for the federal VSL guidance along with the HSM estimates and the values used in California from the National Safety Council. The greatest difference in valuing a fatal life was observed between the federal VSL estimate and that of the HSM and National Safety Council. The federal estimate was based on a review of 15 studies. Nine of these studies were excluded as they did not consider a broad spectrum of population (8). The HSM estimates were based on the 2005 *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash* study completed by FHWA (11). The HSM provides crash costs divided into both human capital costs and comprehensive crash costs. For use in Cal-B/C California determined that the National Safety Council estimates should be used as they could be applied to different transportation modes (31).

Table 17 Crash Cost Estimates from Different Sources (2015 USD)

	Federal	Nevada	California
Crash Type	US VSL Guidance	2010 AASHTO Highway Safety Manual	National Safety Council
Fatal (K)	$9,408,299	$5,625,529	$4,634,848
Disabling Injury (A)	$449,952	$298,906	$233,217
Evident Injury (B)	$122,553	$109,212	$59,516
Possible Injury (C)	$62,579	$61,637	$28,336
Property Damage Only (O)	$3,170	$9,995	$10,744

3.8 Chapter Summary

This chapter discussed the general procedure to be followed for BCA of transportation projects. It also explained the process of converting nominal dollars to real dollars for analysis and went into detail about the economic parameters used by benefit cost analysis along with a discussion of the differences between sources. Based on the review of these values, updated values for use in Nevada BCA are recommended and discussion of such values is provided in Chapter 4.

4 BENEFIT-COST ANALYSIS RECOMMENDATIONS FOR NEVADA

The parameters currently in use by Nevada were investigated to determine if they are representative of the state's transportation characteristics. Once updates to existing parameters were determined for Nevada, test runs were conducted on Cal-B/C to determine if a significant difference in results would be observed when compared to Cal-B/C's default parameters. Additionally, the two projects analyzed were run in BCA.net to see if substantial differences in results were found when compared with Cal-B/C. It is the goal that recommendation found in this thesis will be adopted by NDOT and other transportation agencies in the state so that a more seamless and uniform analysis for transportation projects is conducted.

4.1 Discount Rate

It is recommended that NDOT continue to use a discount rate of 7 percent along with a 3 percent discount rate in any transportation economic analysis. Using these two discount rates will comply with federal programs such as the TIGER Grant.

4.2 Value of Time Cost Parameters

Nevada should follow the federal guidance in terms of valuing travel time. Therefore, business travel should be estimated at 100 percent of the median wage for heavy and light truck drivers plus fridge benefits, while personal travel should be valued at 50 percent of the medial wage for all occupations in the state. Table 18 shows the recommended value to be used for travel time savings in Nevada.

Table 18 Value of Time Values for Use in Nevada (2015 USD)

	Personal Travel	Business Travel
Carson City	$9.02	$24.51
Las Vegas	$7.97	$27.10
Reno-Sparks	$8.10	$28.93
State	$8.09	$28.77

Source: Nevada Workforce Informer (43)

Differences in Table 11and Table 18 can be seen since NDOT was using the mean wage for truck/bus drivers instead of the median wage for heavy and light truck drivers as the federal guidance states.

4.3 Vehicle Operating Cost Parameters

As stated in Chapter 2, operating costs are separated into two categories: fuel costs and non-fuel costs. Therefore updated parameters were considered for each category based on more recent available data.

4.3.1 Fuel Cost

Since the cost of fuel is uncertain through the analysis lifetime of a project, it is best to consider a range of fuel costs instead of a single value. To provide updated fuel costs for use in future BCA analysis of transportation projects, the past twenty years of fuel prices were obtained and converted to 2015 dollars to determine the average cost over the 20 year period as well as a reasonable range to be recommended. To accomplish this, fuel price data from the U.S. Energy Information Administration (EIA) was used (44). Historical gas prices available from the EIA are for regular grade gasoline instead of the mid-grade fuel option provided in NDOT. From Figure 4 it can be seen that gasoline prices over the past 20 year period have been variable. Based on the data found in Figure

4, it is recommended that transportation projects in Nevada use a gasoline price range between $2.01 and $3.50 with a recommended value of $2.75.

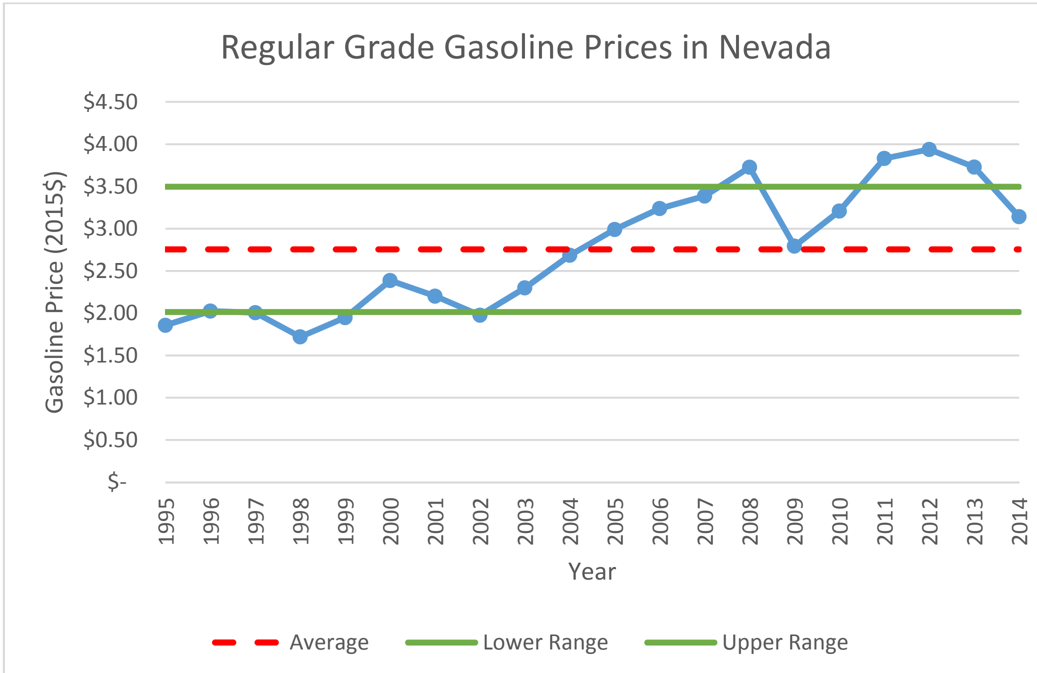


Figure 4 Regular Gasoline Prices in Nevada over the Past 20 Years (2015 USD)

EIA did not contain diesel price information by state, therefore the same analysis as was done for gasoline costs could not be completed. The diesel data available from EIA was divided by region and nation only. Based on the data available, the national annual average diesel price was chosen for Nevada since the regional data only contained prices for the past four years which was not adequate for the analysis. Figure 5 depicts the diesel prices for use in Nevada, as seen in the Figure 5 the average diesel price is $2.69.

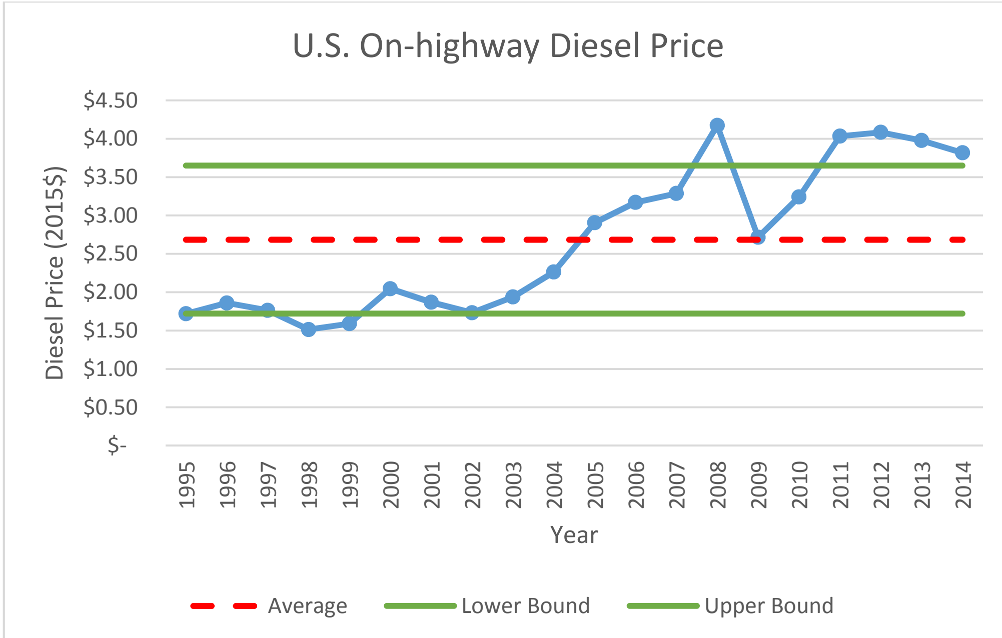


Figure 5 Diesel Gasoline Prices in Nevada over the Past 20 Years (2015 USD)

A summary of the recommended range of values to test for fuel costs is listed in Table 19.

Table 19 Recommended Fuel Cost Values for Use in Nevada (2015 USD)

Fuel Type	Price Range
Regular-Grade Gasoline	$2.01-$3.50
Diesel Fuel	$1.72-$3.65

Source: Data adapted from U.S. Energy Information Administration (44)

If users want to obtain data specific for the year of analysis, they can go to the AAA Daily Fuel Gauge Report which provides daily monitoring of gas prices for each state. AAA does not have its historical data available online, therefore EIA's database was used. Since there is uncertainty in how much the price of fuel will vary over the course of a project's analysis period, it is advisable to conduct sensitivity analysis to determine if varying the cost of fuel will have significant impacts on the results of the analysis.

4.3.2 Non-fuel Operating Costs

Non-fuel operating costs should be separated between passenger vehicles and trucks, therefore the most up-to-date information was obtained for use in Nevada. Non-fuel costs that are currently used in Nevada analysis are shown in Table 12.

For the present research, recent data containing non-fuel operating cost information was analyzed and compared against the values currently used by NDOT. Non-fuel operating costs for vehicles were examined based on the data found in *Your Driving Costs: How much are you really paying to drive?* provided by AAA (38). In this document, average per-mile costs for sedans and sports utility vehicles (SUVs) were presented (39). It is recommended that Nevada updates its "car" non-fuel operating cost to the average of all vehicle types found in AAA's estimates. Therefore, the newly recommended non-fuel cost values for use in Nevada are shown in Table 20. All of the truck costs, except for the depreciation cost which was left the same as the one currently recommended by the Performance Analysis Division, were obtained from a study conducted by the American Transportation Research Institute in September 2014 (41).

Table 20 Recommended Non-Fuel Cost Values for Use in Nevada (2015 USD)

Non-Fuel Operating Costs	Car ($/mile)	Truck ($/mile)
Depreciation	$ 0.2742	$ 0.3405
Finance Charge	$ 0.0491	$ 0.1658
Insurance	$ 0.0705	$ 0.0651
License, Registration, and Taxes	$ 0.0484	$ 0.0264
Maintenance	$ 0.0532	$ 0.1505
Tires	$ 0.0107	$ 0.0417
Total	***$ 0.5061***	***$ 0.7901***

Source: Your Driving Costs: How much are you really paying to drive? and American Transportation Research Institute (39 and 41)

4.4 Emission Cost Parameters

In the literature review different emission costs were provided based on different sources. For example, California used the study by McCubbin and Delucchi (34) which included analysis of the Southern California region in addition to other urban and rural areas in the United States. McCubbin and Delucchi's study was completed in the early 1990s. While the *TIGER BCA Resource Guide* provides recommendations based on a study completed in more recent years. Attempts to find values that already exist for Nevada were made but none were available. Therefore it is recommended that Nevada implement the values provided in McCubbin and Delucchi's study. The urban estimates are to be used for Las Vegas while the midway point between the rural and urban estimates should be used for Carson City and Reno-Sparks. Lastly, the rural estimates can be used for the remaining areas in the state. These values are shown in Table 21.

Table 21 Recommended Emission Cost Values for Nevada (2015 USD)

Pollutant	Las Vegas	Carson City/ Reno-Sparks	Rural Nevada
Carbon Monoxide (CO)	$79	$76	$74
Nitrogen Oxide (NOx)	$18,223	$15,906	$13,589
Particular Matter (PM10)	$147,367	$126,194	$105,021
Sulfur Oxide (SOx)	$73,526	$63,308	$53,090
Volatile Organic Compounds (VOC)	$1,275	$1,138	$1,001
Greenhouse Gases (CO2)		$24	

Source: Values adapted from McCubbin and Delucchi's study found in California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) Technical Supplement to User's Guide (31)

4.5 Safety Cost Parameters

Sources provided different values for the valuation of crashes depending on crash type. This section provides insight on the different values encountered in these studies and provides a recommendation on which values should be used for Nevada. First of all, in Cal-B/C values from the National Safety Council have been used. The values provided at the federal level had the highest fatality crash cost value from all other sources. MnDOT currently uses the federally recommended values updated with the state's three-year crash data (21). In Nevada, the values currently provided in the HSM have been used according to the Discussion of the Calculations of Costs and Benefits document provided by the Performance Analysis Division (2). Discussion with NDOT's Safety Division was also initiated. Based on this discussion it was determined that the Safety Division uses the values provided in the HSM, therefore it was concluded that these values should continue to be used. The costs provided in Table 22 should be used for analysis in Nevada.

Table 22 Crash Cost Recommended by Highway Safety Manual (2015 USD)

	Nevada
Crash Type	**2010 AASHTO Highway Safety Manual**
Fatal (K)	$5,625,529
Disabling Injury (A)	$298,906
Evident Injury (B)	$109,212
Possible Injury (C)	$61,637
Property Damage Only (O)	$9,995

Source: 2010 Highway Safety Manual (45)

These values were converted to 2015 dollars based on the methodology found in Chapter 7 of the HSM. To adjust the value found in Table 22, one has to not only use the CPI but also incorporate the Employment Cost Index (ECI) if both human capital and comprehensive crash costs are used. If only the human capital crash costs are used, then only the CPI is needed to update the dollar values to the year of the analysis. The ECI can be obtained from the BLS.

4.6 Analysis

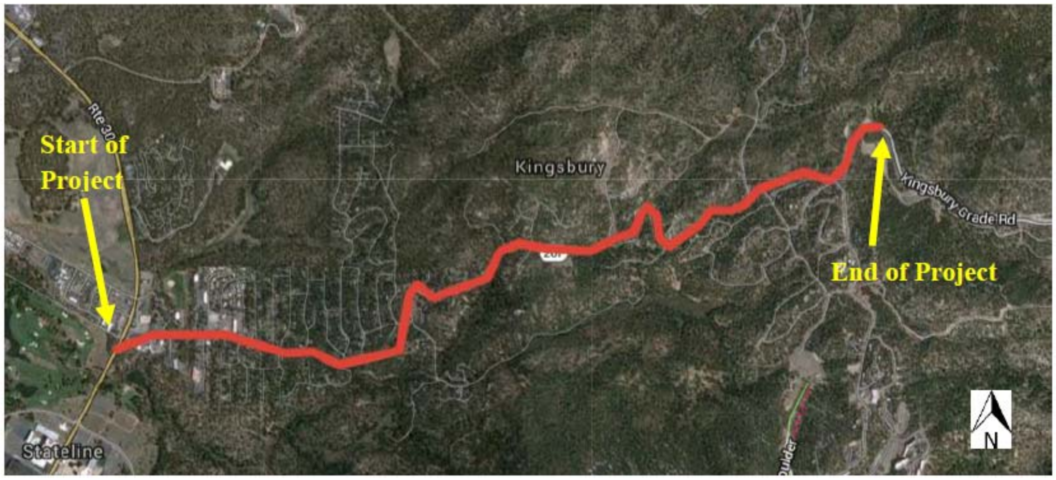
Two projects in Nevada were selected in order to examine the difference in results if projects were analyzed using the default Cal-B/C values versus the Nevada parameters recommended in the Discussion of the Calculation of Costs and Benefits. A sensitivity analysis was also conducted on the newly recommended values. Cal-B/C BCA.net, and AASHTO Redbook were then used for the evaluation of both projects to see if differences in results were found.

4.6.1 Selected Projects

The two projects selected for analysis were the Kingsbury Grade (SR 207) Pavement Reconstruction Project located in Douglas County and U.S. Route 6 Pavement Rehabilitation project in Esmeralda County. These two projects were selected in order to provide analysis for the northern and southern portions of the state. Analysis for these two projects was completed by the Center for Advanced Transportation Education and Research (CATER) in the year.

Kingsbury Grade Pavement Reconstruction Project

The Kingsbury Grade Pavement Reconstruction Project (State Route 207) includes approximately 4 miles of roadway reconstruction and starts at the junction of US50/SR 207 extending just east of Daggett Summit as shown in Figure 6 (46).



Source: Benefit-Cost Analysis: Kingsbury Grade Improvement Project (46)

Figure 6 Project Area of Kingsbury Grade

Construction consisted of a 13-inch full depth pavement reconstruction. In addition accessibility, drainage, and safety improvements were completed (46). Accessibility improvements included the addition of new sidewalks and Americans with Disabilities (ADA) compliant ramps. Curb and gutter were also replaced along the section of roadway totaling approximately 8,000 linear feet (47). The safety improvements included addition of lighting and mitigation of sight distance at intersections along the roadway.

The crash data used was obtained from NDOT's Safety Engineering Division and is the same data used in the original analysis (46). The crash data is found in Table 23.

Table 23 Crash Data for Kingsbury Grade Project

Year	ADT	Fatalities	Injury Crashes	Injuries	Property Damage Only	Total Crashes
2011	12,500	0	6	6	23	29
2012	11,000	0	3	5	16	19
2013	11,000	0	7	11	14	21
2014	11,992	0	3	7	6	9
Total		0	19	29	59	78

Source: Benefit-Cost Analysis: Kingsbury Grade Improvement Project (46)

The traffic data used in this analysis was obtained from NDOT's Traffic Information Systems Division (46) and is shown in Table 24.

Table 24 Average Daily Traffic for Kingsbury Grade Project

	No Build		Build	
Roadway Facility	**2014**	**2033**	**2014**	**2033**
SR 207: DO 0.00-DO3.87	11,992	17,473	11,992	17,473

Source: Benefit-Cost Analysis: Kingsbury Grade Improvement Project (46)

Pavement rehabilitation for this project should provide benefits in ride quality, faster speeds, and reduced vehicle operating costs as the roadway surface will be improved (48). To address the safety benefits for added lighting along the roadway section, a CRF of 0.08 was used as was provided in the original analysis (46).

A baseline case was established for this project. The baseline used a 7 percent discount rate and used the mid-range for preliminary engineering and right-of-way costs parameters found in Table 25 along with the rural emission costs and all other recommended economic parameters for Nevada. The operations and maintenance cost along with the rehabilitation costs were determined to be 10 percent of the total construction costs of the project (46).

Table 25 Kingsbury Grade Project Cost Estimates (2015 USD)

Costs	
Preliminary Engineering and Right-of-Way	$505,446-$855,755
Construction	$14,890,755
Operation and Maintenance (Annual)	$37,227
Rehabilitation Costs (5-years)	$186,134

Source: Benefit-Cost Analysis: Kingsbury Grade Improvement Project (46)

When evaluated in Cal-B/C, the baseline produced a BCR of 1.93. This BCR was then used to conduct the sensitivity analysis specifically covering the effects of the range in preliminary engineering and right-of-way costs, fuel costs, and discount rate. Figure 7 shows the results from the sensitivity analysis. The discount rate had a greater effect on the BCR while the remaining parameters had minimal effects. A 29 percent difference was observed between the use of a 7 percent discount rate and a 3 percent discount rate for this analysis.

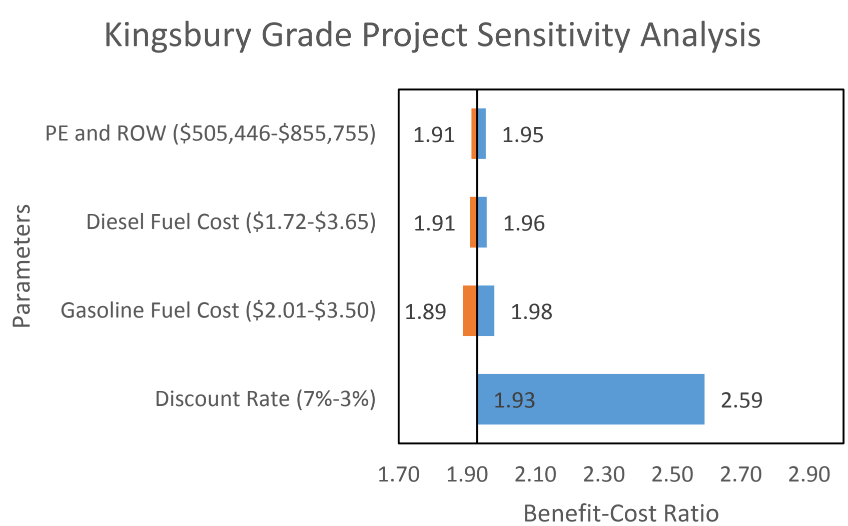


Figure 7 Kingsbury Grade Project Sensitivity Analysis

The baseline was then compared against NDOT's current and Cal-B/C's default values. The results indicate that NDOT's current values provide a greater BCR at 2.06 while the use of Cal-B/C's default values provided BCR of 1.63. Table 26 provides the summary of all analysis run results for Kingsbury Grade. Detailed outputs for all analysis scenarios are found in Appendix A.

Table 26 Kingsbury Grade Results Summary from Cal-B/C (2015 USD)

Run	Details	Present Value of Total User Benefit	Present Value of Total Project Cost	Net Present Value	BCR
1	Recommended Parameters (Baseline at 7% Discount Rate)	$31,527,316	$16,308,634	$15,218,682	1.93
2	Recommended Parameters (6% Discount Rate)	$33,949,754	$16,377,076	$17,572,677	2.07
3	Recommended Parameters (5% Discount Rate)	$36,667,515	$16,455,082	$20,212,434	2.23
4	Recommended Parameters (4% Discount Rate)	$39,726,139	$16,544,318	$23,181,821	2.40
5	Recommended Parameters (3% Discount Rate)	$43,179,382	$16,646,791	$26,532,591	2.59
6	Recommended Parameters, Low PE and ROW	$31,527,316	$16,133,480	$15,393,836	1.95
7	Recommended Parameters, High PE and ROW	$31,527,316	$16,483,789	$15,043,527	1.91
8	Recommended Parameters, Low Gasoline Cost Estimate	$30,781,780	$16,308,634	$14,473,146	1.89
9	Recommended Parameters, High Gasoline Cost Estimate	$32,282,927	$16,308,634	$15,974,293	1.98
10	Recommended Parameters, Low Diesel Cost Estimate	$31,128,491	$16,308,634	$14,819,857	1.91
11	Recommended Parameters, High Diesel Cost Estimate	$31,922,030	$16,308,634	$15,613,396	1.96
12	Current NDOT Recommendation (7% Discount Rate)	$33,669,680	$16,308,634	$17,361,046	2.06
13	Default Cal-B/C Parameters (7% Discount Rate)	$26,536,664	$16,308,634	$10,228,030	1.63

The baseline scenario was then analyzed in BCA.net. BCA.net requires improvement treatments be included for the base case as realistically a “do nothing” case would not exist since maintenance costs to preserve the existing roadway would still be accumulated. Since Cal-B/C does not give the option of including maintenance costs for the base case, the analysis for BCA.net exclude these costs to provide a consistent comparison of results. BCA.net produced a BCR of 0.55 as opposed to the 1.93 ratio provided by Cal-B/C. These results show a great difference, but it should be noted that BCA.net asks for more detailed data than Cal-B/C which was not necessarily available for the project. Therefore input values in BCA.net were updated based on the data NDOT provided. Where data was not available, the default values in BCA.net were used. As had been stated in Chapter 2, Cal-B/C is categorized as a sketchbook-planning method which requires far less data than post-processing methods such as BCA.net, therefore the level of detail and inputs required for analysis can play a major role in results.

Analysis of Kingsbury Grade was also attempted with the AASHTO Redbook Wizard. The BCR produced in the Redbook Wizard was 0.08 which is not reasonable. Observations made during the analysis with this software were that the pavement condition for the base case and improved case were not required inputs as was the case with Cal-B/C and BCA.net. Cal-B/C requires pavement condition data in terms of the International Roughness Index (IRI) which then relates vehicle operating costs for the base and improved case. BCA.net uses the Pavement Serviceability Index (PSI) which also relates vehicle operating costs for the different cases analyzed. Since neither the IRI or PSI were inputs for the Redbook analysis the vehicle operating costs were found to be zero which would not make sense since pavement rehabilitation projects provide benefits in terms of vehicle operating costs as had been previously stated.

U.S. Route 6 Pavement Rehabilitation Project

The U.S. Route 6 pavement rehabilitation project was also selected for analysis in the three software mentioned earlier. This project encompasses the rehabilitation of approximately 25 miles of roadway (49). CATER completed the original analysis of this project earlier this year but analysis in the original report were provided in 2014 dollars. The project milled 2 inches of the pavement then 2 inches of plantmix bituminous surface (PBS) and an open graded wearing coarse were provided (49). The crash data for this project was also obtained from NDOT's Safety Engineering Division and is included in Table 27 (49).

Table 27 Crash Data for U.S. 6 Roadway Segment

Year	ADT	Fatalities	Injury Crashes	Injuries	Property Damage Only	Total Crashes
2011	1,900	0	1	4	4	5
2012	1,900	0	1	1	5	6
2013	2,000	0	2	2	5	7
2014	2,259	0	2	5	0	2
Total		0	6	12	14	20

Source: Benefit-Cost Analysis: U.S. Route 6 Pavement Rehabilitation Project (49)

The traffic data used in this analysis was obtained from NDOT's Traffic Information Systems Division (49) and is shown in Table 28. The costs associated with this project are found in Table 29.

Table 28 Average Daily Traffic on U.S. 6 Roadway Segment

	No Build		Build	
Roadway Facility	**2015**	**2034**	**2015**	**2034**
U.S. Route 6: ES 18.82 to ES 43.89	2,264	2,400	2,264	2,400

Source: Benefit-Cost Analysis: U.S. Route 6 Pavement Rehabilitation Project (49)

Table 29 U.S. 6 Roadway Segment Cost Estimates (2015 USD)

Costs	
Preliminary Engineering and Right-of-Way	$158,139
Construction	$15,743,136
Operation and Maintenance (Annual)	$39,358
Rehabilitation Costs (5-years)	$196,789

Source: Benefit-Cost Analysis: U.S. Route 6 Pavement Rehabilitation Project (49)

The baseline for this project also included a 7 percent discount rate and produced a BCR of 1.34. This BCR was then used to conduct a sensitivity analysis specifically covering the effects of fuel costs and discount rate. Since this project did not have a cost range for preliminary engineering and right-of-way costs, these costs were excluded from the sensitivity analysis. Figure 8 shows the results from the sensitivity analysis. The discount rate had a greater effect on the BCR while the remaining parameters had minimal effects. A 49 percent difference was observed between the use of a 7 percent discount rate and a 3 percent discount rate for this analysis.

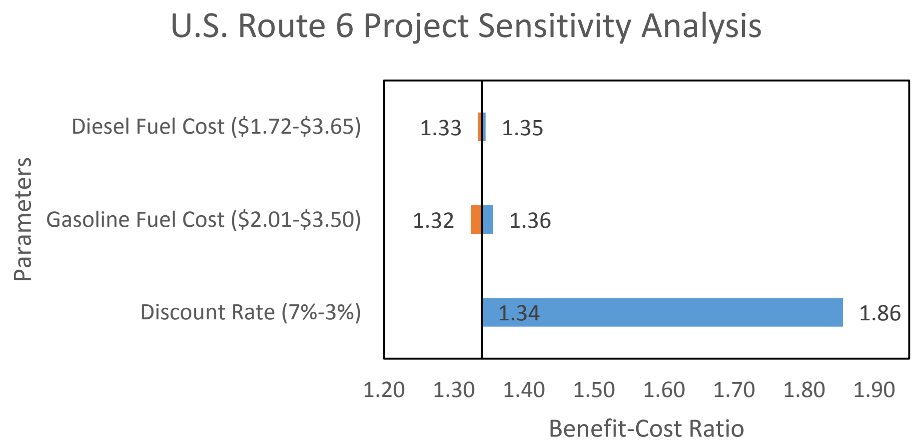


Figure 8 U.S. Route 6 Project Sensitivity Analysis

The baseline was then compared against NDOT's current and Cal-B/C's default values. The results indicate that NDOT's current values provide a greater BCR at 1.38 while the use of Cal-B/C's default values provided BCR of 1.07. Table 30 provides the summary of all analysis run results for the U.S. Route 6 Project. Detailed outputs for all analysis scenarios are found in Appendix B.

Table 30 U.S. Route 6 Results Summary from Cal-B/C (2015 USD)

Run	Details	Present Value of Total User Benefit	Present Value of Total Project Cost	Net Present Value	BCR
1	Recommended Parameters (Baseline at 7% Discount Rate)	$22,352,798	$16,680,759	$5,672,039	1.34
2	Recommended Parameters (6% Discount Rate)	$24,243,062	$16,753,119	$7,489,943	1.45
3	Recommended Parameters (5% Discount Rate)	$26,386,705	$16,835,589	$9,551,116	1.57
4	Recommended Parameters (4% Discount Rate)	$28,826,213	$16,929,934	$11,896,279	1.70
5	Recommended Parameters (3% Discount Rate)	$31,612,297	$17,038,272	$14,574,025	1.86
6	Recommended Parameters, Low Gasoline Cost Estimate	$22,091,259	$16,680,759	$5,410,500	1.32
7	Recommended Parameters, High Gasoline Cost Estimate	$22,617,872	$16,680,759	$5,937,113	1.36
8	Recommended Parameters, Low Diesel Cost Estimate	$22,264,959	$16,680,759	$5,584,200	1.33
9	Recommended Parameters, High Diesel Cost Estimate	$22,439,731	$16,680,759	$5,758,973	1.35
10	Current NDOT Recommendation (7% Discount Rate)	$23,077,338	$16,680,759	$6,396,580	1.38
11	Default Cal-B/C Parameters (7% Discount Rate)	$17,797,195	$16,680,759	$1,116,436	1.07

The baseline scenario was then analyzed in BCA.net. The BCR produced by BCA.net was 0.18 which again is a lot less than the one estimated by Cal-B/C. The project did not produce a BCR when the analysis was completed on the AASHTO Redbook Wizard.

4.6.2 Discussion of Results

The changes in results when comparing NDOT's current values against Cal-B/C indicate that NDOT's current values produced a greater benefit. This was mostly due to the differences in valuing crash costs and vehicle operating costs. Slight differences were observed when comparing the results of the analysis when NDOT's current values were used versus the values recommended in this document. These differences can be mainly attributed to the changes made for the valuation of travel time and the changes in emission costs. In regards to the result outputs from each of the software, differences in methodologies and level of data needed to run the analysis in each software could have attributed to the significant differences observed. As stated earlier in this chapter, the AASHTO Redbook Wizard failed to ask for pavement condition data which would be crucial in determining the benefits users will observe during a pavement reconstruction project. As for the differences in the Cal-B/C and BCA.net results, differences in the methods employed to capture pavement conditions would result in different results especially in vehicle operating costs.

4.7 Chapter Summary

In conclusion this chapter made recommendations on which economic values should be used for BCA of transportation projects in Nevada. Any economic values NDOT decides to adopt for BCA should be regularly updated and posted on their website as other states do. Posting these values will make sure that anyone conducting BCA uses the same values and therefore provide consistent analysis results. In terms of software packages, the results obtained for the two projects analyzed show that great differences can be observed when various software packages are used. It would be beneficial for NDOT to provide a requirement of basic information needed for the analysis of any project. The data provided by NDOT should be sufficient to include in a variety of software packages where little use of default values will be needed creating for more reliable results.

5 CONCLUSIONS AND RECOMMENDATIONS

Project prioritization is very important when allocating funds, especially for transportation projects. Transportation agencies want to make sure that all funding is adequately allocated to projects that will provide the greatest benefit. It is therefore important to have standardized economic values for use in analysis as well as providing a guidance on which software package or packages are recommended for a project. Having a consistent method of conducting BCA will greatly improve the prioritization process transportation agencies use.

This thesis reviewed general methodologies used across the country in regards to project prioritization and the use of BCA analysis for efficient allocation of funds in transportation projects. The findings and recommendations along with future studies in this topic will be discussed below.

5.1 Findings

Updated values for use in BCA were recommended based on the review of existing methodologies across the country. These recommended values were applied to two projects in Nevada. The recommended values in this thesis were then compared against NDOT's current parameters as well as Cal-B/C's default parameters. The following was found in the analysis.

- NDOT's current economic values produced slightly higher BCRs than the results when the newly recommended values and Cal-B/C values were used.
- Cal-B/C's default values generally produced the lowest BCR.

- The sensitivity analysis conducted indicated that the discount rate had the greatest effect on the BCR when compared to the other parameters such as fuel costs.

The two projects selected for analysis were also evaluated using BCA.net and the AASHTO Redbook Wizard. This was done to see if significant differences in results would be obtained. The findings from the analysis are provided below:

- Cal-B/C provided substantially higher BCR results than the other two software packages.
- The AASHTO Redbook provided the lowest BCR. In observations of the input data it was determined that the omission of pavement conditions for the base and alternative cases for each of the projects could have played a major role in such a low BCR since pavement projects usually observe benefits in vehicle operating costs which can be attributed to the roadway conditions.
- The vehicle operating cost savings provided the greatest benefit for the analysis completed in Cal-B/C.
- The three software packages all required various levels of data needs with BCA.net needing more detailed data including traffic characteristics while Cal-B/C was the simplest software where average daily traffic and truck percentage were the major traffic characteristics used for analysis.

5.2 Recommendations

The following recommendations are made based on the analysis complete for this thesis:

- It is recommended that Nevada transportation projects adopt the use of the economic values recommended in this document as these provide the most relevant information available.
- It is recommended that NDOT adopt the establishment of general data that should always be provided for all transportation projects needing BCA. This information should be kept in a data base where the data would be easily accessible and adaptable to different software packages. Providing more detailed information as the stage of a project permits will provide for more reliable results.
- Cal-B/C seems to perform well when minimal data is available for a project, therefore NDOT can continue to use this software in any stage of the project prioritization process but the use of other software should also be considered as Cal-B/C is not able to analyze all kinds of projects
- The use of a more detailed software should also be considered especially for projects having impacts at the regional level, such a software can include STEAM which takes regional measures into account.

5.3 Future Studies

The review of the methods and software covered in this thesis only focused on motor vehicles, but the need for BCA to include other modes should be considered. Projects to be considered for inclusion in BCA software can include complete street projects which also incorporate bicycle, pedestrian, and transit modes. Caltrans developed the Active Transportation Program (ATP) B/C Tool in order to measure the benefits bike, pedestrian, and safe routes to school projects would produce (50). In their website, Caltrans mentioned that many limitations still exist within this tool since limited resources and time were available for the development of the tool. Further research into incorporating such projects into already established BCA tools could be beneficial as transportations agencies would ideally have all their project analysis needs covered in a single software.

In conclusion, this thesis reviewed the various guidelines and methods used throughout the United States in terms of BCA and prioritization frameworks. From this review updated economic values for use in Nevada were recommended. Additionally, three software packages were reviewed to see the variation in results and determine if Nevada should continue to use Cal-B/C which is the tool NDOT has been using in recent years. Even though Cal-B/C is simple to use it provides comprehensive results with limited data and is able to provide the required data needed for ranking of projects. It is currently recommended that NDOT continue to use Cal-B/C for general transportation projects where localized benefits will be observed but for projects having an effect on the regional level other software packages such as BCA.net and STEAM which are both provided by the FHWA should be used.

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APPENDIX A: KINGSBURY GRADE PROJECT

DETAILED RESULTS

Kingsbury Grade –Recommended Parameters (Baseline at 7 % Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,944,937	$118,926	$15,711	$2,777,297	$34,791	$2,742,506
2	$649,156	$1,864,121	$113,820	$15,426	$2,642,523	$32,515	$2,610,008
3	$602,675	$1,778,920	$108,872	$14,366	$2,504,833	$30,388	$2,474,445
4	$558,250	$1,700,699	$104,085	$13,944	$2,376,978	$28,400	$2,348,578
5	$515,843	$1,621,287	$99,458	$12,929	$2,249,519	$159,254	$2,090,265
6	$475,415	$1,549,596	$94,992	$12,699	$2,132,701	$24,806	$2,107,895
7	$436,917	$1,481,010	$90,683	$12,506	$2,021,117	$23,183	$1,997,934
8	$400,300	$1,409,228	$86,532	$10,111	$1,906,172	$21,666	$1,884,505
9	$365,510	$1,340,988	$82,536	$9,364	$1,798,399	$20,249	$1,778,150
10	$332,491	$1,278,542	$78,693	$9,089	$1,698,815	$113,546	$1,585,270
11	$301,184	$1,199,009	$74,999	$6,066	$1,581,258	$17,686	$1,563,572
12	$271,531	$1,142,298	$71,452	$5,884	$1,491,165	$16,529	$1,474,635
13	$243,471	$1,083,702	$68,048	$5,081	$1,400,302	$15,448	$1,384,854
14	$216,943	$1,035,426	$64,783	$5,418	$1,322,569	$14,437	$1,308,132
15	$191,887	$979,578	$61,654	$4,354	$1,237,472	$80,956	$1,156,516
16	$168,241	$326,015	$58,658	$4,120	$557,034	$12,610	$544,424
17	$145,947	$306,894	$55,789	$3,534	$512,164	$11,785	$500,379
18	$124,943	$295,788	$53,045	$3,996	$477,773	$11,014	$466,759
19	$105,172	$278,404	$50,422	$3,442	$437,439	$10,294	$427,145
20	$86,575	$264,053	$47,914	$3,244	$401,786	$57,721	$344,065
Total	$6,890,175	$22,880,495	$1,585,363	$171,283	**$31,527,316**	**$16,308,634**	**$15,218,682**
Project Benefit-Cost Ratio					**$31,527,316/$16,308,634=1.93**		

Kingsbury Grade – Recommended Parameters (6% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$704,305	$1,963,286	$120,048	$15,859	$2,803,498	$35,120	$2,768,379
2	$661,463	$1,899,459	$115,977	$15,719	$2,692,617	$33,132	$2,659,485
3	$619,893	$1,829,743	$111,983	$14,776	$2,576,395	$31,256	$2,545,139
4	$579,616	$1,765,791	$108,069	$14,478	$2,467,953	$29,487	$2,438,466
5	$540,639	$1,699,220	$104,239	$13,551	$2,357,649	$166,909	$2,190,740
6	$502,968	$1,639,404	$100,497	$13,434	$2,256,303	$26,243	$2,230,060
7	$466,600	$1,581,624	$96,844	$13,356	$2,158,424	$24,758	$2,133,666
8	$431,528	$1,519,164	$93,283	$10,899	$2,054,875	$23,357	$2,031,518
9	$397,742	$1,459,238	$89,815	$10,190	$1,956,984	$22,035	$1,934,950
10	$365,224	$1,404,411	$86,440	$9,984	$1,866,059	$124,724	$1,741,335
11	$333,956	$1,329,473	$83,160	$6,726	$1,753,315	$19,611	$1,733,704
12	$303,917	$1,278,540	$79,974	$6,586	$1,669,016	$18,501	$1,650,515
13	$275,081	$1,224,398	$76,882	$5,741	$1,582,102	$17,453	$1,564,648
14	$247,421	$1,180,891	$73,884	$6,179	$1,508,375	$16,465	$1,491,909
15	$220,909	$1,127,736	$70,979	$5,012	$1,424,637	$93,201	$1,331,436
16	$195,515	$378,865	$68,167	$4,787	$647,334	$14,654	$632,680
17	$171,206	$360,009	$65,445	$4,145	$600,805	$13,825	$586,980
18	$147,950	$350,254	$62,813	$4,732	$565,749	$13,042	$552,707
19	$125,713	$332,779	$60,269	$4,114	$522,875	$12,304	$510,571
20	$104,460	$318,602	$57,812	$3,915	$484,790	$69,645	$415,144
Total	$7,396,103	$24,642,886	$1,726,581	$184,183	**$33,949,754**	**$16,377,076**	**$17,572,677**
Project Benefit-Cost Ratio					**$33,949,754/$16,377,076=2.07**		

Kingsbury Grade - Recommended Parameters (5% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$711,013	$1,981,984	$121,192	$16,010	$2,830,198	$35,454	$2,794,744
2	$674,122	$1,935,811	$118,197	$16,019	$2,744,149	$33,766	$2,710,383
3	$637,774	$1,882,521	$115,213	$15,202	$2,650,710	$32,158	$2,618,552
4	$602,014	$1,834,026	$112,245	$15,037	$2,563,322	$30,627	$2,532,695
5	$566,879	$1,781,691	$109,298	$14,208	$2,472,077	$175,009	$2,297,067
6	$532,402	$1,735,344	$106,378	$14,221	$2,388,344	$27,779	$2,360,565
7	$498,610	$1,690,127	$103,488	$14,272	$2,306,496	$26,456	$2,280,040
8	$465,524	$1,638,842	$100,632	$11,758	$2,216,756	$25,197	$2,191,559
9	$433,162	$1,589,188	$97,813	$11,098	$2,131,260	$23,997	$2,107,263
10	$401,536	$1,544,045	$95,034	$10,976	$2,051,592	$137,124	$1,914,467
11	$370,657	$1,475,576	$92,299	$7,465	$1,945,997	$21,766	$1,924,231
12	$340,528	$1,432,561	$89,608	$7,379	$1,870,076	$20,729	$1,849,347
13	$311,154	$1,384,963	$86,964	$6,494	$1,789,575	$19,742	$1,769,832
14	$282,532	$1,348,471	$84,369	$7,056	$1,722,428	$18,802	$1,703,626
15	$254,661	$1,300,038	$81,824	$5,778	$1,642,301	$107,441	$1,534,860
16	$227,533	$440,910	$79,330	$5,571	$753,344	$17,054	$736,290
17	$201,141	$422,955	$76,888	$4,870	$705,854	$16,242	$689,612
18	$175,474	$415,414	$74,499	$5,612	$670,999	$15,469	$655,531
19	$150,520	$398,447	$72,162	$4,926	$626,055	$14,732	$611,323
20	$126,265	$385,106	$69,880	$4,732	$585,982	$84,183	$501,800
Total	$7,963,498	$26,618,019	$1,887,313	$198,686	**$36,667,515**	**$16,455,082**	**$20,212,434**
Project Benefit-Cost Ratio					**$36,667,515/$16,455,082=2.23**		

Kingsbury Grade - Recommended Parameters (4% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$717,849	$2,001,041	$122,357	$16,164	$2,857,412	$35,795	$2,821,617
2	$687,148	$1,973,217	$120,481	$16,329	$2,797,175	$34,418	$2,762,757
3	$656,349	$1,937,348	$118,568	$15,645	$2,727,910	$33,095	$2,694,816
4	$625,504	$1,905,589	$116,625	$15,624	$2,663,342	$31,822	$2,631,521
5	$594,662	$1,869,013	$114,655	$14,905	$2,593,234	$183,587	$2,409,648
6	$563,865	$1,837,897	$112,665	$15,061	$2,529,488	$29,421	$2,500,067
7	$533,154	$1,807,220	$110,658	$15,261	$2,466,292	$28,289	$2,438,003
8	$502,562	$1,769,232	$108,638	$12,693	$2,393,126	$27,201	$2,365,925
9	$472,121	$1,732,124	$106,610	$12,096	$2,322,951	$26,155	$2,296,796
10	$441,860	$1,699,102	$104,578	$12,079	$2,257,618	$150,895	$2,106,724
11	$411,801	$1,639,371	$102,544	$8,294	$2,162,010	$24,182	$2,137,828
12	$381,966	$1,606,884	$100,512	$8,277	$2,097,639	$23,252	$2,074,388
13	$352,373	$1,568,432	$98,485	$7,354	$2,026,643	$22,358	$2,004,286
14	$323,037	$1,541,789	$96,465	$8,067	$1,969,358	$21,498	$1,947,860
15	$293,969	$1,500,705	$94,454	$6,670	$1,895,798	$124,025	$1,771,773
16	$265,179	$513,860	$92,456	$6,493	$877,988	$19,876	$858,113
17	$236,674	$497,675	$90,471	$5,731	$830,551	$19,111	$811,440
18	$208,458	$493,502	$88,502	$6,667	$797,130	$18,376	$778,754
19	$180,533	$477,896	$86,551	$5,908	$750,889	$17,669	$733,219
20	$152,898	$466,337	$84,620	$5,730	$709,584	$101,939	$607,645
Total	$8,601,963	$28,838,235	$2,070,895	$215,048	**$39,726,139**	**$16,544,318**	**$23,181,821**
Project Benefit-Cost Ratio					**$39,726,139/$16,544,318=2.40**		

Kingsbury Grade - Recommended Parameters (3% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$724,819	$2,020,469	$123,545	$16,321	$2,885,154	$36,143	$2,849,011
2	$700,555	$2,011,718	$122,832	$16,648	$2,851,753	$35,090	$2,816,663
3	$675,652	$1,994,325	$122,056	$16,105	$2,808,138	$34,068	$2,774,070
4	$650,152	$1,980,677	$121,220	$16,240	$2,768,289	$33,076	$2,735,213
5	$624,095	$1,961,520	$120,330	$15,643	$2,721,588	$192,673	$2,528,914
6	$597,519	$1,947,592	$119,389	$15,960	$2,680,460	$31,177	$2,649,283
7	$570,460	$1,933,676	$118,401	$16,329	$2,638,866	$30,269	$2,608,597
8	$542,948	$1,911,410	$117,368	$13,713	$2,585,440	$29,387	$2,556,053
9	$515,014	$1,889,487	$116,296	$13,195	$2,533,991	$28,531	$2,505,460
10	$486,682	$1,871,460	$115,186	$13,304	$2,486,633	$166,202	$2,320,431
11	$457,978	$1,823,201	$114,043	$9,224	$2,404,445	$26,893	$2,377,552
12	$428,922	$1,804,421	$112,868	$9,294	$2,355,506	$26,110	$2,329,396
13	$399,533	$1,778,341	$111,665	$8,338	$2,297,877	$25,350	$2,272,527
14	$369,826	$1,765,105	$110,437	$9,235	$2,254,603	$24,611	$2,229,992
15	$339,816	$1,734,751	$109,185	$7,710	$2,191,461	$143,367	$2,048,094
16	$309,512	$599,767	$107,912	$7,579	$1,024,770	$23,199	$1,001,572
17	$278,924	$586,516	$106,621	$6,754	$978,814	$22,523	$956,291
18	$248,056	$587,244	$105,314	$7,934	$948,548	$21,867	$926,681
19	$216,912	$574,195	$103,992	$7,098	$902,198	$21,230	$880,968
20	$185,491	$565,747	$102,658	$6,951	$860,847	$123,670	$737,177
Total	$9,322,864	$31,341,624	$2,281,318	$233,575	**$43,179,382**	**$16,646,791**	**$26,532,591**
Project Benefit-Cost Ratio					**$43,179,382/$16,646,791=2.59**		

Kingsbury Grade – Recommended Parameters, Low PE and ROW Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,396,201	($15,396,201)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,944,937	$118,926	$15,711	$2,777,297	$34,791	$2,742,506
2	$649,156	$1,864,121	$113,820	$15,426	$2,642,523	$32,515	$2,610,008
3	$602,675	$1,778,920	$108,872	$14,366	$2,504,833	$30,388	$2,474,445
4	$558,250	$1,700,699	$104,085	$13,944	$2,376,978	$28,400	$2,348,578
5	$515,843	$1,621,287	$99,458	$12,929	$2,249,519	$159,254	$2,090,265
6	$475,415	$1,549,596	$94,992	$12,699	$2,132,701	$24,806	$2,107,895
7	$436,917	$1,481,010	$90,683	$12,506	$2,021,117	$23,183	$1,997,934
8	$400,300	$1,409,228	$86,532	$10,111	$1,906,172	$21,666	$1,884,505
9	$365,510	$1,340,988	$82,536	$9,364	$1,798,399	$20,249	$1,778,150
10	$332,491	$1,278,542	$78,693	$9,089	$1,698,815	$113,546	$1,585,270
11	$301,184	$1,199,009	$74,999	$6,066	$1,581,258	$17,686	$1,563,572
12	$271,531	$1,142,298	$71,452	$5,884	$1,491,165	$16,529	$1,474,635
13	$243,471	$1,083,702	$68,048	$5,081	$1,400,302	$15,448	$1,384,854
14	$216,943	$1,035,426	$64,783	$5,418	$1,322,569	$14,437	$1,308,132
15	$191,887	$979,578	$61,654	$4,354	$1,237,472	$80,956	$1,156,516
16	$168,241	$326,015	$58,658	$4,120	$557,034	$12,610	$544,424
17	$145,947	$306,894	$55,789	$3,534	$512,164	$11,785	$500,379
18	$124,943	$295,788	$53,045	$3,996	$477,773	$11,014	$466,759
19	$105,172	$278,404	$50,422	$3,442	$437,439	$10,294	$427,145
20	$86,575	$264,053	$47,914	$3,244	$401,786	$57,721	$344,065
Total	$6,890,175	$22,880,495	$1,585,363	$171,283	**$31,527,316**	**$16,133,480**	**$15,393,836**
Project Benefit-Cost Ratio					**$31,527,316/$16,133,480=1.95**		

Kingsbury Grade – Recommended Parameters, High PE and ROW Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,746,510	($15,746,510)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,944,937	$118,926	$15,711	$2,777,297	$34,791	$2,742,506
2	$649,156	$1,864,121	$113,820	$15,426	$2,642,523	$32,515	$2,610,008
3	$602,675	$1,778,920	$108,872	$14,366	$2,504,833	$30,388	$2,474,445
4	$558,250	$1,700,699	$104,085	$13,944	$2,376,978	$28,400	$2,348,578
5	$515,843	$1,621,287	$99,458	$12,929	$2,249,519	$159,254	$2,090,265
6	$475,415	$1,549,596	$94,992	$12,699	$2,132,701	$24,806	$2,107,895
7	$436,917	$1,481,010	$90,683	$12,506	$2,021,117	$23,183	$1,997,934
8	$400,300	$1,409,228	$86,532	$10,111	$1,906,172	$21,666	$1,884,505
9	$365,510	$1,340,988	$82,536	$9,364	$1,798,399	$20,249	$1,778,150
10	$332,491	$1,278,542	$78,693	$9,089	$1,698,815	$113,546	$1,585,270
11	$301,184	$1,199,009	$74,999	$6,066	$1,581,258	$17,686	$1,563,572
12	$271,531	$1,142,298	$71,452	$5,884	$1,491,165	$16,529	$1,474,635
13	$243,471	$1,083,702	$68,048	$5,081	$1,400,302	$15,448	$1,384,854
14	$216,943	$1,035,426	$64,783	$5,418	$1,322,569	$14,437	$1,308,132
15	$191,887	$979,578	$61,654	$4,354	$1,237,472	$80,956	$1,156,516
16	$168,241	$326,015	$58,658	$4,120	$557,034	$12,610	$544,424
17	$145,947	$306,894	$55,789	$3,534	$512,164	$11,785	$500,379
18	$124,943	$295,788	$53,045	$3,996	$477,773	$11,014	$466,759
19	$105,172	$278,404	$50,422	$3,442	$437,439	$10,294	$427,145
20	$86,575	$264,053	$47,914	$3,244	$401,786	$57,721	$344,065
Total	$6,890,175	$22,880,495	$1,585,363	$171,283	**$31,527,316**	**$16,483,789**	**$15,043,527**
Project Benefit-Cost Ratio					**$31,527,316/$16,483,789=1.91**		

Kingsbury Grade – Recommended Parameters, Low Gasoline Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,881,243	$118,926	$15,711	$2,713,603	$34,791	$2,678,811
2	$649,156	$1,802,266	$113,820	$15,426	$2,580,669	$32,515	$2,548,153
3	$602,675	$1,719,754	$108,872	$14,366	$2,445,667	$30,388	$2,415,279
4	$558,250	$1,644,135	$104,085	$13,944	$2,320,414	$28,400	$2,292,014
5	$515,843	$1,567,238	$99,458	$12,929	$2,195,469	$159,254	$2,036,215
6	$475,415	$1,497,974	$94,992	$12,699	$2,081,079	$24,806	$2,056,273
7	$436,917	$1,431,729	$90,683	$12,506	$1,971,836	$23,183	$1,948,653
8	$400,300	$1,363,527	$86,532	$10,111	$1,860,470	$21,666	$1,838,804
9	$365,510	$1,297,397	$82,536	$9,364	$1,754,808	$20,249	$1,734,559
10	$332,491	$1,236,981	$78,693	$9,089	$1,657,254	$113,546	$1,543,709
11	$301,184	$1,164,922	$74,999	$6,066	$1,547,171	$17,686	$1,529,485
12	$271,531	$1,109,823	$71,452	$5,884	$1,458,690	$16,529	$1,442,160
13	$243,471	$1,052,774	$68,048	$5,081	$1,369,374	$15,448	$1,353,926
14	$216,943	$1,004,903	$64,783	$5,418	$1,292,047	$14,437	$1,277,609
15	$191,887	$951,472	$61,654	$4,354	$1,209,367	$80,956	$1,128,410
16	$168,241	$312,261	$58,658	$4,120	$543,280	$12,610	$530,670
17	$145,947	$293,812	$55,789	$3,534	$499,082	$11,785	$487,297
18	$124,943	$283,350	$53,045	$3,996	$465,334	$11,014	$454,320
19	$105,172	$266,581	$50,422	$3,442	$425,616	$10,294	$415,322
20	$86,575	$252,818	$47,914	$3,244	$390,551	$57,721	$332,830
Total	$6,890,175	$22,134,959	$1,585,363	$171,283	**$30,781,780**	**$16,308,634**	**$14,473,146**
Project Benefit-Cost Ratio					**$30,781,780/$16,308,634=1.89**		

Kingsbury Grade – Recommended Parameters, High Gasoline Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$2,009,493	$118,926	$15,711	$2,841,853	$34,791	$2,807,061
2	$649,156	$1,926,811	$113,820	$15,426	$2,705,213	$32,515	$2,672,698
3	$602,675	$1,838,885	$108,872	$14,366	$2,564,798	$30,388	$2,534,410
4	$558,250	$1,758,028	$104,085	$13,944	$2,434,307	$28,400	$2,405,907
5	$515,843	$1,676,068	$99,458	$12,929	$2,304,299	$159,254	$2,145,045
6	$475,415	$1,601,916	$94,992	$12,699	$2,185,021	$24,806	$2,160,215
7	$436,917	$1,530,957	$90,683	$12,506	$2,071,064	$23,183	$2,047,881
8	$400,300	$1,455,548	$86,532	$10,111	$1,952,491	$21,666	$1,930,825
9	$365,510	$1,385,168	$82,536	$9,364	$1,842,580	$20,249	$1,822,331
10	$332,491	$1,320,665	$78,693	$9,089	$1,740,938	$113,546	$1,627,393
11	$301,184	$1,233,557	$74,999	$6,066	$1,615,806	$17,686	$1,598,120
12	$271,531	$1,175,212	$71,452	$5,884	$1,524,078	$16,529	$1,507,549
13	$243,471	$1,115,048	$68,048	$5,081	$1,431,647	$15,448	$1,416,199
14	$216,943	$1,066,361	$64,783	$5,418	$1,353,504	$14,437	$1,339,067
15	$191,887	$1,008,063	$61,654	$4,354	$1,265,957	$80,956	$1,185,001
16	$168,241	$339,955	$58,658	$4,120	$570,974	$12,610	$558,364
17	$145,947	$320,152	$55,789	$3,534	$525,422	$11,785	$513,637
18	$124,943	$308,395	$53,045	$3,996	$490,379	$11,014	$479,365
19	$105,172	$290,387	$50,422	$3,442	$449,422	$10,294	$439,128
20	$86,575	$275,440	$47,914	$3,244	$413,173	$57,721	$355,452
Total	$6,890,175	$23,636,106	$1,585,363	$171,283	$32,282,927	$16,308,634	$15,974,293
Project Benefit-Cost Ratio					$32,282,927/$16,308,634=1.98		

Kingsbury Grade – Recommended Parameters, Low Diesel Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,908,003	$118,926	$15,711	$2,740,363	$34,791	$2,705,572
2	$649,156	$1,828,773	$113,820	$15,426	$2,607,175	$32,515	$2,574,660
3	$602,675	$1,746,982	$108,872	$14,366	$2,472,896	$30,388	$2,442,507
4	$558,250	$1,670,166	$104,085	$13,944	$2,346,445	$28,400	$2,318,045
5	$515,843	$1,593,824	$99,458	$12,929	$2,222,055	$159,254	$2,062,801
6	$475,415	$1,522,861	$94,992	$12,699	$2,105,966	$24,806	$2,081,160
7	$436,917	$1,454,727	$90,683	$12,506	$1,994,835	$23,183	$1,971,652
8	$400,300	$1,384,149	$86,532	$10,111	$1,881,092	$21,666	$1,859,426
9	$365,510	$1,318,488	$82,536	$9,364	$1,775,899	$20,249	$1,755,650
10	$332,491	$1,257,090	$78,693	$9,089	$1,677,363	$113,546	$1,563,817
11	$301,184	$1,179,854	$74,999	$6,066	$1,562,104	$17,686	$1,544,417
12	$271,531	$1,124,049	$71,452	$5,884	$1,472,916	$16,529	$1,456,387
13	$243,471	$1,068,197	$68,048	$5,081	$1,384,797	$15,448	$1,369,349
14	$216,943	$1,020,456	$64,783	$5,418	$1,307,600	$14,437	$1,293,163
15	$191,887	$966,678	$61,654	$4,354	$1,224,573	$80,956	$1,143,617
16	$168,241	$317,937	$58,658	$4,120	$548,956	$12,610	$536,346
17	$145,947	$300,638	$55,789	$3,534	$505,908	$11,785	$494,123
18	$124,943	$288,049	$53,045	$3,996	$470,033	$11,014	$459,019
19	$105,172	$272,284	$50,422	$3,442	$431,319	$10,294	$421,025
20	$86,575	$258,464	$47,914	$3,244	$396,197	$57,721	$338,477
Total	$6,890,175	$22,481,670	$1,585,363	$171,283	**$31,128,491**	**$16,308,634**	**$14,819,857**
Project Benefit-Cost Ratio					**$31,128,491/$16,308,634=1.91**		

Kingsbury Grade – Recommended Parameters, High Diesel Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$697,723	$1,981,490	$118,926	$15,711	$2,813,850	$34,791	$2,779,059
2	$649,156	$1,899,104	$113,820	$15,426	$2,677,507	$32,515	$2,644,991
3	$602,675	$1,810,528	$108,872	$14,366	$2,536,441	$30,388	$2,506,053
4	$558,250	$1,730,918	$104,085	$13,944	$2,407,197	$28,400	$2,378,797
5	$515,843	$1,648,468	$99,458	$12,929	$2,276,699	$159,254	$2,117,446
6	$475,415	$1,576,056	$94,992	$12,699	$2,159,161	$24,806	$2,134,355
7	$436,917	$1,507,021	$90,683	$12,506	$2,047,128	$23,183	$2,023,945
8	$400,300	$1,434,049	$86,532	$10,111	$1,930,993	$21,666	$1,909,326
9	$365,510	$1,363,257	$82,536	$9,364	$1,820,668	$20,249	$1,800,419
10	$332,491	$1,299,774	$78,693	$9,089	$1,720,047	$113,546	$1,606,501
11	$301,184	$1,217,966	$74,999	$6,066	$1,600,216	$17,686	$1,582,529
12	$271,531	$1,160,358	$71,452	$5,884	$1,509,225	$16,529	$1,492,696
13	$243,471	$1,099,047	$68,048	$5,081	$1,415,647	$15,448	$1,400,199
14	$216,943	$1,050,241	$64,783	$5,418	$1,337,384	$14,437	$1,322,947
15	$191,887	$992,344	$61,654	$4,354	$1,250,238	$80,956	$1,169,282
16	$168,241	$334,010	$58,658	$4,120	$565,029	$12,610	$552,419
17	$145,947	$313,085	$55,789	$3,534	$518,355	$11,785	$506,570
18	$124,943	$303,448	$53,045	$3,996	$485,432	$11,014	$474,418
19	$105,172	$284,461	$50,422	$3,442	$443,496	$10,294	$433,202
20	$86,575	$269,584	$47,914	$3,244	$407,317	$57,721	$349,596
Total	$6,890,175	$23,275,209	$1,585,363	$171,283	**$31,922,030**	**$16,308,634**	**$15,613,396**
Project Benefit-Cost Ratio					**$31,922,030/$16,308,634=1.96**		

Kingsbury Grade-Current NDOT Recommendations (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$855,985	$1,994,269	$116,083	$26,472	$2,992,809	$34,791	$2,958,017
2	$796,320	$1,912,290	$111,098	$26,241	$2,845,950	$32,515	$2,813,434
3	$739,236	$1,822,696	$106,269	$24,277	$2,692,478	$30,388	$2,662,089
4	$684,693	$1,742,551	$101,596	$23,420	$2,552,260	$28,400	$2,523,860
5	$632,647	$1,659,178	$97,080	$21,542	$2,410,447	$159,254	$2,251,194
6	$583,045	$1,586,405	$92,720	$21,053	$2,283,223	$24,806	$2,258,417
7	$535,828	$1,517,081	$88,515	$20,711	$2,162,135	$23,183	$2,138,952
8	$490,934	$1,442,235	$84,463	$12,942	$2,030,574	$21,666	$2,008,908
9	$448,294	$1,370,727	$80,563	$11,960	$1,911,545	$20,249	$1,891,296
10	$407,839	$1,306,897	$76,811	$11,564	$1,803,111	$113,546	$1,689,566
11	$369,497	$1,218,552	$73,206	$7,691	$1,668,946	$17,686	$1,651,260
12	$333,194	$1,160,917	$69,743	$7,431	$1,571,286	$16,529	$1,554,757
13	$298,855	$1,099,135	$66,421	$6,388	$1,470,798	$15,448	$1,455,350
14	$266,404	$1,051,525	$63,234	$6,784	$1,387,947	$14,437	$1,373,509
15	$235,766	$992,239	$60,180	$5,448	$1,293,634	$80,956	$1,212,677
16	$206,866	$340,401	$57,255	$5,136	$609,658	$12,610	$597,048
17	$179,628	$318,825	$54,456	$4,385	$557,294	$11,785	$545,508
18	$153,980	$309,331	$51,777	$4,948	$520,036	$11,014	$509,022
19	$129,849	$289,759	$49,216	$4,244	$473,068	$10,294	$462,775
20	$107,162	$274,565	$46,768	$3,987	$432,482	$57,721	$374,762
Total	$8,456,023	$23,409,578	$1,547,456	$256,623	**$33,669,680**	**$16,308,634**	**$17,361,046**
Project Benefit-Cost Ratio					**$33,669,680/$16,308,634=2.06**		

Kingsbury Grade-Default Cal-B/C Parameters (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,571,355	($15,571,355)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$910,904	$1,423,304	$48,444	$15,684	$2,398,335	$34,791	$2,363,544
2	$847,445	$1,366,035	$46,369	$15,402	$2,275,251	$32,515	$2,242,735
3	$786,771	$1,300,425	$44,358	$14,345	$2,145,899	$30,388	$2,115,511
4	$728,841	$1,243,375	$42,412	$13,927	$2,028,555	$28,400	$2,000,154
5	$673,603	$1,182,397	$40,531	$12,915	$1,909,446	$159,254	$1,750,192
6	$621,000	$1,131,121	$38,714	$12,685	$1,803,521	$24,806	$1,778,715
7	$570,966	$1,082,507	$36,962	$12,495	$1,702,930	$23,183	$1,679,747
8	$523,432	$1,027,588	$35,273	$10,113	$1,596,406	$21,666	$1,574,739
9	$478,324	$975,381	$33,647	$9,367	$1,496,720	$20,249	$1,476,471
10	$435,566	$930,036	$32,083	$9,092	$1,406,778	$113,546	$1,293,233
11	$395,079	$859,268	$30,579	$6,069	$1,290,995	$17,686	$1,273,308
12	$356,781	$818,688	$29,135	$5,887	$1,210,491	$16,529	$1,193,961
13	$320,590	$778,032	$27,749	$5,536	$1,131,907	$15,448	$1,116,459
14	$286,426	$741,466	$26,420	$5,421	$1,059,734	$14,437	$1,045,296
15	$254,205	$697,223	$25,146	$4,357	$980,931	$80,956	$899,975
16	$223,846	$249,659	$23,925	$4,123	$501,553	$12,610	$488,943
17	$195,268	$232,602	$22,756	$3,537	$454,163	$11,785	$442,378
18	$168,390	$227,278	$21,638	$4,000	$421,307	$11,014	$410,293
19	$143,134	$211,836	$20,569	$3,445	$378,985	$10,294	$368,691
20	$119,424	$200,539	$19,547	$3,248	$342,758	$57,721	$285,037
Total	$9,039,995	$16,678,760	$646,259	$171,650	**$26,536,664**	**$16,308,634**	**$10,228,030**
Project Benefit-Cost Ratio					**$26,536,664/$16,308,634=1.63**		

APPENDIX B: U.S. ROUTE 6 PROJECT DETAILED RESULTS

U.S. Route 6 –Recommended Parameters (Baseline at 7 % Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$314,192	$1,547,222	$0	($7,522)	$1,853,892	$36,783	$1,817,109
2	$304,453	$1,461,457	$0	($5,746)	$1,760,163	$34,377	$1,725,786
3	$294,791	$1,373,071	$0	($4,609)	$1,663,252	$32,128	$1,631,124
4	$285,230	$1,278,473	$0	($5,512)	$1,558,191	$30,026	$1,528,165
5	$275,794	$1,200,001	$0	($4,795)	$1,471,000	$168,370	$1,302,630
6	$266,498	$1,124,998	$0	($4,537)	$1,386,959	$26,226	$1,360,733
7	$257,360	$1,055,754	$0	($4,209)	$1,308,904	$24,510	$1,284,394
8	$248,391	$990,687	$0	($2,126)	$1,236,952	$22,907	$1,214,045
9	$239,605	$929,927	$0	($1,905)	$1,167,627	$21,408	$1,146,219
10	$231,010	$872,596	$0	($1,652)	$1,101,954	$120,045	$981,909
11	$222,614	$818,018	$0	($1,575)	$1,039,056	$18,699	$1,020,358
12	$214,422	$761,594	$0	($2,147)	$973,869	$17,475	$956,393
13	$206,439	$714,625	$0	($1,901)	$919,163	$16,332	$902,831
14	$198,670	$669,908	$0	($1,813)	$866,765	$15,264	$851,502
15	$191,116	$629,226	$0	($1,520)	$818,822	$85,591	$733,232
16	$183,778	$541,180	$0	($1,449)	$723,509	$13,332	$710,177
17	$176,657	$507,302	$0	($1,382)	$682,577	$12,460	$670,117
18	$169,753	$476,803	$0	($1,124)	$645,432	$11,645	$633,787
19	$163,063	$442,950	$0	($1,587)	$604,427	$10,883	$593,544
20	$156,588	$415,211	$0	($1,515)	$570,284	$61,025	$509,259

Total	$4,600,423	$17,811,002	$0	($58,627)	**$22,352,798**	**$16,680,759**	**$5,672,039**
Project Benefit-Cost Ratio					**$22,352,798/$16,680,759=1.34**		

U.S. Route 6 – Recommended Parameters (6% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$317,156	$1,561,818	$0	($7,593)	$1,871,382	$37,130	$1,834,252
2	$310,224	$1,489,162	$0	($5,855)	$1,793,530	$35,028	$1,758,502
3	$303,213	$1,412,299	$0	($4,741)	$1,710,770	$33,046	$1,677,725
4	$296,147	$1,327,404	$0	($5,723)	$1,617,828	$31,175	$1,586,653
5	$289,050	$1,257,683	$0	($5,025)	$1,541,708	$176,463	$1,365,246
6	$281,943	$1,190,198	$0	($4,800)	$1,467,341	$27,746	$1,439,595
7	$274,844	$1,127,478	$0	($4,495)	$1,397,826	$26,175	$1,371,651
8	$267,769	$1,067,971	$0	($2,292)	$1,333,448	$24,694	$1,308,755
9	$260,734	$1,011,929	$0	($2,073)	$1,270,590	$23,296	$1,247,294
10	$253,752	$958,501	$0	($1,815)	$1,210,438	$131,863	$1,078,575
11	$246,836	$907,026	$0	($1,746)	$1,152,116	$20,733	$1,131,383
12	$239,996	$852,429	$0	($2,403)	$1,090,022	$19,560	$1,070,463
13	$233,241	$807,404	$0	($2,148)	$1,038,498	$18,452	$1,020,045
14	$226,581	$764,022	$0	($2,068)	$988,535	$17,408	$971,127
15	$220,022	$724,395	$0	($1,749)	$942,667	$98,536	$844,131
16	$213,570	$628,910	$0	($1,684)	$840,795	$15,493	$825,302
17	$207,231	$595,102	$0	($1,621)	$800,712	$14,616	$786,096
18	$201,010	$564,601	$0	($1,331)	$764,280	$13,789	$750,492
19	$194,911	$529,463	$0	($1,897)	$722,477	$13,008	$709,469
20	$188,937	$500,987	$0	($1,828)	$688,097	$73,632	$614,465
Total	$5,027,168	$19,278,782	$0	($62,889)	**$24,243,062**	**$16,753,119**	**$7,489,943**
Project Benefit-Cost Ratio					**$24,243,062/$16,753,119=1.45**		

U.S. Route 6 - Recommended Parameters (5% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$320,177	$1,576,693	$0	($7,665)	$1,889,205	$37,484	$1,851,721
2	$316,161	$1,517,662	$0	($5,967)	$1,827,855	$35,699	$1,792,157
3	$311,959	$1,453,036	$0	($4,878)	$1,760,117	$33,999	$1,726,118
4	$307,591	$1,378,699	$0	($5,944)	$1,680,345	$32,380	$1,647,966
5	$303,079	$1,318,725	$0	($5,269)	$1,616,535	$185,027	$1,431,508
6	$298,443	$1,259,849	$0	($5,081)	$1,553,211	$29,369	$1,523,841
7	$293,698	$1,204,825	$0	($4,804)	$1,493,720	$27,971	$1,465,749
8	$288,863	$1,152,105	$0	($2,472)	$1,438,496	$26,639	$1,411,857
9	$283,953	$1,102,045	$0	($2,258)	$1,383,740	$25,370	$1,358,370
10	$278,982	$1,053,800	$0	($1,996)	$1,330,786	$144,974	$1,185,812
11	$273,962	$1,006,704	$0	($1,938)	$1,278,729	$23,012	$1,255,717
12	$268,907	$955,118	$0	($2,692)	$1,221,333	$21,916	$1,199,417
13	$263,828	$913,285	$0	($2,429)	$1,174,684	$20,872	$1,153,811
14	$258,735	$872,445	$0	($2,361)	$1,128,819	$19,878	$1,108,940
15	$253,638	$835,072	$0	($2,017)	$1,086,693	$113,591	$973,102
16	$248,545	$731,903	$0	($1,960)	$978,488	$18,030	$960,458
17	$243,465	$699,154	$0	($1,905)	$940,715	$17,172	$923,543
18	$238,406	$669,638	$0	($1,579)	$906,465	$16,354	$890,111
19	$233,374	$633,943	$0	($2,272)	$865,045	$15,575	$849,470
20	$228,375	$605,561	$0	($2,209)	$831,727	$89,001	$742,725
Total	$5,514,141	$20,940,261	$0	($67,696)	**$26,386,705**	**$16,835,589**	**$9,551,116**
Project Benefit-Cost Ratio					**$26,386,705/$16,835,589=1.57**		

U.S. Route 6 - Recommended Parameters (4% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$323,256	$1,591,853	$0	($7,739)	$1,907,370	$37,844	$1,869,526
2	$322,270	$1,546,988	$0	($6,083)	$1,863,175	$36,389	$1,826,787
3	$321,044	$1,495,355	$0	($5,020)	$1,811,379	$34,989	$1,776,390
4	$319,593	$1,432,495	$0	($6,176)	$1,745,912	$33,643	$1,712,269
5	$317,933	$1,383,356	$0	($5,527)	$1,695,762	$194,096	$1,501,666
6	$316,080	$1,334,303	$0	($5,381)	$1,645,001	$31,105	$1,613,896
7	$314,046	$1,288,296	$0	($5,136)	$1,597,206	$29,909	$1,567,297
8	$311,846	$1,243,769	$0	($2,669)	$1,552,946	$28,758	$1,524,188
9	$309,493	$1,201,166	$0	($2,461)	$1,508,197	$27,652	$1,480,545
10	$306,998	$1,159,625	$0	($2,196)	$1,464,427	$159,532	$1,304,895
11	$304,373	$1,118,452	$0	($2,153)	$1,420,672	$25,566	$1,395,106
12	$301,630	$1,071,343	$0	($3,020)	$1,369,953	$24,583	$1,345,370
13	$298,778	$1,034,270	$0	($2,751)	$1,330,296	$23,637	$1,306,659
14	$295,828	$997,519	$0	($2,699)	$1,290,647	$22,728	$1,267,919
15	$292,788	$963,970	$0	($2,328)	$1,254,429	$131,124	$1,123,305
16	$289,668	$852,999	$0	($2,284)	$1,140,383	$21,013	$1,119,370
17	$286,476	$822,667	$0	($2,241)	$1,106,902	$20,205	$1,086,697
18	$283,220	$795,513	$0	($1,876)	$1,076,857	$19,428	$1,057,429
19	$279,908	$760,350	$0	($2,725)	$1,037,533	$18,681	$1,018,852
20	$276,546	$733,293	$0	($2,675)	$1,007,163	$107,774	$899,389
Total	$6,071,773	$22,827,582	$0	($73,142)	**$28,826,213**	**$16,929,934**	**$11,896,279**
Project Benefit-Cost Ratio					**$28,826,213/$16,929,934=1.70**		

U.S. Route 6 - Recommended Parameters (3% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$326,394	$1,607,308	$0	($7,814)	$1,925,888	$38,211	$1,887,677
2	$328,559	$1,577,172	$0	($6,201)	$1,899,529	$37,099	$1,862,431
3	$330,486	$1,539,333	$0	($5,167)	$1,864,651	$36,018	$1,828,633
4	$332,187	$1,488,941	$0	($6,420)	$1,814,708	$34,969	$1,779,740
5	$333,670	$1,451,826	$0	($5,801)	$1,779,695	$203,703	$1,575,992
6	$334,945	$1,413,940	$0	($5,703)	$1,743,183	$32,962	$1,710,221
7	$336,021	$1,378,442	$0	($5,496)	$1,708,967	$32,002	$1,676,965
8	$336,906	$1,343,720	$0	($2,884)	$1,677,743	$31,069	$1,646,673
9	$337,610	$1,310,291	$0	($2,684)	$1,645,217	$30,165	$1,615,052
10	$338,140	$1,277,259	$0	($2,419)	$1,612,980	$175,716	$1,437,264
11	$338,504	$1,243,869	$0	($2,395)	$1,579,978	$28,433	$1,551,546
12	$338,710	$1,203,045	$0	($3,391)	$1,538,364	$27,605	$1,510,759
13	$338,765	$1,172,690	$0	($3,119)	$1,508,335	$26,801	$1,481,534
14	$338,676	$1,142,002	$0	($3,090)	$1,477,587	$26,020	$1,451,567
15	$338,450	$1,114,307	$0	($2,691)	$1,450,067	$151,574	$1,298,493
16	$338,095	$995,604	$0	($2,666)	$1,331,032	$24,527	$1,306,506
17	$337,615	$969,523	$0	($2,641)	$1,304,497	$23,812	$1,280,685
18	$337,019	$946,623	$0	($2,232)	$1,281,410	$23,119	$1,258,292
19	$336,311	$913,565	$0	($3,274)	$1,246,603	$22,445	$1,224,158
20	$335,498	$889,610	$0	($3,245)	$1,221,862	$130,749	$1,091,113
Total	$6,712,558	$24,979,073	$0	($79,334)	$31,612,297	$17,038,272	$14,574,025
Project Benefit-Cost Ratio					$31,612,297/$17,038,272=1.86		

U.S. Route 6 – Recommended Parameters, Low Gasoline Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$314,192	$1,524,224	$0	($7,522)	$1,830,894	$36,783	$1,794,111
2	$304,453	$1,436,284	$0	($5,746)	$1,734,990	$34,377	$1,700,613
3	$294,791	$1,349,470	$0	($4,609)	$1,639,651	$32,128	$1,607,524
4	$285,230	$1,259,703	$0	($5,512)	$1,539,422	$30,026	$1,509,396
5	$275,794	$1,182,405	$0	($4,795)	$1,453,404	$168,370	$1,285,034
6	$266,498	$1,108,502	$0	($4,537)	$1,370,462	$26,226	$1,344,237
7	$257,360	$1,040,289	$0	($4,209)	$1,293,439	$24,510	$1,268,929
8	$248,391	$976,188	$0	($2,126)	$1,222,454	$22,907	$1,199,547
9	$239,605	$916,335	$0	($1,905)	$1,154,035	$21,408	$1,132,627
10	$231,010	$859,855	$0	($1,652)	$1,089,212	$120,045	$969,167
11	$222,614	$806,073	$0	($1,575)	$1,027,112	$18,699	$1,008,413
12	$214,422	$752,399	$0	($2,147)	$964,674	$17,475	$947,198
13	$206,439	$706,005	$0	($1,901)	$910,543	$16,332	$894,211
14	$198,670	$661,828	$0	($1,813)	$858,685	$15,264	$843,421
15	$191,116	$621,651	$0	($1,520)	$811,248	$85,591	$725,657
16	$183,778	$532,620	$0	($1,449)	$714,949	$13,332	$701,617
17	$176,657	$499,279	$0	($1,382)	$674,554	$12,460	$662,094
18	$169,753	$469,282	$0	($1,124)	$637,910	$11,645	$626,266
19	$163,063	$437,226	$0	($1,587)	$598,703	$10,883	$587,820
20	$156,588	$409,845	$0	($1,515)	$564,918	$61,025	$503,894
Total	$4,600,423	$17,549,463	$0	($58,627)	**$22,091,259**	**$16,680,759**	**$5,410,500**
Project Benefit-Cost Ratio					**$22,091,259/$16,680,759=1.32**		

U.S. Route 6 – Recommended Parameters, High Gasoline Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$314,192	$1,570,531	$0	($7,522)	$1,877,201	$36,783	$1,840,418
2	$304,453	$1,486,970	$0	($5,746)	$1,785,676	$34,377	$1,751,300
3	$294,791	$1,396,990	$0	($4,609)	$1,687,171	$32,128	$1,655,043
4	$285,230	$1,297,495	$0	($5,512)	$1,577,214	$30,026	$1,547,188
5	$275,794	$1,217,835	$0	($4,795)	$1,488,834	$168,370	$1,320,465
6	$266,498	$1,141,717	$0	($4,537)	$1,403,678	$26,226	$1,377,452
7	$257,360	$1,071,428	$0	($4,209)	$1,324,578	$24,510	$1,300,068
8	$248,391	$1,005,381	$0	($2,126)	$1,251,646	$22,907	$1,228,740
9	$239,605	$943,703	$0	($1,905)	$1,181,403	$21,408	$1,159,995
10	$231,010	$885,510	$0	($1,652)	$1,114,868	$120,045	$994,823
11	$222,614	$830,124	$0	($1,575)	$1,051,162	$18,699	$1,032,464
12	$214,422	$770,913	$0	($2,147)	$983,188	$17,475	$965,713
13	$206,439	$723,361	$0	($1,901)	$927,900	$16,332	$911,567
14	$198,670	$678,098	$0	($1,813)	$874,955	$15,264	$859,691
15	$191,116	$636,903	$0	($1,520)	$826,499	$85,591	$740,909
16	$183,778	$549,855	$0	($1,449)	$732,184	$13,332	$718,852
17	$176,657	$515,434	$0	($1,382)	$690,709	$12,460	$678,250
18	$169,753	$484,426	$0	($1,124)	$653,055	$11,645	$641,410
19	$163,063	$448,752	$0	($1,587)	$610,228	$10,883	$599,345
20	$156,588	$420,649	$0	($1,515)	$575,722	$61,025	$514,697
Total	$4,600,423	$18,076,076	$0	($58,627)	$22,617,872	$16,680,759	$5,937,113
Project Benefit-Cost Ratio					$22,617,872/$16,680,759=1.36		

U.S. Route 6 – Recommended Parameters, Low Diesel Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$314,192	$1,544,367	$0	($7,522)	$1,851,038	$36,783	$1,814,255
2	$304,453	$1,458,780	$0	($5,746)	$1,757,487	$34,377	$1,723,110
3	$294,791	$1,369,251	$0	($4,609)	$1,659,432	$32,128	$1,627,304
4	$285,230	$1,274,302	$0	($5,512)	$1,554,020	$30,026	$1,523,995
5	$275,794	$1,195,452	$0	($4,795)	$1,466,450	$168,370	$1,298,081
6	$266,498	$1,120,733	$0	($4,537)	$1,382,693	$26,226	$1,356,468
7	$257,360	$1,051,269	$0	($4,209)	$1,304,420	$24,510	$1,279,910
8	$248,391	$986,061	$0	($2,126)	$1,232,326	$22,907	$1,209,420
9	$239,605	$925,057	$0	($1,905)	$1,162,757	$21,408	$1,141,349
10	$231,010	$867,660	$0	($1,652)	$1,097,018	$120,045	$976,972
11	$222,614	$813,390	$0	($1,575)	$1,034,429	$18,699	$1,015,730
12	$214,422	$756,904	$0	($2,147)	$969,179	$17,475	$951,704
13	$206,439	$709,923	$0	($1,901)	$914,462	$16,332	$898,130
14	$198,670	$665,501	$0	($1,813)	$862,358	$15,264	$847,094
15	$191,116	$624,536	$0	($1,520)	$814,133	$85,591	$728,542
16	$183,778	$536,222	$0	($1,449)	$718,551	$13,332	$705,219
17	$176,657	$502,655	$0	($1,382)	$677,930	$12,460	$665,470
18	$169,753	$471,880	$0	($1,124)	$640,508	$11,645	$628,864
19	$163,063	$438,335	$0	($1,587)	$599,811	$10,883	$588,929
20	$156,588	$410,885	$0	($1,515)	$565,958	$61,025	$504,933
Total	$4,600,423	$17,723,163	$0	($58,627)	**$22,264,959**	**$16,680,759**	**$5,584,200**
Project Benefit-Cost Ratio					**$22,264,959/$16,680,759=1.33**		

U.S. Route 6 – Recommended Parameters, High Diesel Cost Estimate (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$314,192	$1,550,047	$0	($7,522)	$1,856,718	$36,783	$1,819,935
2	$304,453	$1,464,106	$0	($5,746)	$1,762,812	$34,377	$1,728,435
3	$294,791	$1,376,851	$0	($4,609)	$1,667,032	$32,128	$1,634,904
4	$285,230	$1,282,600	$0	($5,512)	$1,562,318	$30,026	$1,532,292
5	$275,794	$1,204,504	$0	($4,795)	$1,475,503	$168,370	$1,307,133
6	$266,498	$1,129,219	$0	($4,537)	$1,391,180	$26,226	$1,364,954
7	$257,360	$1,060,192	$0	($4,209)	$1,313,342	$24,510	$1,288,832
8	$248,391	$995,265	$0	($2,126)	$1,241,530	$22,907	$1,218,624
9	$239,605	$934,747	$0	($1,905)	$1,172,447	$21,408	$1,151,039
10	$231,010	$877,482	$0	($1,652)	$1,106,839	$120,045	$986,794
11	$222,614	$822,597	$0	($1,575)	$1,043,636	$18,699	$1,024,937
12	$214,422	$766,235	$0	($2,147)	$978,510	$17,475	$961,035
13	$206,439	$719,278	$0	($1,901)	$923,816	$16,332	$907,484
14	$198,670	$674,270	$0	($1,813)	$871,127	$15,264	$855,863
15	$191,116	$633,867	$0	($1,520)	$823,464	$85,591	$737,873
16	$183,778	$546,087	$0	($1,449)	$728,416	$13,332	$715,084
17	$176,657	$511,902	$0	($1,382)	$687,177	$12,460	$674,717
18	$169,753	$481,676	$0	($1,124)	$650,304	$11,645	$638,660
19	$163,063	$447,518	$0	($1,587)	$608,994	$10,883	$598,111
20	$156,588	$419,492	$0	($1,515)	$574,565	$61,025	$513,541
Total	$4,600,423	$17,897,935	$0	($58,627)	**$22,439,731**	**$16,680,759**	**$5,758,973**
Project Benefit-Cost Ratio					**$22,439,731/$16,680,759=1.35**		

U.S. Route 6-Current NDOT Recommendations (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS				Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
	Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions			
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$382,978	$1,518,927	$0	($20,046)	$1,881,859	$36,783	$1,845,076
2	$371,610	$1,438,785	$0	($16,454)	$1,793,941	$34,377	$1,759,564
3	$360,275	$1,353,423	$0	($13,171)	$1,700,526	$32,128	$1,668,398
4	$349,008	$1,257,192	$0	($14,636)	$1,591,564	$30,026	$1,561,538
5	$337,840	$1,180,836	$0	($12,534)	$1,506,142	$168,370	$1,337,773
6	$326,799	$1,107,031	$0	($11,793)	$1,422,037	$26,226	$1,395,811
7	$315,907	$1,039,505	$0	($11,160)	$1,344,253	$24,510	$1,319,742
8	$305,186	$975,971	$0	($3,326)	$1,277,831	$22,907	$1,254,924
9	$294,652	$916,787	$0	($3,024)	$1,208,414	$21,408	$1,187,006
10	$284,320	$860,732	$0	($2,556)	$1,142,495	$120,045	$1,022,450
11	$274,202	$806,896	$0	($2,422)	$1,078,675	$18,699	$1,059,977
12	$264,309	$749,461	$0	($3,047)	$1,010,723	$17,475	$993,248
13	$254,650	$703,626	$0	($2,621)	$955,654	$16,332	$939,322
14	$245,230	$659,597	$0	($2,488)	$902,339	$15,264	$887,075
15	$236,054	$620,245	$0	($2,074)	$854,226	$85,591	$768,635
16	$227,127	$537,088	$0	($1,969)	$762,246	$13,332	$748,914
17	$218,450	$503,466	$0	($1,869)	$720,047	$12,460	$707,587
18	$210,024	$473,903	$0	($1,520)	$682,406	$11,645	$670,762
19	$201,850	$438,816	$0	($2,033)	$638,632	$10,883	$627,749
20	$193,927	$411,335	$0	($1,933)	$603,329	$61,025	$542,304
Total	$5,654,397	$17,553,621	$0	($130,679)	**$23,077,338**	**$16,680,759**	**$6,396,580**
Project Benefit-Cost Ratio					**$23,077,338/$16,680,759=1.38**		

U.S. Route 6-Default Cal-B/C Parameters (7% Discount Rate)

Year	PRESENT VALUE OF USER BENEFITS: Travel Time Savings	Vehicle Op. Cost Savings	Accident Reductions	Vehicle Emission Reductions	Present Value of Total User Benefits	Present Value of Total Project Costs	NET PRESENT VALUE
Construction Period							
1					$0	$15,901,276	($15,901,276)
2					$0	$0	$0
3					$0	$0	$0
4					$0	$0	$0
5					$0	$0	$0
6					$0	$0	$0
7					$0	$0	$0
8					$0	$0	$0
Project Open							
1	$398,976	$1,016,220	$0	($7,491)	$1,407,706	$36,783	$1,370,923
2	$388,884	$967,626	$0	($5,720)	$1,350,791	$34,377	$1,316,414
3	$378,613	$911,633	$0	($4,588)	$1,285,658	$32,128	$1,253,530
4	$368,219	$842,840	$0	($5,489)	$1,205,570	$30,026	$1,175,544
5	$357,751	$792,345	$0	($4,776)	$1,145,321	$168,370	$976,951
6	$347,254	$742,822	$0	($4,519)	$1,085,557	$26,226	$1,059,331
7	$336,769	$698,039	$0	($4,192)	$1,030,616	$24,510	$1,006,105
8	$326,329	$655,832	$0	($2,123)	$980,037	$22,907	$957,131
9	$315,966	$616,638	$0	($1,903)	$930,701	$21,408	$909,293
10	$305,707	$579,335	$0	($1,650)	$883,391	$120,045	$763,346
11	$295,575	$543,099	$0	($1,573)	$837,101	$18,699	$818,402
12	$285,590	$502,068	$0	($2,145)	$785,513	$17,475	$768,038
13	$275,771	$471,695	$0	($1,900)	$745,567	$16,332	$729,235
14	$266,133	$442,179	$0	($1,812)	$706,501	$15,264	$691,237
15	$256,687	$416,405	$0	($1,519)	$671,574	$85,591	$585,983
16	$247,445	$364,618	$0	($1,448)	$610,615	$13,332	$597,283
17	$238,416	$341,793	$0	($1,381)	$578,828	$12,460	$566,368
18	$229,605	$322,323	$0	($1,124)	$550,804	$11,645	$539,159
19	$221,019	$296,673	$0	($1,586)	$516,105	$10,883	$505,222
20	$212,661	$278,094	$0	($1,514)	$489,240	$61,025	$428,216
Total	$6,053,370	$11,802,278	$0	($58,453)	**$17,797,195**	**$16,680,759**	**$1,116,436**
Project Benefit-Cost Ratio					**$17,797,195/$16,680,759=1.07**		