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Washington State Department of Transportation

Benefit-Cost Analysis of the Cross-Base Highway Project

Final Report

April 25, 2007

HDR | HLB Decision Economics Inc.

Risk Analysis • Investment and Finance
Economics and Policy

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

BENEFIT-COST ANALYSIS OF THE CROSS-BASE HIGHWAY PROJECT

FINAL REPORT

Prepared By:
HDR|HLB DECISION ECONOMICS INC.
8403 Colesville Road, Suite 910
Silver Spring, MD 20910

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TABLE OF CONTENTS

List of Figures iii

List of Tables iv

Executive Summary v

1. Introduction 1
   1.1 Background and Purpose 1
   1.2 Plan of the Report 2

2. Investment Alternatives 3
   2.1 Description of Base Case and Investment Alternatives 3
   2.2 Representative Highway Segments and Origin-Destination Pairs for User Cost Savings Estimation 4

3. Methodology 8
   3.1 Benefit-Cost Analysis 8
      3.1.1 Principles 8
      3.1.2 Valuation 9
      3.1.3 The Opportunity Cost of Capital 9
      3.1.4 Evaluation Benchmarks of Economic Merit 10
   3.2 Risk Analysis 10
      3.2.1 Principles 10
      3.2.2 Application 11
   3.3 Overview of Benefit-Cost Study 11
      3.3.1 Benefit Categories 11
      3.3.2 Investment Evaluation Criteria 11
   3.4 Methodology for Measuring Benefits from Transportation Improvements 12
      3.4.1 Model Overview 13

4. S&L Diagrams and Estimating Assumptions 14
   4.1 Cost Savings from Transportation Improvements 14
      4.1.1 Travel Time Savings 14
      4.1.2 Vehicle Operating Cost Savings 16
      4.1.3 Accident Cost Savings 19
      4.1.4 Emission Cost Savings 21
   4.2 Other Assumptions Used in Estimating Travel Costs 23
   4.3 Other Assumptions 28

5. Simulation Results 29
   5.1 Alternative 1: SR 704 Build Alternative 29
   5.2 Alternative 2: SR 7 Widening 32
   5.3 Alternative 3: Transit Development 34
   5.4 Summary Tables 38

Appendix A: References and Data Sources 40

Appendix B: Traffic Summary Tables and Study Area Map 41

Appendix C: StratBENCOST Data Tables 51

Appendix D: Risk Analysis Primer.....60

LIST OF FIGURES

Figure 1: Segment Map.....5
Figure 2: Map of Representative Routes 6
Figure 3: Structure and Logic Diagram for Estimating Transportation Improvement Benefits....13
Figure 4: Structure and Logic Diagram for Estimating Travel Time Savings.....15
Figure 5: Structure and Logic Diagram for Estimating Vehicle Operating Cost Savings.....17
Figure 6: Structure and Logic Diagram for Estimating Accident Cost Savings.....20
Figure 7: Structure and Logic Diagram for Estimating Emission Cost Savings 22
Figure 8: Annual Project Benefits for Alternative 1.....30
Figure 9: Project Benefits and Costs for Alternative 1.....30
Figure 10: Annual Project Benefits for Alternative 2.....33
Figure 11: Project Benefits and Costs for Alternative 2.....33
Figure 12: Annual Project Benefits for Alternative 3.....36
Figure 13: Project Benefits and Costs for Alternative 3.....36
Figure 14: Comparison of Modified Internal Rate of Return 39
Figure 15: Comparison of Benefit-Cost Ratio.....39

LIST OF TABLES

Table 1: Selected Segments 7
Table 2: Summary of Traffic Characteristics for Selected Origin-Destination Pairs 7
Table 3: Detailed Benefits, Costs, and Net Benefits for Alternative 1 29
Table 4: Tangible Benefits for Alternative 1 31
Table 5: Detailed Benefits, Costs, and Net Benefits for Alternative 2 32
Table 6: Tangible Benefits for Alternative 2 34
Table 7: Detailed Benefits, Costs, and Net Benefits for Alternative 3 35
Table 8: Tangible Benefits for Alternative 3 37
Table 9: Summary of Simulation Results 38

EXECUTIVE SUMMARY

HDR|HLB was retained by the Washington Department of Transportation to conduct a benefit-cost analysis for the mid-Pierce County area south of Tacoma, WA. The purpose of this study is to compare the economic benefits of implementing the proposed Cross Base Highway (SR 704) to maintaining the status quo or focusing on widening of current roads or transit enhancement. The current roads used in this project to estimate the major benefits and costs of travel in the region are I-5, SR 512, SR 7. These roads and their present condition and capacity are used as a baseline for are analysis with one exception. The addition of an HOV lane to both I-5 and SR 512 within the study area is included in the model and expected to occur simultaneous to the implementation of any of the three construction alternatives.

The three alternatives to the base case are as follows:

Alternative 1 – The Build Alternative. This scenario is to construct a 6 mile limited access highway to connect I-5 in the west and SR 7 in the east across Ft. Lewis and Mc Chord Air Force Base.

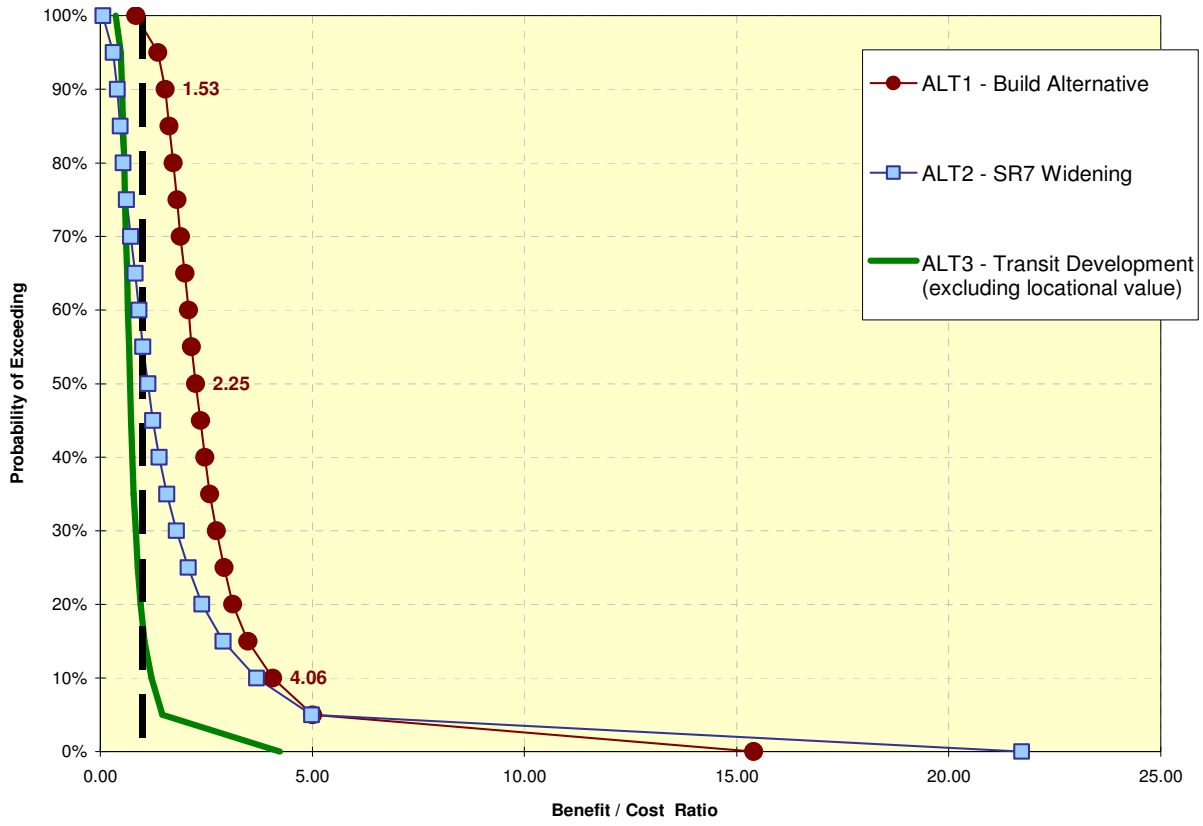
Alternative 2 – Widening of SR 7. This scenario would involve the addition of another general purpose traffic lane in both directions on SR 7 between SR 512 in the north and SR 507 in the south.

Alternative 3 – Transit Enhancement. This scenario would involve the building of a light rail system from Spanaway in the east to Lakewood in the west. This would be the first direct east-west transit link between the two cities.

Benefit-Cost Ratio

The figure below illustrates the probability of the benefit-cost ratio for the three alternatives. The black dashed line is 1.0 or the break even point for a project. The percent at which one of the alternatives crosses this line indicates the probability the benefits produced from its implementation will exceed the costs of implementation. As the results show the Build Alternative is a very safe alternative as there is less than a five percent likelihood it will not break even. The SR 7 widening alternative has a much lower probability of success only bettering the break even point less than 60% of the time. The transit enhancement alternative is show to be the option with the largest financial risk of the three. This alternative is only likely to have a benefit-cost ratio better than the break even point less than 20% of the time.

Figure ES-1: Comparison of Alternatives Based on Benefit-Cost Ratio



Benefits

The chart below summarizes the expected benefits and costs of the three alternatives over the 30 year period of the study. Each alternative has measurable advantages over the other two with the Build Alternative most clearly represented. The Build Alternative has the largest savings in travel time costs and accident costs. It also has the highest benefit-cost ratio, modified internal rate of return, and has a payback period of only 15 years. This payback period is nearly twice as fast as all other alternatives and the benefits will be seen immediately with a 10.5% first year return. The Widening Alternative has a much shorter list of advantages with the biggest being it has the smallest overall cost while still maintaining an expected benefit-cost ratio over 1. The Transit Enhancement Alternative offers opportunity for affordable mobility that is featured in neither of the other two alternatives. This is the measurable benefit of opening up transportation destinations and trips for low income people, and others who would not have otherwise used public transportation. This alternative also has the highest vehicle operating cost and emissions cost savings due to the reduced use of drivers as they switch from driving to using the proposed light rail system.

SUMMARY

Mean Expected Outcomes
Millions of Dollars of 2006, Unless Stated Otherwise
5% Real Discount Rate
30 Year Horizon, 2006-2035

Categories of Benefits	ALT1 - BUILD	ALT2 - SR7	ALT3 - LRT
Affordable Mobility			
Value to Low-Income Households	$0.0	$0.0	$31.0
Cross Sector Benefits	$0.0	$0.0	$48.0
Total Affordable Mobility	**$0.0**	**$0.0**	**$79.0**
Locational Value			
Residential Development	$0.0	$0.0	TBD
Commercial Development	$0.0	$0.0	TBD
Total Locational Value	**$0.0**	**$0.0**	**$0.0**
Congestion Management			
Travel Time Savings	$458.7	$223.7	$119.7
Accident Cost Savings	$369.7	$10.8	$28.0
Vehicle Operating Cost Savings	$185.9	$61.1	$264.6
Emission Cost Savings	$2.0	-$2.2	$7.3
Total Congestion Management	**$1,016.3**	**$293.4**	**$419.6**
Grand Total Benefits	**$1,016.3**	**$293.4**	**$498.6**
Project Costs			
Capital Costs	$323.7	$215.2	$467.4
Incremental O&M Costs	$156.5	$55.1	$270.7
Total Project Costs	**$480.2**	**$270.4**	**$738.1**
Net Present Value	**$536.1**	**$23.0**	**-$239.5**
Benefit/Cost Ratio	2.12	1.09	0.68
Modified Internal Rate of Return, %	6.3%	3.7%	0.8%
Payback Period, Years	15.0	28.0	30.0
First Year Return, %	10.5%	1.9%	2.9%

Tangible Benefits

Tangible Benefits of these different alternatives represent the benefits to each user making a trip between the intersection of I-5 and SR 704 and the intersection of SR 7 and SR 704 during peak travel times. In the base scenario in 2010 the expected duration of this trip is just over 14 minutes. By the year 2035 the expected duration of this same trip will increase to just over 36 minutes because of increased congestion. Fuel consumption is also expected to increase during this time frame from 0.33 gallons per trip in 2010 to 0.46 gallons per trip in 2035. The first alternative offers the greatest savings to commuters in travel time and fuel consumption. The addition of the new route will save travelers over 6 minutes a trip in 2010 and nearly 30 minutes a trip by 2035. Fuel consumption savings during this time frame range from 0.1 to 0.2 gallons per trip. While this does not seem like much initially, over the course of the year this could save a person making this trip 300 days a year for work over 60 gallons of fuel. The savings created by alternative 2 are much smaller. The widening of SR 7 saves less than 2 minutes and 0.1 gallons of fuel per trip in 2010, but by 2035 the widening will offset an increase in traffic to create a savings of around 23 minutes. Finally the transit enhancements are likely to create minimal savings for drivers on the current routes in 2010 of less than 1 minute and 0.01 gallons

of fuel per trip. Ultimately by 2035 the transit enhancement is expected to reduce traffic enough to save drivers 12 minutes per trip. This is only half of the time savings created by the second alternative and a third of the savings created by the first alternative.

1. INTRODUCTION

HDR|HLB was retained by the Washington Department of Transportation to conduct a benefit-cost analysis for the SR 704 Cross-Base Highway project. The team conducted the analysis in the form of a business case that assesses credible alternatives to provide better access and lower congestion in the region. The analysis was conducted in a transparent process, using risk analysis to account for uncertainties surrounding key assumptions and engaging local experts, stakeholders, and community leaders to shed light and provide credibility to the process.

HDR|HLB used a computer algorithm based on the model StratBENCOST to carry out the benefit-cost analysis for the Cross-Base Highway project. StratBENCOST is a widely used model developed by HDR|HLB and the National Cooperative Highway Research Program (NCHRP) to help state and local transportation agencies evaluate and prioritize highway investments. The model estimates the user and social benefits over the life cycle of the project using a risk analysis framework to account for uncertainty surrounding the assumptions.

1.1 Background and Purpose

The Cross-Base Highway project involves the construction of a 6-mile, multi-lane divided highway that would provide the mid-Pierce County region with an alternate east-west route. The highway would ease congestion in the region, enhance highway safety, and would benefit the environment. The goal of the highway is to serve the region with a direct link between I-5 and SR 7.

The purpose of the Cross-Base Highway project is to improve the movement of people and goods between Pierce County and destinations along the I-5 corridor. This is very important in securing the economic vitality of the region, since an efficient transportation network that connects regional job centers, neighborhoods, shopping centers, and attractions is necessary. The proposed Cross-Base Highway would provide a more efficient east-west connection between major employment centers in the region. Population and employment growth rates in the mid-Pierce County region are expected to be quite high in the next 30 years (expected population and employment growth between 2000 an 2030 is around 50% and 75%, respectively).[1] Thus, it is expected that congestion in the region will be very high in the near future without improvements to the roadway infrastructure.

The Cross-Base Highway would serve to reduce current and projected traffic volumes and congestion on the existing roadways in the region by providing a direct east-west link between I-5 (at Lakewood) and SR 7 (at 176th Street E). Congestion management in the region is crucial since congestion-related costs take a toll on economic productivity and growth. For example, slow traffic causes trucks to miss "just-in-time" delivery commitments, leading carriers to incur late-penalties and their customers to suffer production losses and higher inventory carrying costs. The loss in competitiveness threatens jobs. In the service sector, traffic congestion creates thousands of hours of lost working time each week. Workers sacrifice productive working hours

[1] Washington State Department of Transportation, *Potential Economic Benefits of Cross-Base Highway*, September 2003.

at the office by leaving for meetings earlier than desired in order to arrive on time. Meetings often start late because people are delayed.

Increased congestion also results in costs to the environment and in social costs. Congestion produces higher levels of vehicle emissions and reduces highway safety. The incidence and severity of road accidents rise significantly with increased traffic congestion. The economic and social costs of safety include expenditures for emergency services, medical outlays, repair and replacement of damaged property and, of course, the pain and grief that follows from death and serious injury. The social costs of congestion include increased childcare expenses and other household costs rise that results when people need to leave their homes earlier than desired in order to arrive at work on time. There are also secondary social consequences such as reduced family time and quality of life issues. Thus, congestion tends to reverse the positive effects from the region's economic growth by eroding the increase in living standards and quality of life that such growth would otherwise permit.

1.2 Plan of the Report

The paper is organized in five chapters as follows. A description of the assessed alternative investment options is presented in Chapter 2, followed by an overview of the methodological framework in Chapter 3. Chapter 4 introduces and explains the key assumptions used in the model. Finally, a presentation of the simulation results is provided in Chapter 5.

2. INVESTMENT ALTERNATIVES

The Cross-Base Highway project would provide the Pierce County region with an alternate east-west route. This new 6-mile, multi-lane divided highway would serve to ease congestion in the area, enhance highway safety and would benefit the environment.

2.1 Description of Base Case and Investment Alternatives

The Base Case scenario (or baseline) includes only those highway, intersection, and interchange improvements planned as part of the transportation plan and the transit service improvements as outlined in the Final EIS. These exclude the addition of *any major new capacity* with the exception of the addition of an HOV lane on portions of I-5 and SR 512.

- The concept of the HOV addition consists of two parts:
    - Adding an HOV lane (one in each direction) on the portion of I-5 between SR 512 and the proposed SR 704; and
    - Adding an HOV lane (one in each direction) to an HOV lane on the portion of SR 512 between I-5 and SR 7.

A total of three transportation alternatives were evaluated in comparison with the base case scenario:

- Alternative 1: Build, as defined in the Final EIS, with the addition of an HOV lane on portions of I-5 and SR 512;
    - The Build Alternative assumes that the Cross-Base Highway would be built. This proposed six-mile route is a significant east-west link between I-5 and SR 7. The building of this road is expected to alleviate worsening traffic congestion in Parkland, Spanaway, Frederickson and Lakewood as well as providing a link between two major employment centers, DuPont, in the west, and Spanaway/Frederickson in the east.
- Alternative 2: Widening of SR 7, with the addition of an HOV lane on portions of I-5 and SR 512;
    - In this alternative, one lane in each direction would be added on SR 7 (Pacific Ave), a five lane arterial connecting SR 512 to the north and SR 507 to the south. This alternative will reduce the congestions on SR 7, which is currently operating at a very low level of service. Without any improvements in the existing network system, the congestion in SR 7 will worsen with the expected increase in travel volume in the future.
- Alternative 3: Enhanced transit, with the addition of an HOV lane on portions of I-5 and SR 512;

- Four routes provided by Pierce Transit operate within the Cross-Base Highway area at the present time:
    - Route 1: Operates north-south along SR 7 and east-west on 6th Avenue in Tacoma;
    - Route 204: Serves Lakewood and Parkland and operates along 112th Street E.;
    - Route 206 (Ft. Lewis): Serves Fort Lewis, Portland-Union Avenue, American Lake Gardens, Gravelly Lake, and Lakewood Transit Center;
    - Route 300 (South Tacoma): Serves McChord AFB and continues north on SR 99 and S Tacoma Way.
- The Transit Development Alternative considers building a light rail which connects Spanaway in the east and Lakewood in the west. The availability of light rail would divert some highway traffic to transit since currently there is no direct east-west transit service in the study area and no transit to Dupont.

2.2 Representative Highway Segments and Origin-Destination Pairs for User Cost Savings Estimation

A set of seven road segments were selected for the purpose of estimating user cost savings in the Cross-Base Highway area. These representative segments were selected by first analyzing traffic patterns as reported in the Final EIS. Major population and employment centers were also identified to determine a set of routes representing those areas individuals are most likely to be traveling to and from.

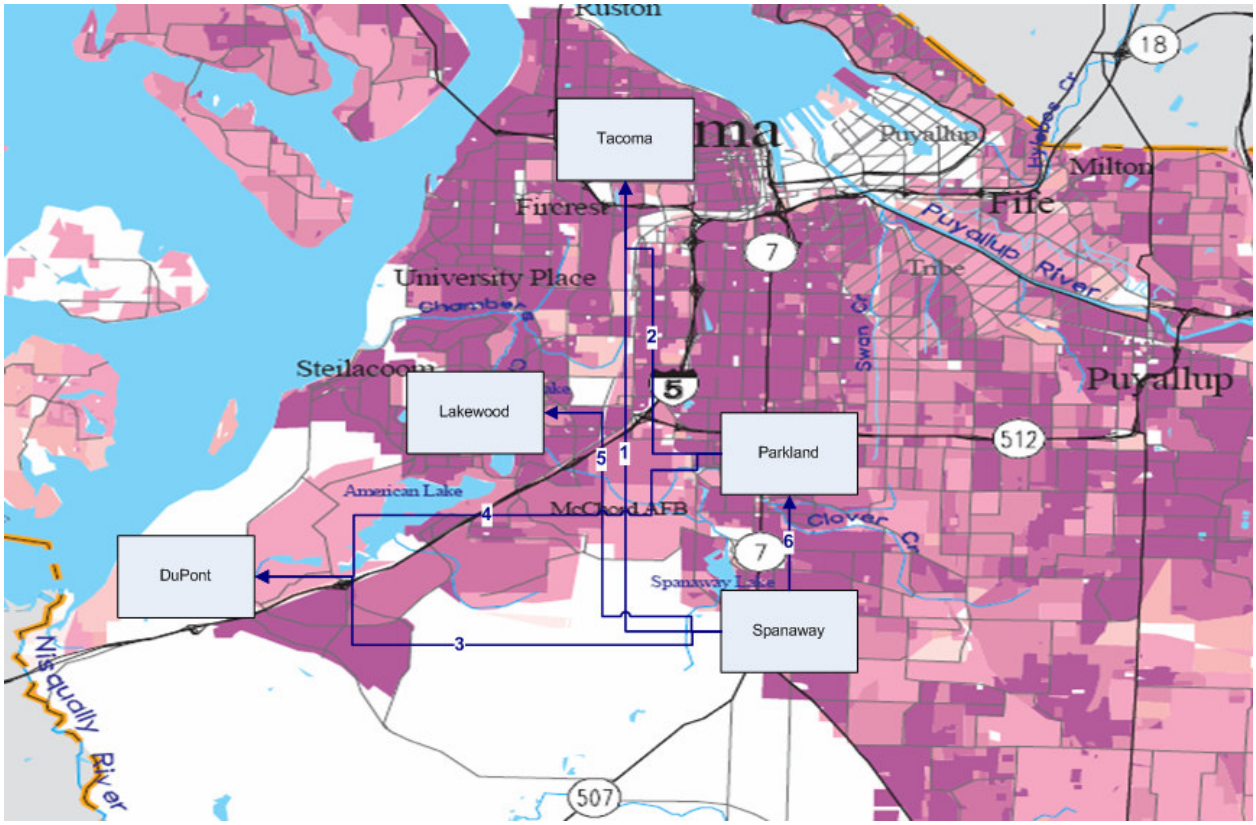
The highway segments chosen to estimate user costs savings are illustrated in Figure 1.

Figure 1: Segment Map

Additionally, six representative routes were selected for the purpose of analyzing origin-destination pairs (see Figure 2):

- Route 1: Spanaway – Tacoma;
- Route 2: Parkland – Tacoma;
- Route 3: Spanaway – DuPont;
- Route 4: Parkland – DuPont;
- Route 5: Spanaway – Lakewood; and
- Route 6: Spanaway – Parkland.

Figure 2: Map of Representative Routes



Tables 1 and 2, on the following page, show some of the basic characteristics of the selected origin-destination pairs, as reported in the Final EIS. The purpose of selecting these six representative routes was to calibrate the model to accurately reflect the distribution of traffic in the area.

Table 1: Selected Segments

Origin	Destination	Distance
168th St. and SR 7	SR 7 and SR 512	3.7
SR 7 and SR 512	SR 512 and I-5	2.2
SR 512 and I-5	I-5 and I-705	6.2
I-5 and I-705	I-705 and S. 15th St.	1.1
Spanaway	**Tacoma**	**13.2**
112th St. and SR 7	SR 7 and SR 512	0.2
SR 7 and SR 512	SR 512 and I-5	2.2
SR 512 and I-5	I-5 and I-705	6.2
I-5 and I-705	I-705 and S. 15th St.	1.1
Parkland	**Tacoma**	**9.7**
168th St. and SR 7	SR 7 and SR 512	3.7
SR 7 and SR 512	SR 512 and I-5	2.4
SR 512 and I-5	I-5 exit 123	3.8
I-5 exit 123	I-5 exit 119	4.5
Spanaway	**Dupont**	**14.4**
112th St. and SR 7	SR 7 and SR 512	0.2
SR 7 and SR 512	SR 512 and I-5	2.4
SR 512 and I-5	I-5 exit 123	3.8
I-5 exit 123	I-5 exit 119	4.5
Parkland	**Dupont**	**10.9**
168th St. and SR 7	SR 7 and SR 512	3.7
SR 7 and SR 512	SR 512 and Tacoma Way	2.5
SR 512 and Tacoma Way	Steiliacoom Blvd. and Gravelly Lake Dr. SW.	2.1
Spanaway	**Lakewood**	**8.3**
168th St. and SR 7	112th St. and SR 7	3.5
Spanaway	**Parkland**	**3.5**

Table 2: Summary of Traffic Characteristics for Selected Origin-Destination Pairs

Origin	Destination	Distance	Average Traffic Counts	Average Peak V/C
Spanaway	Tacoma	13.2	114,382	0.88
Parkland	Tacoma	9.7	139,314	0.84
Spanaway	Dupont	14.4	108,536	0.85
Parkland	Dupont	10.9	128,845	0.84
Spanaway	Lakewood	8.3	51,785	0.79
Spanaway	Parkland	3.5	45,634	0.97

3. METHODOLOGY

The analysis framework used here is identical in concept to business case evaluation in the private sector. A private firm needs to assess whether the costs, returns and risks of undertaking major investments will yield profit and shareholder value. The only difference in public sector investment appraisal is the nature of the costs, returns and risks considered in the evaluation. Since the "shareholder" is the *taxpayer*, all the effects of a project on the community at-large must be considered.

The analysis framework has two key components:

- Benefit-Cost Analysis (the name for business case analysis when conducted in the public sector); and
- Risk Analysis.

3.1 Benefit-Cost Analysis

Benefit-cost analysis evaluates the fundamental merit of undertaking possible investments. The basic idea is straightforward. An investment option 'A' is worthwhile if its economic benefits exceed its economic costs. Importantly, the benefits of the next best alternative to option 'A' are viewed as costs of option 'A'. This is because the alternative benefits are lost if 'A' is implemented. So the benefit-cost rule is: Option 'A' is economically worthwhile only if its net benefits (gross benefits minus gross costs) exceed the net benefits of the next best alternative.

3.1.1 Principles

Benefit-Cost Analysis counts all the negative and positive economic effects of an investment, regardless of how they are paid for. The fact that the federal government, the taxpayer, the road user or the passenger might pay this or that share of a project's costs under different financing plans cannot change the project's fundamental economic merit. It is fundamental merit with which we are concerned here.

Benefit-Cost Analysis treats all negative effects as costs. In addition to a project option's capital outlays, the analysis accounts for the cost of capital (interest)[2]; yearly operating expenses; and the costs associated with maintaining the infrastructure. Also included are the disruptive effects of construction, such as noise and detours.

On the other side of the coin, benefit-cost analysis treats all the positive effects as benefits. The principal categories of benefit considered in this study are those associated with congestion relief:

- Delays;

[2] More precisely, benefit-cost analysis accounts for the "opportunity cost" of capital. This reflects a combination of interest and the "time-preference" of the community for benefits now versus greater benefits later.

- Vehicle Operating Costs;
- Safety; and
- Environmental Factors.

3.1.2 Valuation

To permit the ready comparison of options, benefit-cost analysis measures benefits and costs on one scale, monetary value. Not all relevant variables in a benefit-cost analysis can be assigned a monetary value and a benefit-cost analysis cannot analyze every variable in monetary terms. Variables that cannot be assigned monetary factors must be anticipated in qualitative terms and examined separately from those variables that can be examined in monetary terms. For example, the use of public transit options may lead commuters to experience less stress in their commutes. While this may be a benefit to commuters it is not possible to place a monetary benefit upon the decreased stress level. Hence only a qualitative benefit may be assigned to such a benefit. For example, a value of 0 to 10 may be assigned based on a survey conducted of commuters.

The monetary valuation of many effects is simplified by the fact that market prices exist for many variables. For example, the cost of building a light rail station or a lane-mile of highway, hinges on the market price of land, labor and materials – prices that are easily observed. The valuation of many "non-market" effects, such as safety, environmental pollution or commuting times, is based on measurements of how much individuals are willing to pay to acquire the benefits or avoid the costs. For example, a recent California-based study found that people are willing to pay about $0.17 a minute ($10.20 an hour) to save travel time and about twice that rate for a reduction in travel time variability.[3]

3.1.3 The Opportunity Cost of Capital

An important rule for private sector investment is that new capital projects should not be undertaken if the rate of return were to be higher in low-risk, interest bearing securities (such as U.S. Treasury Bonds). Benefit-cost analysis presumes the same for public sector investments. The real-dollar (i.e., post inflation) return on low-risk securities today is approximately four percent. This study thus examines the investment alternatives under consideration in relation to a four percent benchmark, or "hurdle" rate of return. Stated differently, all costs and benefits are discounted to their present day values at a rate ("discount rate") of five percent per annum.

The above means that if the light rail option, when compared to the Base Case, fails to offer a minimum of a five percent return with minimal risk, it is not economically logical to undertake it from a taxpayer perspective. As different interest rate assumptions may have different impacts on the decision to undertake an investment and it is impossible to forecast interest rates (especially in the long-term) with certainty, the analysis performed includes scenarios with different interest rates.

[3] HLB Decision Economics Inc. and University of California, Irvine, *Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User Cost Estimation*, Transportation Research Board, National Research Council, NCHRP Report 431, 1999.

3.1.4 Evaluation Benchmarks of Economic Merit

Several criteria are used by decision-makers to determine whether investments projects are economically reasonable to undertake. The most widely used of these decision criteria are described below.

Net Present Value (NPV) – The net present value is the discounted present value of benefits minus the discounted present value of costs. The net present value is measured over the life-cycle of the project under consideration (30 years in this analysis). A net present value of greater than zero suggests that the investment is economically worthwhile.

Benefit-Cost Ratio – This is the total present value of benefits divided by the total present value of costs. A benefit-cost ratio of greater than one means that a project is economically reasonable to undertake.

Internal Rate of Return (IRR) – The internal rate of return is the discount rate that equates the present value of cash inflows with the initial investment associated with a project. In other words it is the discount rate that equates the NPV of an investment opportunity with zero (as this is the point where the present value of the cash inflows equal the initial investment). If the IRR is greater than the cost of capital of the investment then it is logical to accept the project. If IRR is equal to the cost of capital then decision makers should be indifferent between going forth and not going forth with the project as the returns on the project are the same as can be earned in an alternative investment. If IRR is less than the cost of capital, then the project would not be logical to undertake from an economic perspective.

3.2 Risk Analysis

Like business case analysis in the private sector, benefit-cost analysis involves the formulation of analysis models and estimates of future conditions. Although some models and estimates will be more reliable than others, all entail an element of uncertainty and thus pose a risk of error in the final assessment of net benefit. Risk Analysis is employed in this analysis to take into account uncertainty.

3.2.1 Principles

Risk Analysis is a departure from traditional cost estimating and forecasting methods. Traditional methods develop “most likely” outcomes. The term “most likely” equates to the statistical concept of a “mean expected outcome.” In this context, the question of risk is immaterial if the bandwidth of uncertainty around the most likely outcome is trivial. For example, if an expected mean outcome has little variation associated with it (i.e., an expected mean may be 50% and the odds are 95% that the true mean will be between 49% and 51%) the question of uncertainty does not take on a significant degree of importance. On the other hand, if an expected mean had a large variation associated with it (i.e., an expected mean may be 50% and the odds are 95% that the true mean will be between 15% and 85%) uncertainty takes on great importance.

3.2.2 Application

Risk Analysis applies an assigned probability range to every assumption in the benefit-cost analysis. These probabilities are then combined using the technique of "simulation." Simulation reflects the reality that the actual result for each estimate will differ from the assumed result according to its own probability range of uncertainty. The simulation thus yields not just the mean expected net benefits of the investment, but also the range of all other possible outcomes and their associated probabilities.

The assigned probability ranges for each assumption are drawn from two sources. The first is historic data on the actual range of a variable's variation. For example, for capital costs, the historical variation of capital costs will be calculated and used.

The second source of information regarding uncertainty is drawn from the opinions of experts in relation. For example, when the Food and Drug Administration needs to decide whether it is safe to release a new drug for public use, it presents the various scientific studies to expert panels that modify the probabilities according to their experience and expert opinion (see Appendix D for more details). This second source is of particular use when objective data (i.e., historical) is not available.

3.3 Overview of Benefit-Cost Study

This section gives an overview of the benefit-cost analysis for the Cross-Base Highway project, presenting the benefit categories and the evaluation criteria of the project.

3.3.1 Benefit Categories

Three main categories of benefits are considered in the analysis:

- *Congestion Management Benefits (transit and highway investments):* These are the savings in vehicle ownership and operating cost, travel time, accidents and environmental emissions due to less congestion and fewer miles traveled by personal vehicles resulting from the implementation of the project.

- *Affordable Mobility Benefits (transit investment only):* These are the benefits from providing low-cost mobility to low-income households.

- *Community Development Benefits (transit investment only), beyond and above the benefits resulting directly from transit use:* Proximity to transit has a positive effect on residential property values due to the increased availability of travel opportunities and the ability of others to access the residence by transit. Locational value benefits have not been quantified in this study and have thus been omitted from the analysis.

3.3.2 Investment Evaluation Criteria

The outcomes of the benefit-cost analysis will be summarized through a number of evaluation criteria, including: net benefits and measures of project worth, measures of project risk, and project timing. Each is discussed in greater detail below.

- *Net Benefits and Project Worth*

Annual net benefits are estimated as follows: total benefits in a year (congestion management benefits) minus total costs in that year. Project worth will be assessed with Net Present Value (NPV) the present-day value of the entire stream of future net benefits. The streams of costs and benefits will be discounted with an annual real discount rate, to be determined.

- *Project Risk*

The risk analysis framework to be used in the study indicates how likely it is that the project under review will fall beneath a predetermined "hurdle" rate of return, given the uncertainty associated with the relevant input variables. It will also allow for an explicit comparison of the level of risk between two (or more) projects.

- *Project Timing*

A project that shows strong returns over its economic life but fails to deliver reasonable annual returns until late in the life cycle should usually be delayed. In assessing the quality of project timing, a common rule of thumb is that a major capital investment may be considered "well timed" (neither premature nor late) if it begins to earn at least the hurdle rate of return in its first full year of operation. An analysis of the first-year rate of return will be provided for all five investment alternatives under review.

3.4 Methodology for Measuring Benefits from Transportation Improvements

This section presents the structure and logic diagrams that describes the economic benefit sub-models that are integrated into the larger benefit-cost model. These diagrams summarize, in graphical form, the logic behind how congestion management benefits and other economic benefits stemming from transportation improvement investments in the Cross-Base Highway area are derived.

For each benefit sub-model, the input variables are first defined and then they are given estimates and ranges taken from the best available information. The sources of the estimates are also provided for each variable.

The sub-models presented in this section cover the cost savings resulting from the implementation of the project. The savings include the following:

- Travel Time Cost Savings
- Vehicle Operating Cost Savings
- Accident Cost Savings
- Emission Cost Savings

The methodology used to assess these cost savings, along with the underlying assumptions, is discussed in Chapter 4.

3.4.1 Model Overview

The figure below provides a brief overview as to how, on a strategic level, all cost savings listed above, contribute to aggregate annual savings expected to be derived from the implementation of the project. The "base case" is the pre-project implementation scenario while the "alternative case" is the scenario after the project has been implemented.

Figure 3: Structure and Logic Diagram for Estimating Transportation Improvement Benefits

4. S&L DIAGRAMS AND ESTIMATING ASSUMPTIONS

Various economic assumptions are needed to build a model to estimate the costs and benefits of a given project. This chapter presents the estimation methodology for each of the model components and describes the economic assumptions for each. The assumptions draw from historical data and existing literature.

4.1 Cost Savings from Transportation Improvements

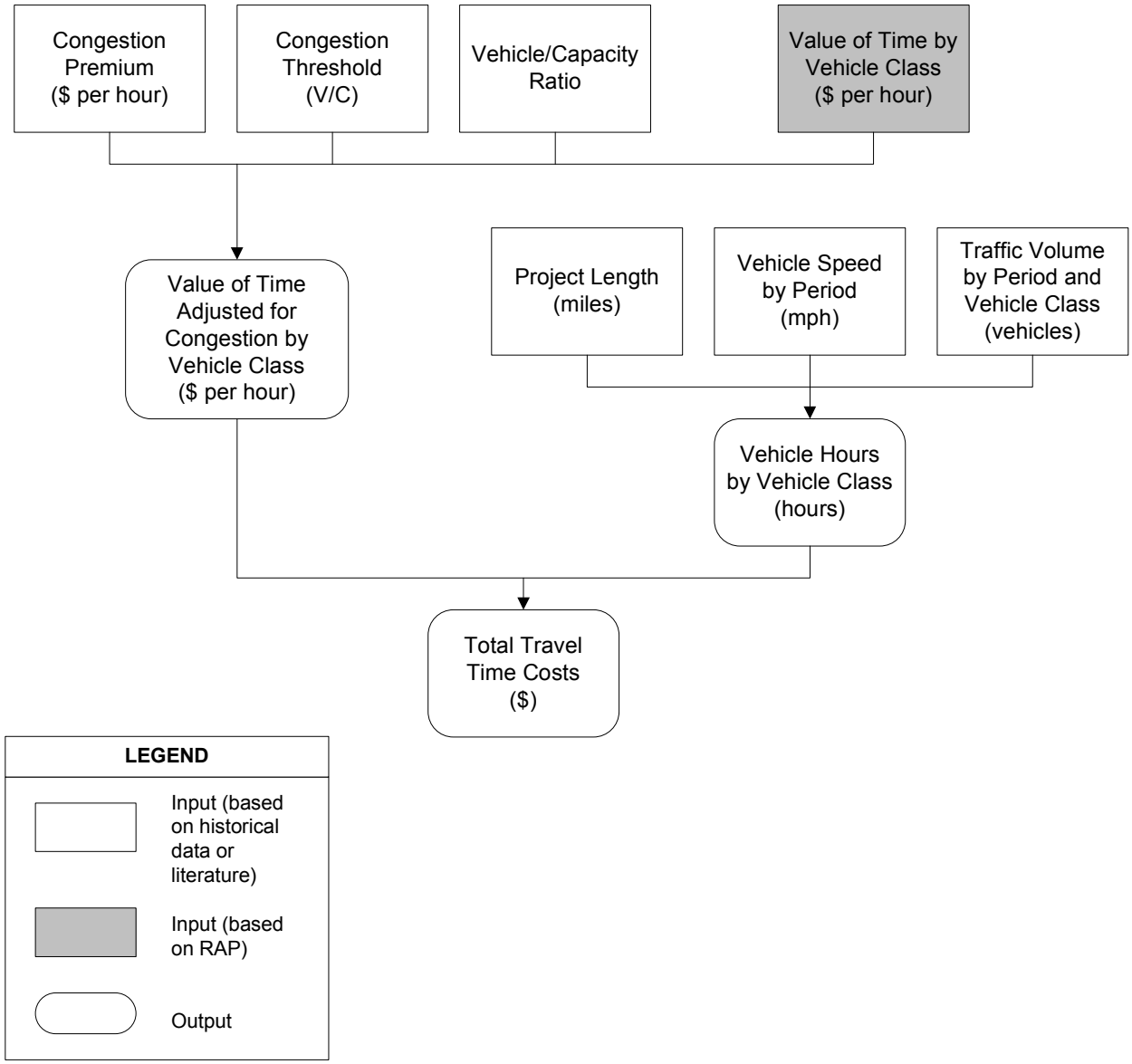
This section introduces the structure and logic diagrams used to evaluate benefits associated with transportation improvement investments and discuss the underlying economic assumptions for the input variables to and sub-model.

4.1.1 Travel Time Savings

Travel time savings are estimated by calculating the difference between travel time costs in the base case (pre-project investment) and travel time costs in the alternate case (post-project investment). Travel time costs are estimated by multiplying total vehicle hours traveled by vehicle class (derived from average vehicle speed and updated traffic projections from the Final EIS), by an estimate of the value of time, adjusted for congestion. This is illustrated in Figure 4, below.[4]

[4] A "congestion premium", expressed in dollars per hour, is added to the value of time when congestion, measured by the volume-to-capacity ratio, exceeds a given threshold.

Figure 4: Structure and Logic Diagram for Estimating Travel Time Savings



In the above figure, the white boxes are based on data that is obtained from historical sources, surveys or literature searches. The shaded boxes are based on input obtained from RAP sessions (sessions whereby subject matter experts provide their opinions). The white ovals represent output that is derived from combining the two aforementioned types of inputs. The data used in the input boxes based on historical data, surveys or literature surveys is discussed below. The sources for the data are also listed.

Value of Travel Time by Vehicle Class ($ per hour)

Description:
This variable is the cost per hour of traveling in a vehicle. The variable is expressed as 2006 dollars per hour of travel.

How the Variable Affects the Model:
The model uses the value of travel time by vehicle class to estimate travel time savings. A higher travel time value leads to larger travel time savings.

Assumptions:

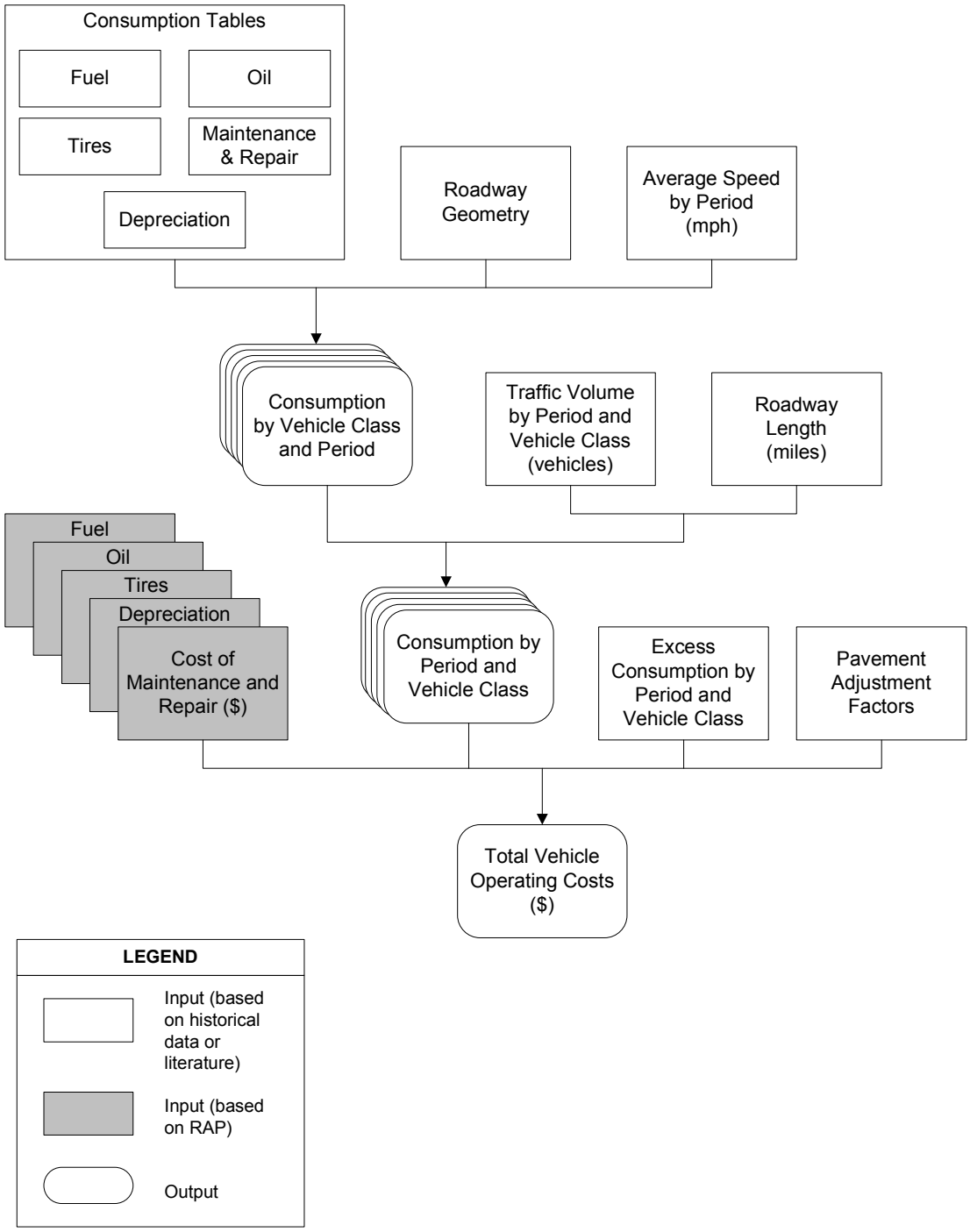
Value of Travel Time ($/hour)	Median Estimate	10% Lower Limit	10% Upper Limit
Auto	$12.50	$10.00	$15.00
Buses	$12.50	$10.00	$15.00
Truck	$45.00	$40.00	$50.00

Source:
Federal Highway Administration, *Highway Economic Requirements System Technical Report*, U.S. Department of Transportation, December 2000; U. S. Department of Transportation, *The Value of Saving Travel Time: Departmental Guidance for Conducting Economic Evaluations*, April 1997. Ranges are based on Regional Rail Study.

4.1.2 Vehicle Operating Cost Savings

The structure and logic diagram for estimating Vehicle Operating Costs (VOC) in the base and alternate cases is shown in Figure 5, below. Operating costs are estimated from parameters and relationships developed by the Texas Transportation Institute for the National Cooperative Highway Research Program.

Figure 5: Structure and Logic Diagram for Estimating Vehicle Operating Cost Savings



The data used in the input boxes based on historical data, surveys or literature surveys is discussed below. The sources for the data are also listed.

Vehicle Operating Costs

Description:
The vehicle operating costs include annual driving and ownership costs (excluding parking costs). The associated variables are expressed in dollars per unit of consumption.

How the Variable Affects the Model:
The model uses those unit costs to estimate the vehicle operating cost savings. Higher unit costs lead to larger vehicle operating cost savings.

Assumptions:

Variable	Vehicle Type	Median Estimate	10% Lower Limit	10% Upper Limit
Cost of Fuel ($ per gallon)*	Auto	$2.67	$2.22	$3.20
	Truck	$2.74	$2.26	$3.26
Cost of Oil ($ per quart)	Auto	$4.42	$3.74	$5.26
	Truck	$1.77	$1.52	$2.10
Cost of Tire ($ per tire)	Auto	$80.60	$67.70	$96.20
	Truck	$582.14	$484.91	$698.81
Maintenance and Repair ($)	Auto	$130.27	$108.09	$156.54
	Truck	$434.97	$362.33	$521.19
Vehicle Depreciation ($ per Vehicle)	Auto	$25,770	$20,620	$30,920
	Truck	$106,660	$90,040	$128,820

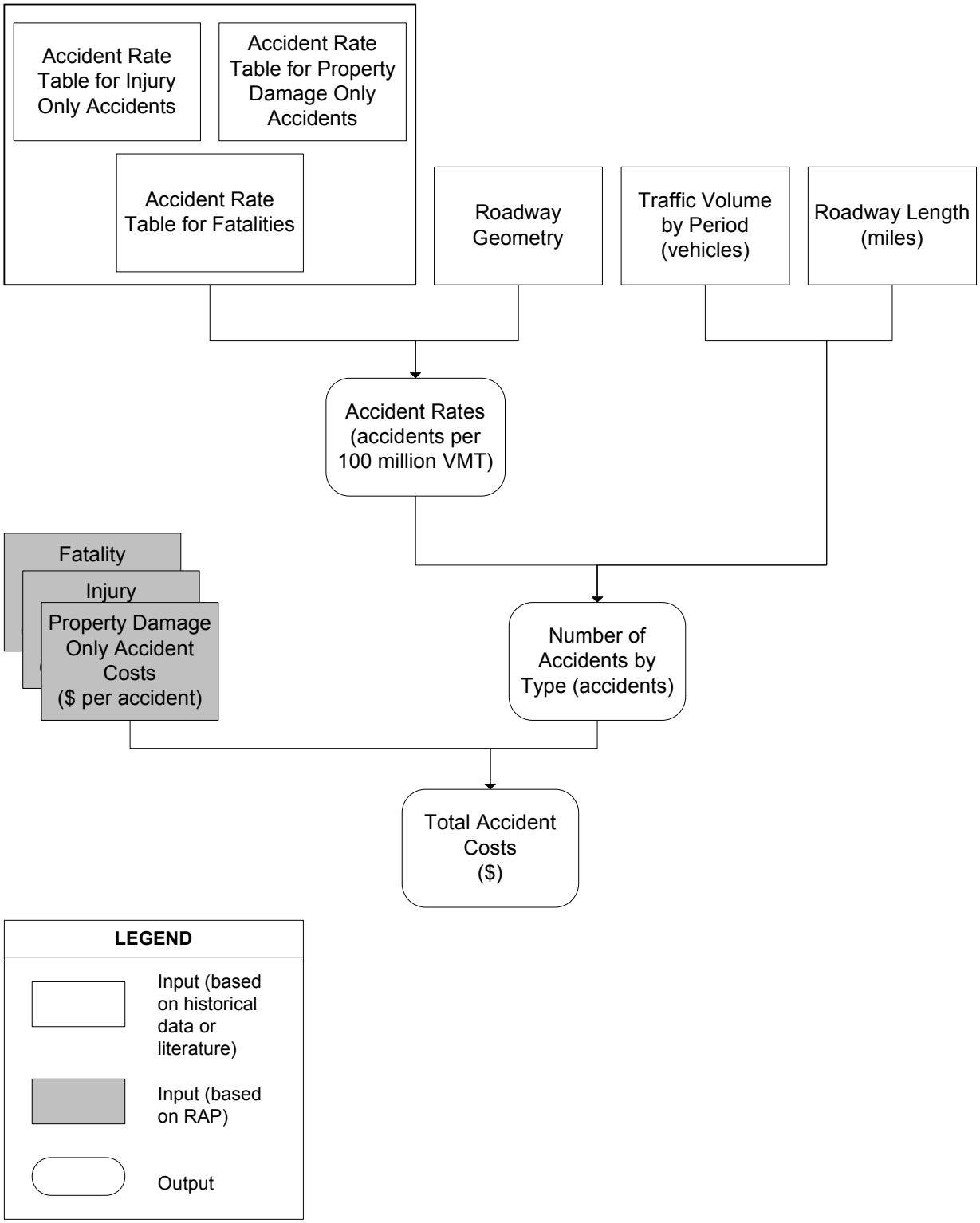
* Excluding taxes

Source:
AAA Daily Fuel Gauge Report; Federal Highway Administration, *Highway Economic Requirements System Technical Report*, U.S. Department of Transportation, December 2000.

4.1.3 Accident Cost Savings

StratBENCOST uses incident rate tables developed for the Federal Highway Administration. Incident rates, expressed as the number of fatalities, injuries, and Property Damage Only (PDO) accidents per 100 million Vehicle Miles Traveled (VMT) are estimated under alternative highway designs (geometry) and traffic levels, and combined with accident unit costs to arrive at total accident costs, in the base and alternate cases. This is illustrated in Figure 6, below. Accident rate tables can be found in the Appendix. A description of the data assumptions can be found immediately underneath the figure.

Figure 6: Structure and Logic Diagram for Estimating Accident Cost Savings



Accident Costs

Description:
This variable is the average cost per fatal, injury only, and property damage only accident. The variable is expressed in year 2006 dollars per accident.

How the Variable Affects the Model:
The model uses the accident cost by type of accident to estimate the net reduction in accident costs.

Assumptions:

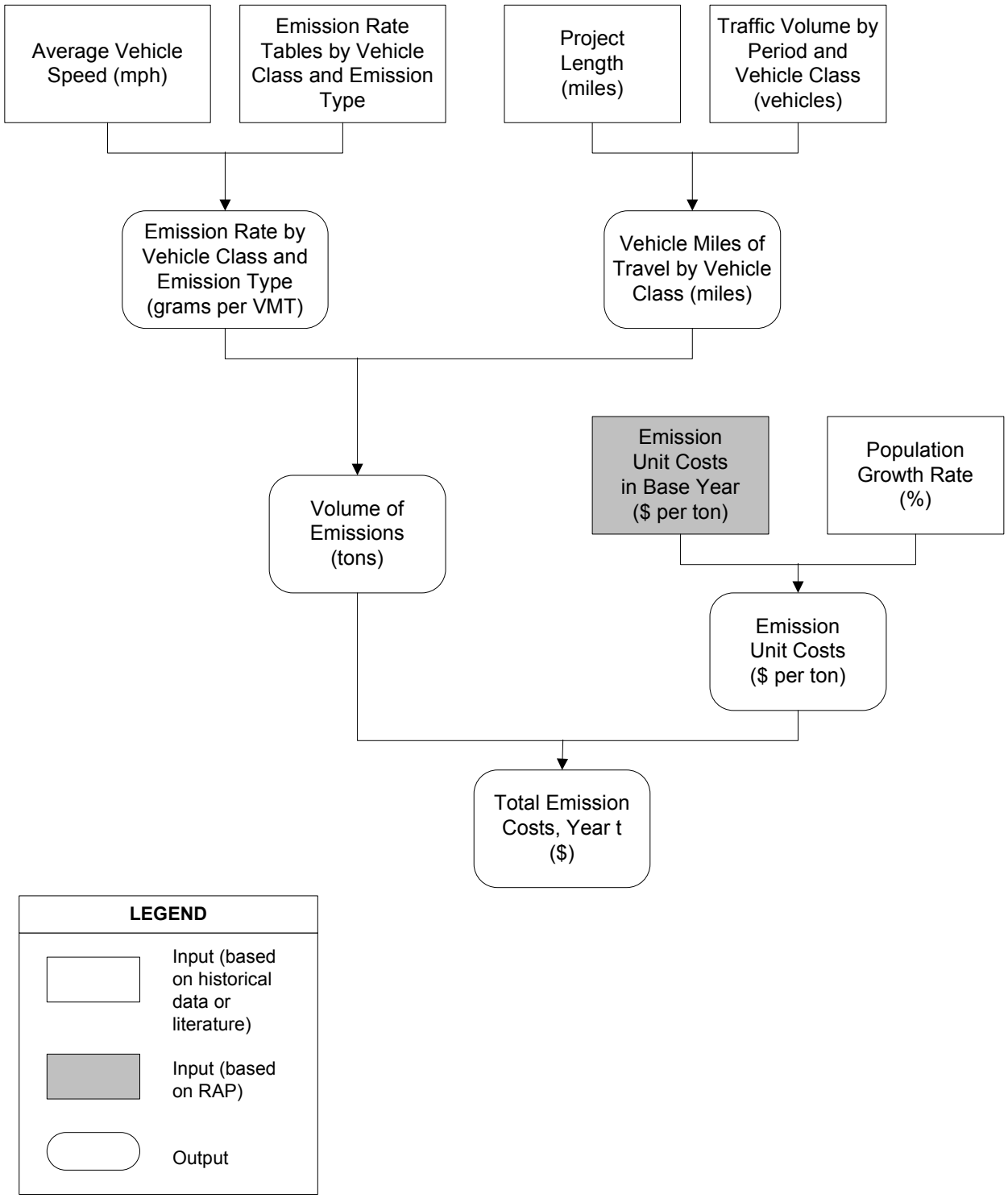
Accident Costs ($/accident)	Median Estimate	10% Lower Limit	10% Upper Limit
Fatal Accident	$3,930,000	$2,000,000	$6,000,000
Injury Accident	$52,000	$25,000	$75,000
Property Damage Accident	$3,000	$1,500	$4,500

Source:
National Highway Traffic Safety Administration, *The Economic Impact of Motor Vehicle Crashes 2000*, U.S. Department of Transportation, May 2002.

4.1.4 Emission Cost Savings

As illustrated in Figure 7, below, emission volumes in the base and alternate cases are estimated from average vehicle speed, emission rate tables (emission factors as a function of average vehicle speed and vehicle class), and traffic levels. The volumes of emissions are combined with unit damage values (expressed in $ per ton of pollutants) to arrive at total emission costs. The Emission Rate Tables by Vehicle Class and Emission type can be found in *StratBENCOST*. *StratBENCOST* has data for all major pollutants, including Hydro Carbon (HC), Carbon Monoxide (CO), and Nitrogen Oxides (NO_x).

Figure 7: Structure and Logic Diagram for Estimating Emission Cost Savings



Emission Costs

Description:
This variable describes the estimated average emission cost by vehicle emission. The variable is expressed in year 2009 dollars per ton of vehicle emission.

How the Variable Affects the Model:
The model uses the annual emission costs to estimate the net reduction of emission cost due to transportation improvements.

Assumptions:

Emission Costs ($/ton)	Median Estimate	10% Lower Limit	10% Upper Limit
Hydro Carbon	$1,000	$500	$2,000
Carbon Monoxide	$115	$59	$201
Nitrogen Oxide	$4,179	$768	$8,276

Source:
Federal Highway Administration, *Highway Economic Requirements System Technical Report*, U.S. Department of Transportation, December 2000.

4.2 Other Assumptions Used in Estimating Travel Costs

There are several other variables considered in estimating travel cost savings, such as growth in annual average daily traffic (AADT), percentage truck traffic, variables affecting transit use, the discount rate, and traffic characteristics in the peak period. Each of these variables is discussed below in detail.

Projected Growth in Average Daily Vehicle Traffic along the Six Routes in the Study Area

Description:
This variable represents the average daily traffic (ADT) growth between 2006 and 2030. The traffic volumes are expressed as the count of annual daily vehicles traveling along each of the six routes. Population growth is the main determinant of growth in ADT.

How the Variable Affects the Model:
The model uses projected ADT to estimate total travel time savings. A faster ADT growth leads to larger travel time savings for highway users resulting from diversion to transit.

Assumptions:

ADT Growth (%)	Median Estimate	10% Lower Limit	10% Upper Limit
2006 – 2010	1.41%	0.50%	2.16%
2011-2020	1.27%	0.29%	2.19%
2021-2030	0.98%	0.15%	2.19%

Source:
Population Estimates for Pierce County, Puget Sound Regional Council County Forecasts, December 2003.

Truck Traffic as Percentage of Total Traffic

Description:
This variable is the share of trucks in total highway traffic on I-5, SR 7, and SR 512. It is expressed as a percentage of average daily traffic.

How the Variable Affects the Model:
A higher percentage leads to a higher overall traffic count attributed to truck traffic.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
I-5	9%	8%	10%
SR 7	9%	8%	10%
SR 512	9%	8%	10%

Source:
Washington State Department of Transportation, "2005 Annual Traffic Report."

Average LRT Fare

Description:
The average fare to be charged per light rail trip. The variable is expressed in year 2006 dollars.

How the Variable Affects the Model:
The model uses the average LRT fare to estimate travel cost savings due to LRT for low-income travelers. A higher LRT fare reduces the savings due to LRT for these individuals.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Average LRT Fare ($ per trip)	$2.50	$2.00	$3.00

Source:
Median estimate and range based on fare levels in the Pierce County region; Pierce Transit website (www.piercetransit.org).

Percentage of Transit Riders below Poverty Level

Description:
The percentage of transit riders whose annual revenue is less than or equal to the poverty level as defined by the U.S. Department of Health and Human Resources.

How the Variable Affects the Model:
The model uses this variable to estimate the baseline travel demand of low-income people. A higher percentage means a higher ridership of low-income people.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Percentage of Transit Riders Below Poverty Level (%)	28%	20%	35%

Source:
David Lewis and Fred Laurence Williams (1999). "Policy and Planning as Public Choice: Mass Transit in the United States." p. 144.

Percentage of Transit Trips by Purposes

Description:
The percentage of trips for medical purposes as part of all LRT trips and the percentage of trips for work purposes as part of all LRT trips.

How the Variable Affects the Model:
Affects the potential for cross-sector savings.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Percentage of Trips for Medical Purposes (%)	5%	3%	7%
Percentage of Trips for Work Purposes (%)	54%	48%	60%

Source:
David Lewis and Fred Laurence Williams (1999). "Policy and Planning as Public Choice: Mass Transit in the United States." p. 172.

Discount Rate

Description:
The discount rate can be thought as the interest rate that can be gained from a risk-free investment (opportunity cost).

How the Variable Affects the Model:
The model uses the discount rate to estimate the net present value of expected yearly benefits and costs. Selecting a lower discount rate will increase the present value of future benefits.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Discount Rate (%)	5%	5%	5%

Source:
Office of Management and Budget, Circular No. A-94, Appendix C (Revised February 2002).

Peak Period Characteristics

Description:
The length of the peak period represents the average number of hours peak traffic levels are experienced in a typical weekday. The percent of traffic in peak period represents the relative ratio of average daily traffic that occurs in the peak period compared to the overall average.

How the Variable Affects the Model:
A long peak period would indicate that traffic levels are high for an extended period of time. A higher percentage of traffic in the peak period indicates more traffic, relative to the average annual daily traffic, occurs within the peak traffic period.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Length of Peak Period (hours, morning and evening peak)	4	3	5
Percent of Traffic in Peak Period (%)	30%	29%	34%

Source:
Washington State Department of Transportation (September 2003). "Cross-Base Highway (State Route 704), I-5 to SR 7: Final Environmental Impact Statement"

Average Vehicle Occupancy

Description:
Average vehicle occupancy refers to the typical number of passengers traveling in a personal vehicle (auto).

How the Variable Affects the Model:
This variable is important in assessing the transit alternative. In order to understand how traffic is diverted from the roadway to transit, it is necessary to estimate ridership. Traffic volumes combined with average vehicle occupancy provides an estimate of the number of people typically using the current roadway. It is estimated that a percentage of these individuals will use transit, if available.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Average Vehicle Occupancy	1.14	1.10	1.24

Source:
Puget Sound Regional Council; Washington State Department of Transportation (September 2003). "Cross-Base Highway (State Route 704), I-5 to SR 7: Final Environmental Impact Statement"

4.3 Other Assumptions

Several other assumptions related to project construction were made by the consultant team. These variables are outlined in the table below.

Other Assumptions

Variable	**Median**	**Source**
Opening Year of SR 704	2010	HDR|HLB Assumption
Start of Construction	2007	HDR|HLB Assumption
Duration of Construction in Years	3	HDR|HLB Assumption
Period of Analysis in Years	30	HDR|HLB Assumption

5. SIMULATION RESULTS

This chapter presents the results of the benefit-cost analysis for the Cross-Base Highway project for 3 different alternatives. The benefits have been estimated over a 30-year horizon, from 2006 to 2035.

5.1 Alternative 1: SR 704 Build Alternative

Table 3, below, presents a summary of the simulation results under the build alternative in terms of gross benefits, costs, and net benefits. The table displays the most likely estimate of project benefits and costs under alternative 1, along with the range of projected benefits at the 80% confidence level. Additionally, an estimate of the internal rate of return, net present value, payback period and first year of return are provided. All dollar amounts are given in 2006 dollars.

Under the build alternative, project costs are significantly outweighed by benefits over the 30-year forecast period, with a benefits-cost ratio of 2.57. Travel time savings is the main driver of congestion management benefits under this alternative, accounting for about half of total project benefits. Total project benefits are estimated around $1,000 million, while costs are expected to be between $293 million and $353 million. The modified internal rate of return for this alternative exceeds 6.3%. The results of this simulation suggest that the build alternative is economically logical to implement.

Table 3: Detailed Benefits, Costs, and Net Benefits for Alternative 1

ALTERNATIVE 1: Build Alternative

Simulation Results
Millions of Dollars of 2006, Unless Stated Otherwise
5% Real Discount Rate
30 Year Horizon, 2006-2035

Categories of Benefits	Mean	Lower 10%	Upper 10%
Congestion Management			
Travel Time Savings	$458.7	$258.5	$1,299.8
Accident Cost Savings	$369.7	$199.9	$539.3
Vehicle Operating Cost Savings	$185.9	$142.2	$259.9
Emission Cost Savings	$2.0	$1.2	$6.3
Total Congestion Management	**$1,016.3**	**$601.8**	**$2,105.3**
Grand Total Benefits	**$1,016.3**	**$601.8**	**$2,105.3**
Project Costs			
Capital Costs	$323.7	$293.5	$353.3
Incremental O&M Costs	$156.5	$0.0	$172.4
Total Project Costs	**$480.2**	**$293.5**	**$525.6**
Net Present Value	**$536.1**	**$308.3**	**$1,579.7**
Modified Internal Rate of Return, %	6.3%	4.8%	9.1%
Payback Period, Years	15.0	11.0	20.0
First Year Return, %	10.5%	7.7%	14.4%

Annual project benefits under the build scenario are shown in Figure 8. Cumulative benefits include travel time savings, accident cost savings, vehicle operating cost savings and emission cost savings.

Figure 8: Annual Project Benefits for Alternative 1

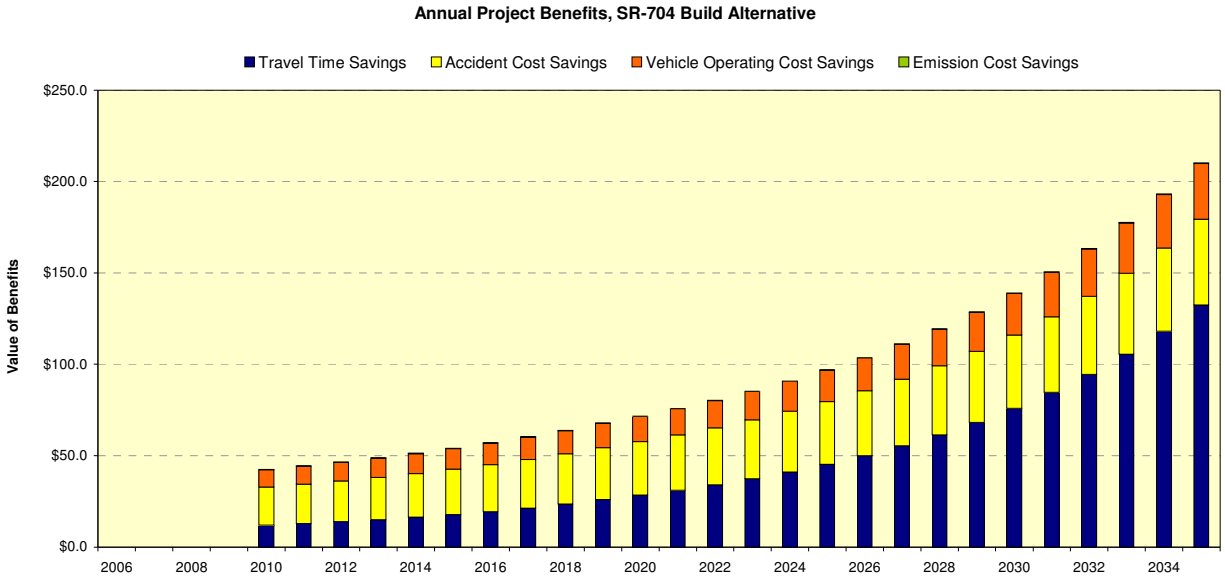


Figure 9 shows that the benefits over the project lifespan clearly outweigh the project costs. Most of the project costs occur in the first 3 years of the project, during the construction. Relatively small operating costs, compared to the benefits of the highway, are incurred after the construction phase is complete.

Figure 9: Project Benefits and Costs for Alternative 1

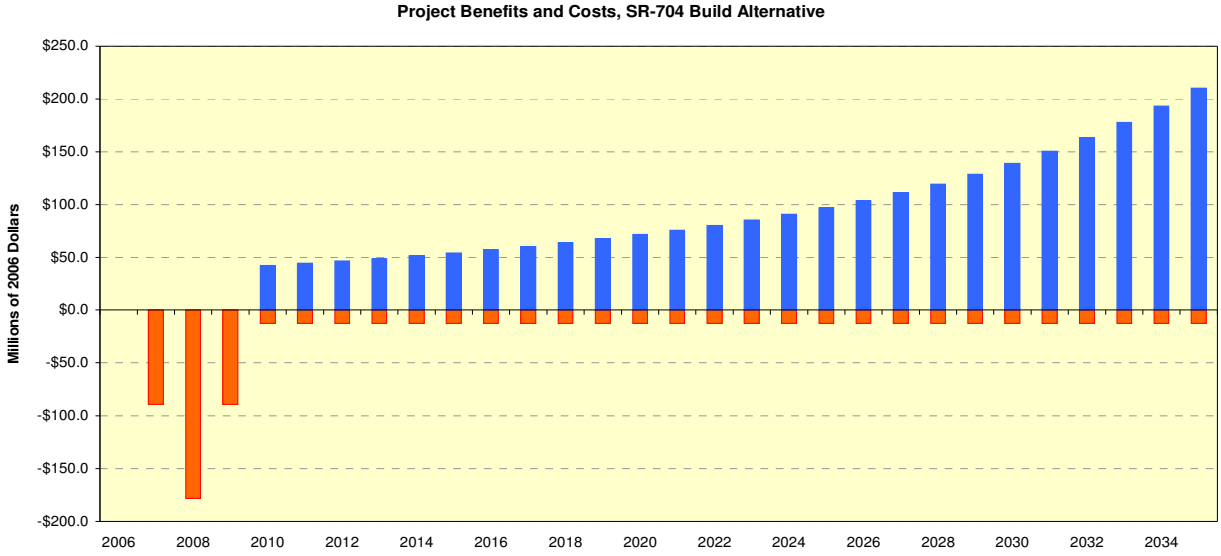


Table 4 shows the tangible benefits from alternative 1 over the 30-year forecasting horizon in terms of travel time savings, fuel savings, and lives saved. In the base year, travel time savings to users of the new highway would be around 6.4 minutes due to shorter travel distances. By the year 2035 savings is estimated to reach almost 30 minutes. For those travelers not using the new route, travel time savings in the base year are projected around 1.5 minutes. This is expected to increase to 23 minutes by the year 2035 as a result of congestion relief from traffic being diverted to the Cross-Base Highway. Savings are also realized in terms of fuel savings and lives saved. Fuel consumption to users of the new route is expected to be around 1/10 of a gallon, while that of users of alternate routes is estimated to be approximately 3/100 of a gallon. Approximately 0.2 lives would be saved per year as a result of the Cross-Base Highway being built (1 life saved every 5 years).

Table 4: Tangible Benefits for Alternative 1

Alternative 5 - Build Alternative	2010	2015	2020	2025	2030	2035
PEAK PERIOD TRAVEL TIME						
BASE CASE (HOV)						
TRAVELERS ON HOV LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
TRAVELERS ON GP LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
BUILD + HOV						
TRAVELERS ON HOV LANES	12.7 min	12.8 min	12.9 min	13.0 min	13.1 min	13.4 min
TRAVELERS ON GP LANES	12.8 min	12.8 min	12.9 min	13.0 min	13.2 min	13.5 min
TRAVELERS ON NEW ROUTE	7.9 min	7.9 min	7.9 min	7.9 min	7.9 min	7.9 min
PEAK PERIOD TRAVEL TIME SAVINGS PER TRIP						
BUILD + HOV						
TRAVELERS ON HOV LANES	1.6 min	2.9 min	5.3 min	8.7 min	14.1 min	23.0 min
TRAVELERS ON GP LANES	1.5 min	2.9 min	5.3 min	8.6 min	14.0 min	22.9 min
TRAVELERS ON NEW ROUTE	6.4 min	7.8 min	10.3 min	13.7 min	19.3 min	28.4 min
HOURS SAVED PER DAY	1,936.8 hr	3,140.8 hr	5,349.9 hr	8,551.2 hr	13,984.0 hr	23,223.3 hr
HOURS SAVED PER YEAR	581,052.6 hr	942,251.8 hr	1,604,968.6 hr	2,565,345.5 hr	4,195,198.2 hr	6,966,975.2 hr

Alternative 5 - Build Alternative	2010	2015	2020	2025	2030	2035
PEAK PERIOD FUEL CONSUMPTION						
BASE CASE (HOV)						
TRAVELERS ON HOV LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.45 gal
TRAVELERS ON GP LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.46 gal
BUILD + HOV						
TRAVELERS ON HOV LANES	0.30 gal	0.30 gal	0.30 gal	0.31 gal	0.31 gal	0.32 gal
TRAVELERS ON GP LANES	0.30 gal	0.30 gal	0.31 gal	0.31 gal	0.32 gal	0.33 gal
TRAVELERS ON NEW ROUTE	0.24 gal	0.24 gal	0.24 gal	0.24 gal	0.24 gal	0.24 gal
PEAK PERIOD FUEL SAVINGS PER TRIP						
BUILD + HOV						
TRAVELERS ON HOV LANES	0.036 gal	0.044 gal	0.060 gal	0.078 gal	0.103 gal	0.133 gal
TRAVELERS ON GP LANES	0.031 gal	0.039 gal	0.054 gal	0.073 gal	0.098 gal	0.126 gal
TRAVELERS ON NEW ROUTE	0.095 gal	0.104 gal	0.122 gal	0.145 gal	0.176 gal	0.212 gal
GALLONS OF FUEL SAVED PER DAY	2,113.4 gal	2,838.6 gal	4,132.8 gal	5,537.7 gal	7,318.8 gal	9,096.3 gal
GALLONS OF FUEL SAVED PER YEAR	634,006.5 gal	851,585.6 gal	1,239,854.9 gal	1,661,310.1 gal	2,195,643.8 gal	2,728,884.3 gal

Alternative 5 - Build Alternative	2010	2015	2020	2025	2030	2035
NUMBER OF LIVES SAVED PER YEAR	0.170 lives	0.181 lives	0.192 lives	0.201 lives	0.211 lives	0.222 lives

5.2 Alternative 2: SR 7 Widening

Table 5 below presents a summary of the simulation results under the widening alternative in terms of gross benefits, costs, and net benefits. Overall, the benefit-cost ratio for this alternative is 1.69, suggesting that the project would be economically worthwhile to undertake. The expected modified internal rate of return is 3.7%. Total costs for the project are estimated to range between $257 million and $282 million. Nearly 75% of benefits are realized in terms of travel time savings under this alternative. Congestion management benefits are projected to be between $87 million and $1,010 million. This wide variance is due to the high uncertainty surrounding the initial congestion benefits assumptions.

Table 5: Detailed Benefits, Costs, and Net Benefits for Alternative 2

ALTERNATIVE 2: SR 7 Widening

Simulation Results
Millions of Dollars of 2006, Unless Stated Otherwise
5% Real Discount Rate
30 Year Horizon, 2006-2035

Categories of Benefits	Mean	Lower 10%	Upper 10%
Congestion Management			
Travel Time Savings	$223.7	$69.5	$873.6
Accident Cost Savings	$10.8	-$14.0	$16.8
Vehicle Operating Cost Savings	$61.1	$35.5	$118.2
Emission Cost Savings	-$2.2	-$3.9	$1.3
Total Congestion Management	**$293.4**	**$87.1**	**$1,010.0**
Grand Total Benefits	**$293.4**	**$87.1**	**$1,010.0**
Project Costs			
Capital Costs	$215.2	$206.7	$223.6
Incremental O&M Costs	$55.1	$51.2	$59.0
Total Project Costs	**$270.4**	**$257.9**	**$282.6**
Net Present Value	**$23.0**	**-$170.8**	**$727.3**
Modified Internal Rate of Return, %	3.7%	-0.8%	8.5%
Payback Period, Years	28.0	16.0	30.0
First Year Return, %	1.9%	0.7%	4.9%

Annual project benefits under the SR 7 widening scenario are represented in Figure 10. Cumulative benefits are calculated based on travel time savings, accident cost savings, vehicle operating cost savings and emission cost savings. The value of the benefits under the widening alternative is projected to have a high rate of growth over the 30-year period assessed, especially with respect to travel time savings.

Figure 10: Annual Project Benefits for Alternative 2

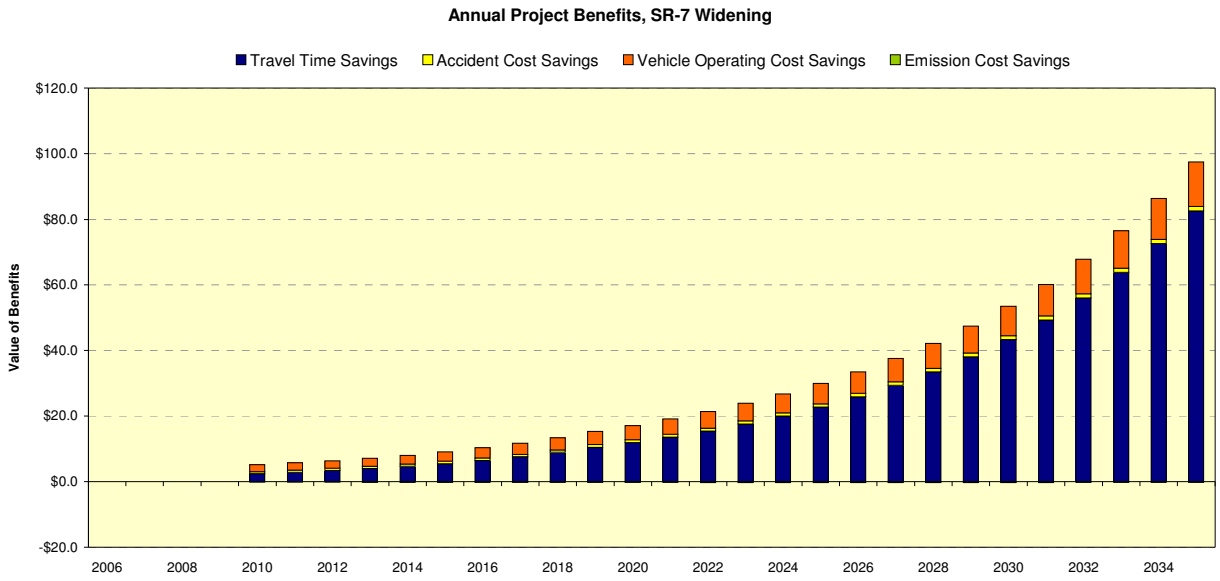


Figure 11 shows that the benefits outweigh the project costs over time. Most of the project costs occur in the first 5 years of the project, during the construction. However, relative to project benefits, construction costs are rather high. When compared to the benefits of the widening, the project costs incurred after the construction phase is complete are small.

Figure 11: Project Benefits and Costs for Alternative 2

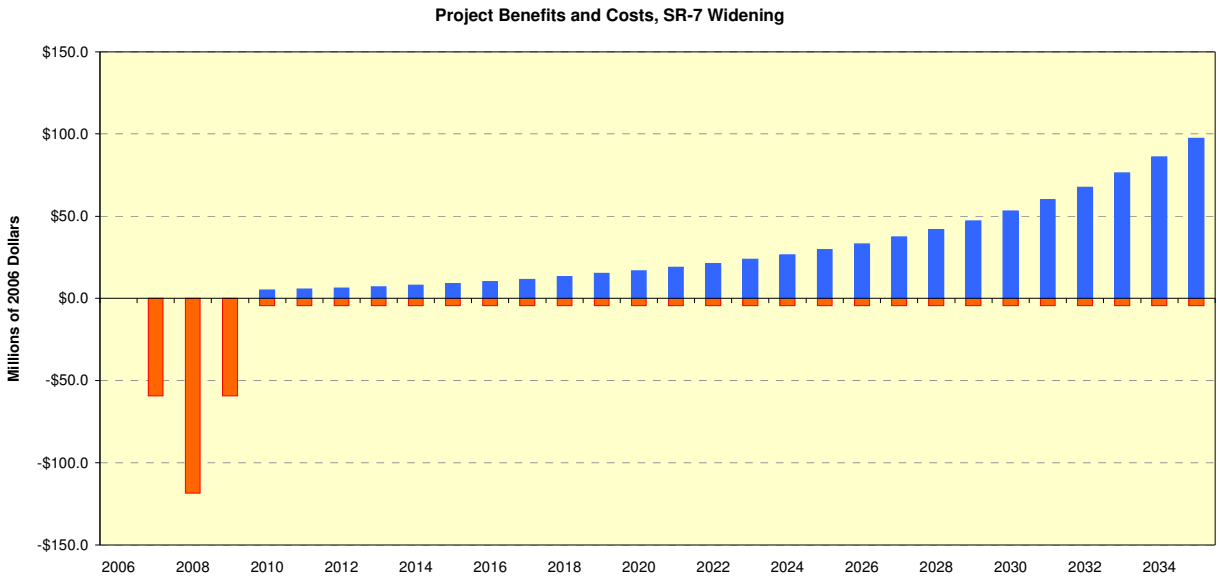


Table 6 shows the tangible benefits from alternative 2 over the 30-year forecasting horizon in terms of travel time savings, fuel savings and lives saved. In the base year, travel time savings are expected to be around 1.6 minutes and are projected to increase to 23.2 minutes by the year

2035. The reduction in travel time is attributed to congestion relief from the lane widening. Fuel consumption savings are only expected to be a little over 1/10 of a gallon by the year 2035. The number of lives saved per year is negligible under this alternative.

Table 6: Tangible Benefits for Alternative 2

Alternative 2 - SR 7 Widening	2010	2015	2020	2025	2030	2035
PEAK PERIOD TRAVEL TIME						
BASE CASE						
TRAVELERS ON HOV LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
TRAVELERS ON GP LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
SR-7 WIDENING						
OTHER TRAVELERS HOV	12.7 min	12.7 min	12.8 min	12.9 min	13.0 min	13.1 min
OTHER TRAVELERS GP	12.7 min	12.8 min	12.8 min	12.9 min	13.0 min	13.1 min
PEAK PERIOD TRAVEL TIME SAVINGS PER TRIP						
SR-7 WIDENING						
OTHER TRAVELERS HOV	1.6 min	3.0 min	5.4 min	8.8 min	14.3 min	23.2 min
OTHER TRAVELERS GP	1.6 min	3.0 min	5.4 min	8.8 min	14.3 min	23.2 min
HOURS SAVED PER DAY	401.1 hr	801.1 hr	1,550.9 hr	2,649.8 hr	4,527.5 hr	7,735.8 hr
HOURS SAVED PER YEAR	120,320.9 hr	240,326.3 hr	465,262.3 hr	794,950.3 hr	1,358,257.3 hr	2,320,727.5 hr

Alternative 2 - SR 7 Widening	2010	2015	2020	2025	2030	2035
PEAK PERIOD FUEL CONSUMPTION						
BASE CASE						
TRAVELERS ON HOV LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.45 gal
TRAVELERS ON GP LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.46 gal
SR-7 WIDENING						
OTHER TRAVELERS HOV	0.30 gal	0.30 gal	0.30 gal	0.31 gal	0.31 gal	0.32 gal
OTHER TRAVELERS GP	0.30 gal	0.30 gal	0.30 gal	0.31 gal	0.31 gal	0.32 gal
PEAK PERIOD FUEL SAVINGS PER TRIP						
SR-7 WIDENING						
OTHER TRAVELERS HOV	0.033 gal	0.041 gal	0.059 gal	0.080 gal	0.105 gal	0.136 gal
OTHER TRAVELERS GP	0.033 gal	0.041 gal	0.059 gal	0.080 gal	0.105 gal	0.136 gal
GALLONS OF FUEL SAVED PER DAY	511.3 gal	672.9 gal	1,012.0 gal	1,449.1 gal	2,006.8 gal	2,713.6 gal
GALLONS OF FUEL SAVED PER YEAR	153,391.9 gal	201,875.8 gal	303,598.6 gal	434,723.8 gal	602,050.5 gal	814,083.2 gal

Alternative 2 - SR 7 Widening	2010	2015	2020	2025	2030	2035
NUMBER OF LIVES SAVED PER YEAR	0.019 lives	0.020 lives	0.021 lives	0.022 lives	0.024 lives	0.025 lives

5.3 Alternative 3: Transit Development

Table 7 presents a summary of the simulation results under the transit alternative in terms of gross benefits, costs, and net benefits. Total project costs exceed total benefits under this alternative, with a benefit-cost ratio being 0.80. The modified internal rate of return for this project is projected to be between -1.3% and 4.1%. Project costs are relatively high under this alternative, ranging from $662.9 million to $815.1 million. Total project benefits, which are expected to be around $498 million under the transit alternative, are realized in terms of affordable mobility and congestion management, with congestion management benefits accounting for more than 90% of total project benefits. The largest source of benefits under this alternative is in terms of vehicle operating cost savings, which range from $227 million to $314 million. This accounts for nearly 64% of congestion management benefits and 53% of total project benefits.

Table 7: Detailed Benefits, Costs, and Net Benefits for Alternative 3

ALTERNATIVE 3: Transit Development

Simulation Results
Millions of Dollars of 2006, Unless Stated Otherwise
5% Real Discount Rate
30 Year Horizon, 2006-2035

Categories of Benefits	Mean	Lower 10%	Upper 10%
Affordable Mobility			
Value to Low-Income Households	$31.0	$18.0	$44.9
Cross Sector Benefits	$48.0	$23.5	$75.6
Total Affordable Mobility	**$79.0**	**$41.4**	**$120.4**
Congestion Management			
Travel Time Savings	$119.7	$43.3	$458.9
Accident Cost Savings	$28.0	-$7.9	$48.4
Vehicle Operating Cost Savings	$264.6	$227.0	$314.5
Emission Cost Savings	$7.3	$2.4	$13.8
Total Congestion Management	**$419.6**	**$264.8**	**$835.6**
Grand Total Benefits	**$498.6**	**$306.2**	**$956.0**
Project Costs			
Capital Costs	$467.4	$404.7	$531.8
Incremental O&M Costs	$270.7	$258.1	$283.3
Total Project Costs	**$738.1**	**$662.9**	**$815.1**
Net Present Value	**-$239.5**	**-$356.7**	**$141.0**
Modified Internal Rate of Return, %	0.8%	-1.3%	4.1%
Payback Period, Years	30.0	28.0	30.0
First Year Return, %	2.9%	2.3%	3.9%

Annual project benefits under the transit alternative are represented in Figure 12. Cumulative benefits are calculated using travel time savings, accident cost savings, vehicle operating cost savings, and emission cost savings. The value of the benefits under the transit alternative is projected to have a high rate of growth over the 30-year period assessed, particularly due to vehicle operating cost savings.

Figure 12: Annual Project Benefits for Alternative 3

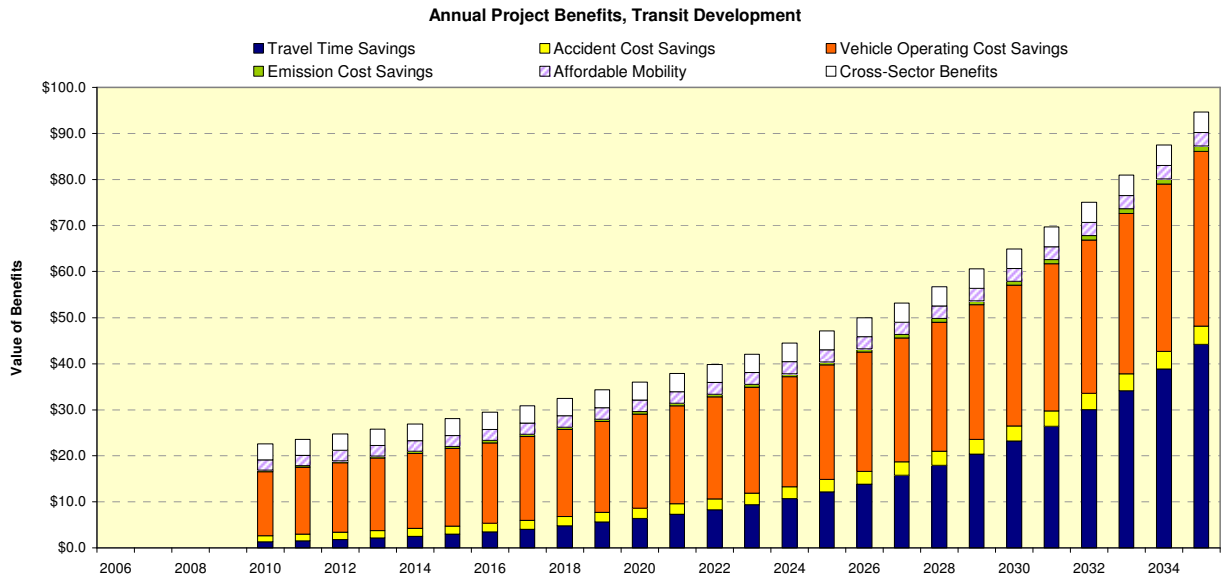


Figure 13 shows that the cost of implementing the transit alternative is very high, particularly in the first 3 years of the project.

Figure 13: Project Benefits and Costs for Alternative 3

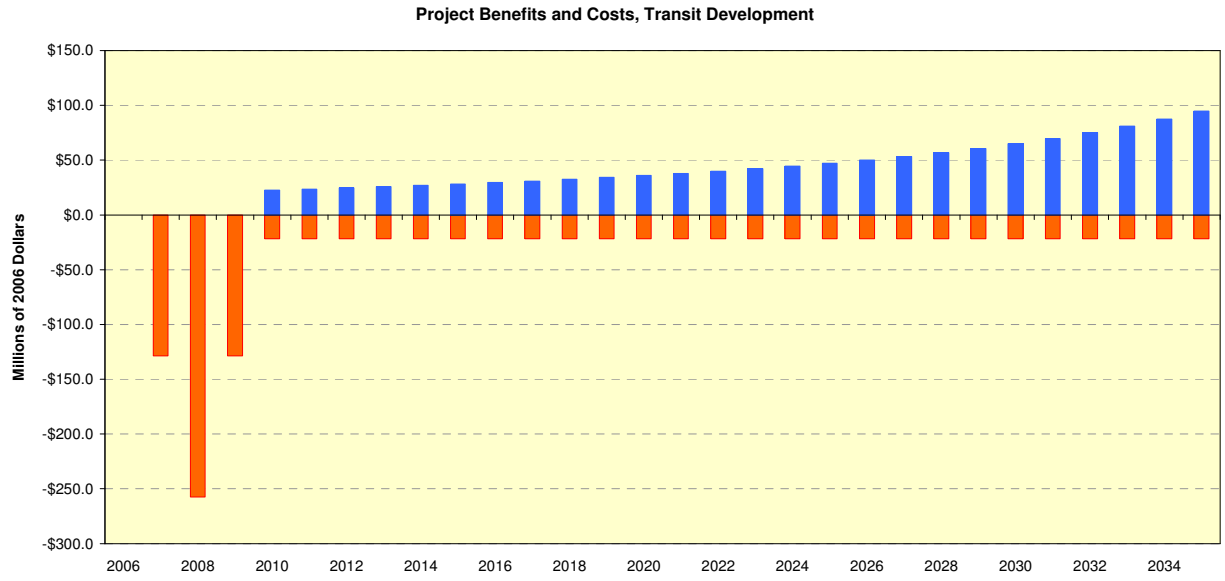


Table 8 shows the tangible benefits from alternative 3 over the 30-year forecasting horizon in terms of travel time savings, fuel savings and lives saved. Travel time savings for those individuals choosing not to use transit are expected to be slightly less than 1 minute in the base year. This reduction in travel time is due to congestion relief from traffic being diverted from the highway to transit. By the year 2035, travel time savings is projected to reach nearly 13 minutes.

Fuel consumption savings in the base year is estimated at 1/100 of a gallon, but is forecast to increase to 1/20 of a gallon by the year 2035. The number of lives saved under this alternative is not very significant, with about 1 life saved every 20 years.

Table 8: Tangible Benefits for Alternative 3

Alternative 3 - Transit Development	2010	2015	2020	2025	2030	2035
PEAK PERIOD TRAVEL TIME						
BASE CASE						
TRAVELERS ON HOV LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
TRAVELERS ON GP LANES	14.3 min	15.7 min	18.2 min	21.6 min	27.2 min	36.3 min
TRANSIT						
TRANSIT USERS / ROUTE SHIFTERS						
OTHER TRAVELERS HOV	13.4 min	14.1 min	15.2 min	16.8 min	19.4 min	23.5 min
OTHER TRAVELERS GP	13.4 min	14.1 min	15.2 min	16.8 min	19.4 min	23.5 min
PEAK PERIOD TRAVEL TIME SAVINGS PER TRIP						
TRANSIT						
TRANSIT USERS / ROUTE SHIFTERS	0.0 min	0.0 min	0.0 min	0.0 min	0.0 min	0.0 min
OTHER TRAVELERS HOV	0.9 min	1.6 min	3.0 min	4.8 min	7.9 min	12.8 min
OTHER TRAVELERS GP	0.9 min	1.6 min	3.0 min	4.8 min	7.9 min	12.8 min
HOURS SAVED PER DAY	215.5 hr	430.4 hr	833.3 hr	1,423.8 hr	2,432.8 hr	4,156.7 hr
HOURS SAVED PER YEAR	64,652.1 hr	129,134.6 hr	249,999.5 hr	427,150.8 hr	729,832.8 hr	1,246,997.2 hr

Alternative 3 - Transit Development	2010	2015	2020	2025	2030	2035
PEAK PERIOD FUEL CONSUMPTION						
BASE CASE	0.34 gal	0.36 gal	0.39 gal	0.43 gal	0.46 gal	0.49 gal
TRAVELERS ON HOV LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.45 gal
TRAVELERS ON GP LANES	0.33 gal	0.34 gal	0.36 gal	0.39 gal	0.42 gal	0.46 gal
TRANSIT						
TRANSIT USERS / ROUTE SHIFTERS						
OTHER TRAVELERS HOV	0.32 gal	0.33 gal	0.34 gal	0.35 gal	0.37 gal	0.40 gal
OTHER TRAVELERS GP	0.32 gal	0.33 gal	0.34 gal	0.35 gal	0.37 gal	0.40 gal
PEAK PERIOD FUEL SAVINGS PER TRIP						
TRANSIT						
TRANSIT USERS / ROUTE SHIFTERS	0.05 gal	0.09 gal	0.19 gal	0.29 gal	0.37 gal	0.39 gal
OTHER TRAVELERS HOV	0.008 gal	0.009 gal	0.020 gal	0.033 gal	0.046 gal	0.056 gal
OTHER TRAVELERS GP	0.010 gal	0.010 gal	0.022 gal	0.035 gal	0.047 gal	0.057 gal
GALLONS OF FUEL SAVED PER DAY	796.5 gal	1,440.7 gal	3,401.1 gal	5,403.7 gal	7,338.4 gal	8,299.2 gal
GALLONS OF FUEL SAVED PER YEAR	238,963.9 gal	432,199.7 gal	1,020,332.4 gal	1,621,104.1 gal	2,201,516.8 gal	2,489,749.3 gal

Alternative 3 - Transit Development	2010	2015	2020	2025	2030	2035
NUMBER OF LIVES SAVED PER YEAR	0.042 lives	0.045 lives	0.047 lives	0.050 lives	0.052 lives	0.055 lives

5.4 Summary Tables

Table 9 below shows a comparison summary of benefits for all three alternatives. Alternative 1 has the highest benefit to cost ratio and internal rate of return (see Figures 14 and 15). However, alternative 2 had nearly a high enough rate of return to make it a viable alternative. Additionally, the benefit-cost ratio for this alternative is over one. Alternative 1 is extremely likely to exceed the viability threshold as it is more than 95% likely to have a benefit-cost ratio over 1. Alternative 2 has a median benefit-cost ratio of 1.12 and is likely to exceed the threshold of 1 about 55% of the time. Alternative 3 has the most risk, as it is likely to only exceed the benefit-cost threshold 20% of the time and has a median benefit-cost ratio of 0.7.

Table 9: Summary of Simulation Results

SUMMARY

Mean Expected Outcomes
Millions of Dollars of 2006, Unless Stated Otherwise
5% Real Discount Rate
30 Year Horizon, 2006-2035

Categories of Benefits	ALT1 - BUILD	ALT2 - SR7	ALT3 - LRT
Affordable Mobility			
Value to Low-Income Households	$0.0	$0.0	$31.0
Cross Sector Benefits	$0.0	$0.0	$48.0
Total Affordable Mobility	**$0.0**	**$0.0**	**$79.0**
Locational Value			
Residential Development	$0.0	$0.0	TBD
Commercial Development	$0.0	$0.0	TBD
Total Locational Value	**$0.0**	**$0.0**	**$0.0**
Congestion Management			
Travel Time Savings	$458.7	$223.7	$119.7
Accident Cost Savings	$369.7	$10.8	$28.0
Vehicle Operating Cost Savings	$185.9	$61.1	$264.6
Emission Cost Savings	$2.0	-$2.2	$7.3
Total Congestion Management	**$1,016.3**	**$293.4**	**$419.6**
Grand Total Benefits	**$1,016.3**	**$293.4**	**$498.6**
Project Costs			
Capital Costs	$323.7	$215.2	$467.4
Incremental O&M Costs	$156.5	$55.1	$270.7
Total Project Costs	**$480.2**	**$270.4**	**$738.1**
Net Present Value	**$536.1**	**$23.0**	**-$239.5**
Benefit/Cost Ratio	2.12	1.09	0.68
Modified Internal Rate of Return, %	6.3%	3.7%	0.8%
Payback Period, Years	15.0	28.0	30.0
First Year Return, %	10.5%	1.9%	2.9%

Figures 14 and 15 illustrate the internal rate of return and the benefit-cost ratio for the five alternatives considered, respectively. According to both of these criteria, alternative 1 would be the most favorable.

Figure 14: Comparison of Alternatives Based on Modified Internal Rate of Return

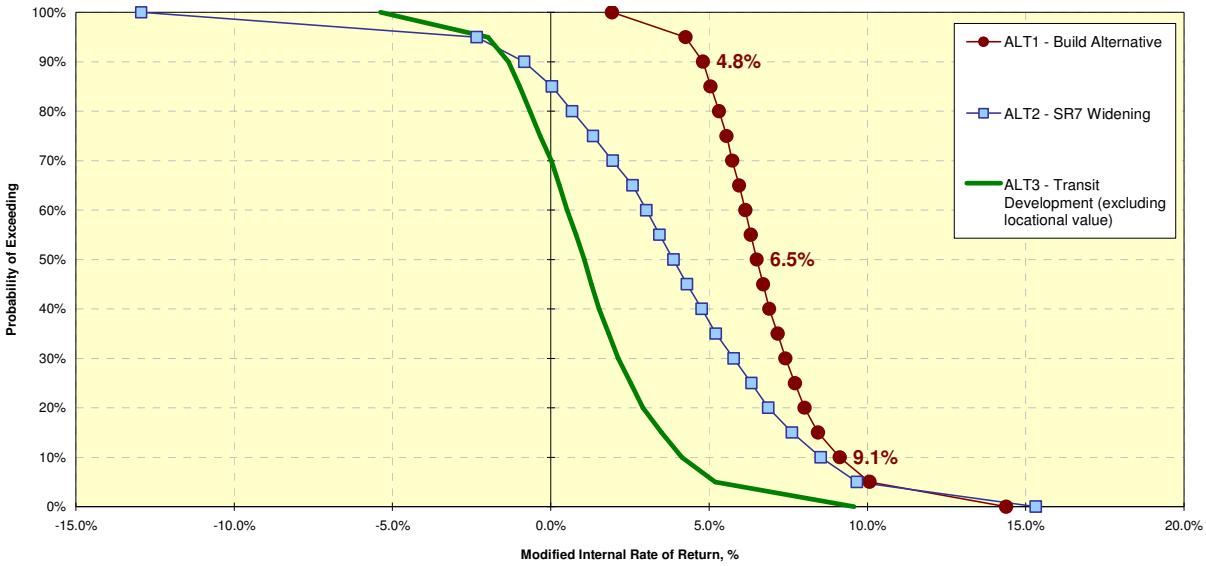
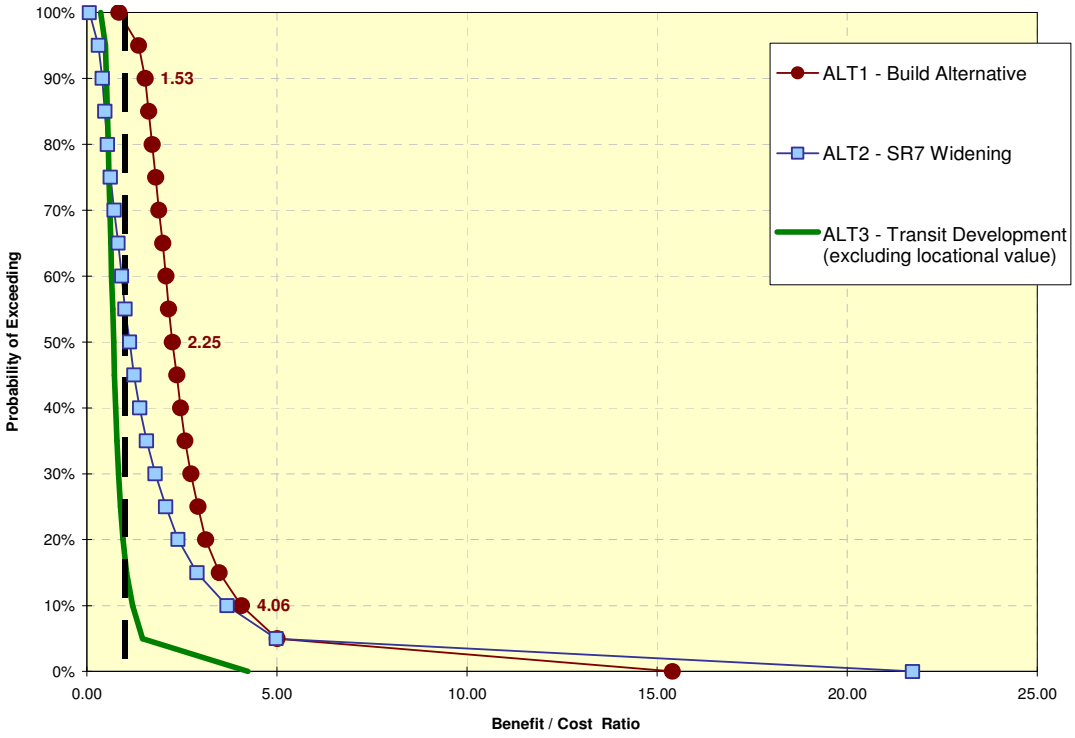


Figure 15: Comparison of Alternatives Based on Benefit-Cost Ratio



APPENDIX A: REFERENCES AND DATA SOURCES

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APPENDIX B: TRAFFIC SUMMARY TABLES AND STUDY AREA MAP

Traffic Summary Tables

Summary Calculations - Base Case - HOV Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	0	0.00	2.20	$0	0	N/A	$0	N/A
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	0	0.00	3.80	$0	0	N/A	$0	N/A
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	21,076	0.43	2.20	$18,332,377	16,923,991	$1.08	$9,565,212	$0.57
b	112th St. and SR 7	SR 7 and SR 512	0.2	58,164	1.14	0.60	$7,029,007	4,245,984	$1.66	$3,667,497	$0.86
c	SR 512 and I-5	I-5 exit 123	3.8	32,053	0.59	3.80	$48,433,650	44,457,529	$1.09	$25,271,035	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	149,402	0.98	5.24	$280,377,005	245,392,874	$1.14	$146,291,204	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	51,321	1.09	8.32	$102,681,489	65,562,982	$1.57	$53,575,715	$0.82
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,776	0.83	0.77	$10,418,862	7,076,639	$1.47	$5,436,209	$0.77
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	23,497	0.48	2.20	$25,430,441	18,868,335	$1.35	$6,552,813	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	64,846	1.27	1.12	$11,397,381	4,733,791	$2.41	$2,936,831	$0.62
c	SR 512 and I-5	I-5 exit 123	3.8	35,735	0.65	3.81	$67,229,970	49,565,114	$1.36	$17,323,546	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	166,566	1.09	6.69	$397,174,622	273,585,285	$1.45	$102,342,345	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	57,217	1.22	13.67	$158,803,081	73,095,305	$2.17	$40,919,734	$0.56
f	168th St. and SR 7	SR 7 and 176th St.	0.5	43,231	0.92	0.82	$14,694,861	7,889,652	$1.86	$3,786,512	$0.48
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	25,901	0.53	2.20	$34,878,048	20,798,506	$1.68	$4,438,376	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	71,480	1.40	2.40	$21,025,853	5,218,043	$4.03	$2,675,627	$0.51
c	SR 512 and I-5	I-5 exit 123	3.8	39,391	0.72	3.83	$92,284,681	54,635,469	$1.69	$11,743,608	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	183,606	1.20	10.30	$579,477,129	301,572,196	$1.92	$73,740,865	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	63,071	1.34	26.98	$272,970,022	80,572,724	$3.39	$34,736,566	$0.43
f	168th St. and SR 7	SR 7 and 176th St.	0.5	47,653	1.01	0.92	$20,565,264	8,696,738	$2.36	$2,617,015	$0.30
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Summary Calculations - Base Case - GP Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	97,353	0.73	2.22	$68,064,783	78,174,251	$0.87	$68,064,783	$0.87
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	148,057	0.75	3.84	$181,782,876	205,355,466	$0.89	$181,782,876	$0.89
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	83,756	0.57	2.20	$72,081,680	67,256,380	$1.07	$37,609,774	$0.56
b	112th St. and SR 7	SR 7 and SR 512	0.2	58,164	1.14	0.60	$7,029,007	4,245,984	$1.66	$3,667,497	$0.86
c	SR 512 and I-5	I-5 exit 123	3.8	127,380	0.58	3.80	$192,427,785	176,675,377	$1.09	$100,402,287	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	149,402	0.98	5.24	$280,377,005	245,392,874	$1.14	$146,291,204	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	51,321	1.09	8.32	$102,681,489	65,562,982	$1.57	$53,575,715	$0.82
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,776	0.83	0.77	$10,418,862	7,076,639	$1.47	$5,436,209	$0.77
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	93,379	0.64	2.20	$100,034,536	74,983,252	$1.33	$25,776,493	$0.34
b	112th St. and SR 7	SR 7 and SR 512	0.2	64,846	1.27	1.12	$11,397,381	4,733,791	$2.41	$2,936,831	$0.62
c	SR 512 and I-5	I-5 exit 123	3.8	142,014	0.65	3.81	$267,100,666	196,973,051	$1.36	$68,825,416	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	166,566	1.09	6.69	$397,174,622	273,585,285	$1.45	$102,342,345	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	57,217	1.22	13.67	$158,803,081	73,095,305	$2.17	$40,919,734	$0.56
f	168th St. and SR 7	SR 7 and 176th St.	0.5	43,231	0.92	0.82	$14,694,861	7,889,652	$1.86	$3,786,512	$0.48
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	102,931	0.70	2.21	$137,286,813	82,653,802	$1.66	$17,470,316	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	71,480	1.40	2.40	$21,025,853	5,218,043	$4.03	$2,675,627	$0.51
c	SR 512 and I-5	I-5 exit 123	3.8	156,541	0.72	3.83	$366,631,662	217,122,773	$1.69	$46,655,397	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	183,606	1.20	10.30	$579,477,129	301,572,196	$1.92	$73,740,865	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	63,071	1.34	26.98	$272,970,022	80,572,724	$3.39	$34,736,566	$0.43
f	168th St. and SR 7	SR 7 and 176th St.	0.5	47,653	1.01	0.92	$20,565,264	8,696,738	$2.36	$2,617,015	$0.30
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Summary Calculations - Alternative 1: Build Alternative - HOV Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	0	0.00	2.20	$0	0	N/A	$0	N/A
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	0	0.00	3.80	$0	0	N/A	$0	N/A
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	15,327	0.31	2.20	$13,301,970	12,307,518	$1.08	$6,940,516	$0.56
b	112th St. and SR 7	SR 7 and SR 512	0.2	39,797	0.78	0.35	$4,327,528	2,905,147	$1.49	$2,257,957	$0.78
c	SR 512 and I-5	I-5 exit 123	3.8	25,451	0.47	3.80	$38,271,149	35,300,636	$1.08	$19,968,586	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	147,205	0.97	5.14	$275,495,603	241,784,156	$1.14	$143,744,254	$0.59
e	168th St. and SR 7	112th St. and SR 7	3.5	35,993	0.77	5.68	$66,635,876	45,981,460	$1.45	$34,768,338	$0.76
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$9,197,101	6,292,435	$1.46	$4,798,735	$0.76
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	30,423	0.30	6.00	$89,260,342	84,145,853	$1.06	$46,577,191	$0.55

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	17,088	0.35	2.20	$18,448,274	13,721,490	$1.34	$4,753,676	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	44,369	0.87	0.36	$6,073,893	3,238,910	$1.88	$1,565,096	$0.48
c	SR 512 and I-5	I-5 exit 123	3.8	28,375	0.52	3.80	$53,098,876	39,356,214	$1.35	$13,682,303	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	164,117	1.08	6.39	$389,591,685	269,561,972	$1.45	$100,388,405	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	40,128	0.85	5.83	$93,425,719	51,264,125	$1.82	$24,073,560	$0.47
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$11,432,992	6,292,435	$1.82	$2,946,007	$0.47
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	42,837	0.42	6.00	$123,830,866	93,813,103	$1.32	$31,908,235	$0.34

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	18,836	0.39	2.20	$25,296,473	15,125,155	$1.67	$3,219,081	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	48,907	0.96	0.39	$8,462,599	3,570,240	$2.37	$1,076,901	$0.30
c	SR 512 and I-5	I-5 exit 123	3.8	31,278	0.57	3.80	$72,841,598	43,382,230	$1.68	$9,269,395	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	180,906	1.19	9.51	$562,598,283	297,137,311	$1.89	$71,592,961	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	44,233	0.94	6.22	$130,172,832	56,508,283	$2.30	$16,565,032	$0.29
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$14,212,447	6,292,435	$2.26	$1,808,593	$0.29
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	47,219	0.46	6.00	$169,836,222	103,409,887	$1.64	$21,612,363	$0.21

Summary Calculations - Alternative 1: Build Alternative - GP Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	97,353	0.73	2.22	$68,064,783	78,174,251	$0.87	$68,064,783	$0.87
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	148,057	0.75	3.84	$181,782,876	205,355,466	$0.89	$181,782,876	$0.89
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	86,853	0.59	2.20	$74,777,441	69,742,603	$1.07	$39,016,330	$0.56
b	112th St. and SR 7	SR 7 and SR 512	0.2	39,797	0.78	0.35	$4,327,528	2,905,147	$1.49	$2,257,957	$0.78
c	SR 512 and I-5	I-5 exit 123	3.8	144,223	0.66	3.81	$218,261,323	200,036,936	$1.09	$113,881,350	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	147,205	0.97	5.14	$275,495,603	241,784,156	$1.14	$143,744,254	$0.59
e	168th St. and SR 7	112th St. and SR 7	3.5	35,993	0.77	5.68	$66,635,876	45,981,460	$1.45	$34,768,338	$0.76
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$9,197,101	6,292,435	$1.46	$4,798,735	$0.76
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	30,423	0.30	6.00	$69,260,342	84,145,853	$1.06	$46,577,191	$0.55

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	96,831	0.66	2.21	$103,787,394	77,755,110	$1.33	$26,743,515	$0.34
b	112th St. and SR 7	SR 7 and SR 512	0.2	44,369	0.87	0.36	$6,073,893	3,238,910	$1.88	$1,565,096	$0.48
c	SR 512 and I-5	I-5 exit 123	3.8	160,792	0.74	3.84	$303,107,229	223,018,546	$1.36	$78,103,441	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	164,117	1.08	6.39	$389,591,685	269,561,972	$1.45	$100,388,405	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	40,128	0.85	5.83	$93,425,719	51,264,125	$1.82	$24,073,560	$0.47
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$11,432,992	6,292,435	$1.82	$2,946,007	$0.47
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	42,837	0.42	6.00	$123,830,866	93,813,103	$1.32	$31,908,235	$0.34

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	106,736	0.73	2.22	$142,460,854	85,709,212	$1.66	$18,128,734	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	48,907	0.96	0.39	$6,073,893	3,570,240	$1.70	$1,076,901	$0.30
c	SR 512 and I-5	I-5 exit 123	3.8	177,241	0.81	3.89	$303,107,229	245,832,639	$1.23	$53,139,356	$0.22
d	I-5 exit 123	I-5 exit 119	4.5	180,906	1.19	9.51	$389,591,685	297,137,311	$1.31	$71,592,961	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	44,233	0.94	6.22	$93,425,719	56,508,283	$1.65	$16,565,032	$0.29
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$11,432,992	6,292,435	$1.82	$1,808,593	$0.29
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	47,219	0.46	6.00	$123,830,866	103,409,887	$1.20	$21,612,363	$0.21

Summary Calculations - Alternative 2: SR 7 Widening GP Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	97,353	0.73	2.22	$68,481,315	78,174,251	$0.88	$68,481,315	$0.88
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	148,057	0.75	3.84	$181,782,876	205,355,466	$0.89	$181,782,876	$0.89
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,046,765	58,297,559	$1.20	$70,046,765	$1.20
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,348,821	6,292,435	$1.17	$7,348,821	$1.17
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	83,756	0.57	2.20	$72,524,409	67,256,380	$1.08	$37,840,775	$0.56
b	112th St. and SR 7	SR 7 and SR 512	0.2	58,164	0.76	0.35	$6,320,350	4,245,984	$1.49	$3,297,744	$0.78
c	SR 512 and I-5	I-5 exit 123	3.8	127,380	0.58	3.80	$192,427,785	176,675,377	$1.09	$100,402,287	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	149,402	0.98	5.24	$280,377,005	245,392,874	$1.14	$146,291,204	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	51,321	0.73	5.65	$93,827,890	65,562,982	$1.43	$48,956,208	$0.75
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,776	0.55	0.75	$10,180,068	7,076,639	$1.44	$5,311,614	$0.75
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	93,379	0.64	2.20	$100,648,125	74,983,252	$1.34	$25,934,601	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	64,846	0.85	0.36	$8,844,702	4,733,791	$1.87	$2,279,067	$0.48
c	SR 512 and I-5	I-5 exit 123	3.8	142,014	0.65	3.81	$267,100,666	196,973,051	$1.36	$68,825,416	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	166,566	1.09	6.69	$397,174,622	273,585,285	$1.45	$102,342,345	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	57,217	0.81	5.74	$130,678,279	73,095,305	$1.79	$33,672,649	$0.46
f	168th St. and SR 7	SR 7 and 176th St.	0.5	43,231	0.61	0.75	$14,119,347	7,889,652	$1.79	$3,638,216	$0.46
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	102,931	0.70	2.21	$138,127,599	82,653,802	$1.67	$17,577,309	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	71,480	0.94	0.38	$12,304,933	5,218,043	$2.36	$1,565,854	$0.30
c	SR 512 and I-5	I-5 exit 123	3.8	156,541	0.72	3.83	$366,631,662	217,122,773	$1.69	$46,655,397	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	183,606	1.20	10.30	$579,477,129	301,572,196	$1.92	$73,740,865	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	63,071	0.90	5.97	$181,858,964	80,572,724	$2.26	$23,142,306	$0.29
f	168th St. and SR 7	SR 7 and 176th St.	0.5	47,653	0.68	0.75	$19,366,140	8,696,738	$2.23	$2,464,422	$0.28
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Summary Calculations - Alternative 2: SR 7 Widening HOV Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	0	0.00	2.20	$0	0	n/a	$0	n/a
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	0	0.00	3.80	$0	0	n/a	$0	n/a
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,046,765	58,297,559	$1.20	$70,046,765	$1.20
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,348,821	6,292,435	$1.17	$7,348,821	$1.17
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	21,076	0.43	2.20	$18,332,377	16,923,991	$1.08	$9,565,212	$0.57
b	112th St. and SR 7	SR 7 and SR 512	0.2	58,164	0.76	0.35	$6,320,350	4,245,984	$1.49	$3,297,744	$0.78
c	SR 512 and I-5	I-5 exit 123	3.8	32,053	0.59	3.80	$48,433,650	44,457,529	$1.09	$25,271,035	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	149,402	0.98	5.24	$280,377,005	245,392,874	$1.14	$146,291,204	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	51,321	0.73	5.65	$93,827,890	65,562,982	$1.43	$48,956,208	$0.75
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,776	0.55	0.75	$10,180,068	7,076,639	$1.44	$5,311,614	$0.75
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	23,497	0.48	2.20	$25,430,441	18,868,335	$1.35	$6,552,813	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	64,846	0.85	0.36	$8,844,702	4,733,791	$1.87	$2,279,067	$0.48
c	SR 512 and I-5	I-5 exit 123	3.8	35,735	0.65	3.81	$67,229,970	49,565,114	$1.36	$17,323,546	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	166,566	1.09	6.69	$397,174,622	273,585,285	$1.45	$102,342,345	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	57,217	0.81	5.74	$130,678,279	73,095,305	$1.79	$33,672,649	$0.46
f	168th St. and SR 7	SR 7 and 176th St.	0.5	43,231	0.61	0.75	$14,119,347	7,889,652	$1.79	$3,638,216	$0.46
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	25,901	0.53	2.20	$34,878,048	20,798,506	$1.68	$4,438,376	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	71,480	0.94	0.38	$12,304,933	5,218,043	$2.36	$1,565,854	$0.30
c	SR 512 and I-5	I-5 exit 123	3.8	39,391	0.72	3.83	$92,284,681	54,635,469	$1.69	$11,743,608	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	183,606	1.20	10.30	$579,477,129	301,572,196	$1.92	$73,740,865	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	63,071	0.90	5.97	$181,858,964	80,572,724	$2.26	$23,142,306	$0.29
f	168th St. and SR 7	SR 7 and 176th St.	0.5	47,653	0.68	0.75	$19,366,140	8,696,738	$2.23	$2,464,422	$0.28
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Summary Calculations - Alternative 3: Transit Development GP Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	97,353	0.73	2.22	$68,481,315	78,174,251	$0.88	$68,481,315	$0.88
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	148,057	0.75	3.84	$181,782,876	205,355,466	$0.89	$181,782,876	$0.89
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	81,215	0.55	2.20	$70,300,726	65,215,835	$1.08	$36,680,533	$0.56
b	112th St. and SR 7	SR 7 and SR 512	0.2	53,572	1.05	0.46	$6,157,806	3,910,774	$1.57	$3,212,934	$0.82
c	SR 512 and I-5	I-5 exit 123	3.8	125,909	0.58	3.80	$190,178,119	174,635,448	$1.09	$99,228,487	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	148,853	0.98	5.21	$279,155,479	244,490,695	$1.14	$145,653,853	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	47,489	1.01	6.85	$92,014,708	60,667,601	$1.52	$48,010,151	$0.79
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,830	0.74	0.76	$9,292,467	6,356,408	$1.46	$4,848,494	$0.76
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	90,546	0.62	2.20	$97,554,316	72,708,276	$1.34	$25,137,400	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	59,727	1.17	0.68	$9,209,380	4,360,071	$2.11	$2,373,036	$0.54
c	SR 512 and I-5	I-5 exit 123	3.8	140,374	0.64	3.81	$263,968,986	194,698,762	$1.36	$68,018,457	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	165,954	1.09	6.61	$395,244,162	272,579,456	$1.45	$101,844,912	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	52,945	1.13	9.31	$134,521,606	67,637,510	$1.99	$34,662,982	$0.51
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,831	0.83	0.77	$12,973,040	7,086,675	$1.83	$3,342,840	$0.47
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	99,808	0.68	2.21	$133,865,744	80,146,103	$1.67	$17,034,970	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	65,837	1.29	1.25	$14,894,168	4,806,092	$3.10	$1,895,345	$0.39
c	SR 512 and I-5	I-5 exit 123	3.8	154,734	0.71	3.82	$362,316,070	214,615,831	$1.69	$46,106,220	$0.21
d	I-5 exit 123	I-5 exit 119	4.5	182,931	1.20	10.09	$575,132,066	300,463,474	$1.91	$73,187,937	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	58,361	1.24	15.44	$208,244,772	74,556,614	$2.79	$26,500,010	$0.36
f	168th St. and SR 7	SR 7 and 176th St.	0.5	42,803	0.91	0.81	$18,055,645	7,811,620	$2.31	$2,297,656	$0.29
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Summary Calculations - Alternative 3: Transit Development GP Lanes

						2006					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	0	0.00	2.20	$0	0	n/a	$0	n/a
b	112th St. and SR 7	SR 7 and SR 512	0.2	51,719	1.02	0.42	$4,753,865	3,775,461	$1.26	$4,753,865	$1.26
c	SR 512 and I-5	I-5 exit 123	3.8	0	0.00	3.80	$0	0	n/a	$0	n/a
d	I-5 exit 123	I-5 exit 119	4.5	132,846	0.87	4.73	$197,242,414	218,199,436	$0.90	$197,242,414	$0.90
e	168th St. and SR 7	112th St. and SR 7	3.5	45,634	0.97	6.44	$70,821,972	58,297,559	$1.21	$70,821,972	$1.21
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,479	0.73	0.76	$7,444,413	6,292,435	$1.18	$7,444,413	$1.18
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2015					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	23,617	0.48	2.20	$20,562,363	18,964,536	$1.08	$10,728,743	$0.57
b	112th St. and SR 7	SR 7 and SR 512	0.2	53,572	1.05	0.46	$6,157,806	3,910,774	$1.57	$3,212,934	$0.82
c	SR 512 and I-5	I-5 exit 123	3.8	33,524	0.61	3.81	$50,689,021	46,497,458	$1.09	$26,447,811	$0.57
d	I-5 exit 123	I-5 exit 119	4.5	148,853	0.98	5.21	$279,155,479	244,490,695	$1.14	$145,653,853	$0.60
e	168th St. and SR 7	112th St. and SR 7	3.5	47,489	1.01	6.85	$92,014,708	60,667,601	$1.52	$48,010,151	$0.79
f	168th St. and SR 7	SR 7 and 176th St.	0.5	34,830	0.74	0.76	$9,292,467	6,356,408	$1.46	$4,848,494	$0.76
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2025					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	26,330	0.54	2.20	$28,526,907	21,143,311	$1.35	$7,350,698	$0.35
b	112th St. and SR 7	SR 7 and SR 512	0.2	59,727	1.17	0.68	$9,209,380	4,360,071	$2.11	$2,373,036	$0.54
c	SR 512 and I-5	I-5 exit 123	3.8	37,375	0.68	3.82	$70,378,457	51,839,404	$1.36	$18,134,835	$0.35
d	I-5 exit 123	I-5 exit 119	4.5	165,954	1.09	6.61	$395,244,162	272,579,456	$1.45	$101,844,912	$0.37
e	168th St. and SR 7	112th St. and SR 7	3.5	52,945	1.13	9.31	$134,521,606	67,637,510	$1.99	$34,662,982	$0.51
f	168th St. and SR 7	SR 7 and 176th St.	0.5	38,831	0.83	0.77	$12,973,040	7,086,675	$1.83	$3,342,840	$0.47
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

						2035					
Segment	Origin	Destination	Length (miles)	Traffic Count	Peak V/C	Current Peak Hour Duration (minutes)	Total highway user costs, year of expenditure dollars	Total Vehicle Miles per Year	Average User Cost per Mile Year of Expenditure dollars	Total highway user costs discounted, 2006 dollars	Average User Cost per Mile discounted 2006 dollars
a	SR 7 and SR 512	SR 512 and I-5	2.2	29,024	0.59	2.20	$39,130,888	23,306,205	$1.68	$4,979,568	$0.21
b	112th St. and SR 7	SR 7 and SR 512	0.2	65,837	1.29	1.25	$14,894,168	4,806,092	$3.10	$1,895,345	$0.39
c	SR 512 and I-5	I-5 exit 123	3.8	41,199	0.75	3.85	$96,654,134	57,142,411	$1.69	$12,299,639	$0.22
d	I-5 exit 123	I-5 exit 119	4.5	182,931	1.20	10.09	$575,132,066	300,463,474	$1.91	$73,187,937	$0.24
e	168th St. and SR 7	112th St. and SR 7	3.5	58,361	1.24	15.44	$208,244,772	74,556,614	$2.79	$26,500,010	$0.36
f	168th St. and SR 7	SR 7 and 176th St.	0.5	42,803	0.91	0.81	$18,055,645	7,811,620	$2.31	$2,297,656	$0.29
g	SR 7 and 176th St.	SR 704 and I-5 exit 123	6.0	0	0.00	6.00	$0	0	N/A	$0	N/A

Study Area Map

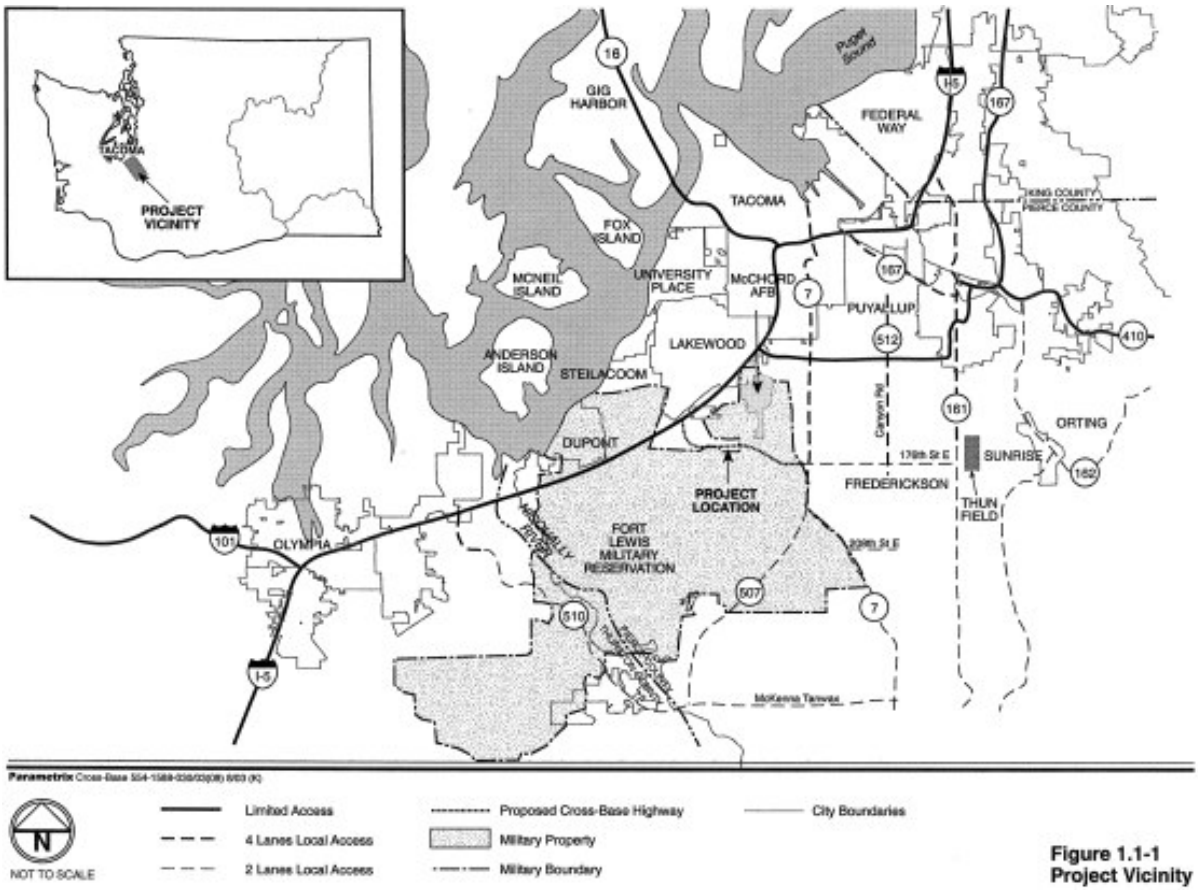


Figure 1.1-1
Project Vicinity

APPENDIX C: STRATBENCOST DATA TABLES

Overview

The supplementary data tables are listed in this appendix. They are grouped into four main categories: Accident Rates, Emission Factors, Speed-Flow Factors and Vehicle Operating Costs. Data sources and measurement units are provided with each table.

Accident Rates

Accident rates are based on relationships and data put forth in *Highway Economic Requirements System Technical Report*, Federal Highway Administration, U.S. Department of Transportation, Jack Faucett Associates, Bethesda, MD, July 1991.

Fatal Accidents

Fatal Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000 174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	2.0	2.0	2.0	2.0	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
Urban 6+ Lanes Full Access Control	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Urban 4 Lanes Partial Access Control	3.0	3.0	3.0	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Urban 6+ Lanes Partial Access Control	2.5	2.5	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0
Urban 2 or 3 Lanes	2.5	2.5	4.0	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Urban Multilane Undivided	6.5	6.5	6.5	4.0	3.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0
Urban Multilane Divided	4.0	4.0	4.0	3.5	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0
Rural Multilane Full Access Control	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Rural Multilane Partial Access Control	2.5	2.5	2.5	2.5	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5
Rural 2 or 3 Lanes	5.0	5.0	5.0	5.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Rural Multilane Undivided	5.0	5.0	5.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Rural Multilane Divided	3.5	3.5	3.5	3.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0

Injury Only Accidents

Injury Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000-174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	40.0	40.0	40.0	35.0	35.0	35.0	40.0	60.0	60.0	60.0	60.0	60.0
Urban 6+ Lanes Full Access Control	65.0	65.0	65.0	65.0	65.0	70.0	40.0	45.0	55.0	70.0	70.0	70.0
Urban 4 Lanes Partial Access Control	185.0	185.0	185.0	185.0	200.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0
Urban 6+ Lanes Partial Access Control	365.0	365.0	365.0	365.0	365.0	365.0	225.0	225.0	225.0	225.0	225.0	225.0
Urban 2 or 3 Lanes	195.0	195.0	195.0	270.0	330.0	395.0	395.0	395.0	395.0	395.0	395.0	395.0
Urban Multilane Undivided	580.0	580.0	580.0	365.0	365.0	365.0	335.0	335.0	335.0	335.0	335.0	335.0
Urban Multilane Divided	275.0	275.0	275.0	275.0	325.0	335.0	335.0	335.0	335.0	335.0	335.0	335.0
Rural Multilane Full Access Control	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Rural Multilane Partial Access Control	120.0	120.0	120.0	120.0	120.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Rural 2 or 3 Lanes	150.0	150.0	150.0	165.0	195.0	195.0	195.0	195.0	195.0	195.0	195.0	195.0
Rural Multilane Undivided	150.0	150.0	170.0	200.0	205.0	230.0	230.0	230.0	230.0	230.0	230.0	230.0
Rural Multilane Divided	150.0	150.0	150.0	150.0	175.0	210.0	225.0	225.0	225.0	225.0	225.0	225.0

Property Damage Only Accidents

PDO Accidents Per 100 Million VMT	AADT Under 1,000	AADT 1,000-2,999	AADT 3,000-5,999	AADT 6,000-11,999	AADT 12,000-19,999	AADT 20,000-29,999	AADT 30,000-46,999	AADT 47,000-66,999	AADT 67,000-87,999	AADT 88,000-124,999	AADT 125,000-174,999	AADT Above 175,000
Urban 4 Lanes Full Access Control	70.0	70.0	70.0	65.0	65.0	65.0	80.0	120.0	140.0	140.0	140.0	140.0
Urban 6+ Lanes Full Access Control	140.0	140.0	140.0	140.0	140.0	125.0	90.0	90.0	100.0	120.0	120.0	120.0
Urban 4 Lanes Partial Access Control	275.0	275.0	275.0	275.0	300.0	350.0	375.0	375.0	375.0	375.0	375.0	375.0
Urban 6+ Lanes Partial Access Control	515.0	515.0	515.0	515.0	515.0	515.0	375.0	375.0	375.0	375.0	375.0	375.0
Urban 2 or 3 Lanes	345.0	345.0	345.0	490.0	590.0	660.0	660.0	660.0	660.0	660.0	660.0	660.0
Urban Multilane Undivided	785.0	785.0	785.0	685.0	685.0	685.0	590.0	590.0	590.0	590.0	590.0	590.0
Urban Multilane Divided	415.0	415.0	415.0	415.0	490.0	590.0	590.0	590.0	590.0	590.0	590.0	590.0
Rural Multilane Full Access Control	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
Rural Multilane Partial Access Control	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
Rural 2 or 3 Lanes	185.0	185.0	185.0	195.0	240.0	240.0	240.0	240.0	240.0	240.0	240.0	240.0
Rural Multilane Undivided	175.0	175.0	195.0	220.0	230.0	230.0	230.0	230.0	230.0	230.0	230.0	230.0
Rural Multilane Divided	175.0	175.0	175.0	175.0	200.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0

Emission Factors

Emission rates have been derived for both Criteria Air Contaminants (CAC) and Greenhouse Gases (GhG): Nitrogen Oxides (NO_x), Carbon Monoxide (CO), and Hydro Carbon (HC).

Highway emissions are estimated for seven (7) types of vehicles, listed in the table below. The Environmental Protection Agency (EPA) default distribution of vehicles across vehicle types is also shown in the table.

Vehicle Class Distribution

	Description	EPA "Default"
LDGV	Gasoline fueled cars	78.2%
LDGT	Pick-ups and commercial vans	13.0%
HDGV	Gasoline-fueled trucks	4.2%
LDDV	Diesel fueled cars	0.2%
LDDT	Diesel-fueled trucks < 8500 lbs	0.0%
HDDV	Diesel-fueled trucks >8500 lbs	3.5%
MC	Motorcycles	0.9%

Highway Base Emission Factors by Vehicle Class

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV
Year 2005						
VOC	0.880889	1.131383	1.855434	0.405589	0.511686	0.651608
CO	8.265604	8.970138	18.704818	1.087576	1.147909	7.319185
NOx	0.998962	1.178407	6.019372	1.047441	1.138319	9.688231
SOx	0.005734	0.003030	0.012648	0.070029	0.088875	0.047150
PM10	0.004887	0.005567	0.044851	0.111126	0.116644	0.320489
PM2.5	0.004504	0.005039	0.034354	0.102236	0.107312	0.294849
CO2	0.375927	0.505033	0.759448	0.439257	0.571034	1.752635
Year 2010						
VOC	0.569037	0.695522	1.614976	0.417222	0.535245	0.433870
CO	5.974581	6.081468	16.167361	1.101703	1.169323	7.295433
NOx	0.585546	0.752182	5.533304	1.041343	1.152021	8.355836
SOx	0.005751	0.045647	0.012346	0.067329	0.087106	0.045647
PM10	0.004882	0.005418	0.035813	0.100405	0.109016	0.238489
PM2.5	0.004502	0.004911	0.028280	0.092373	0.100538	0.219410
CO2	0.345549	0.489844	0.759448	0.439257	0.571034	1.695532
Year 2020						
VOC	0.443751	0.490407	1.539250	0.432929	0.560597	0.392499
CO	4.693733	4.654050	16.230144	1.120966	1.192736	7.290994
NOx	0.326534	0.469450	5.297483	1.059430	1.174200	7.889629
SOx	0.005757	0.044347	0.012209	0.065613	0.085748	0.044347
PM10	0.004882	0.215424	0.032582	0.099978	0.108978	0.215424
PM2.5	0.004504	0.198190	0.026116	0.091980	0.100260	0.198190
CO2	0.315171	0.463263	0.759448	0.439257	0.571034	1.625251

Units: Grams per mile

Base emission factors were derived by ICF Consulting for HDR|HLB Decision Economics, and adjusted for local conditions.

Speed Adjustment Factors

Speed	VOC	CO	NOX	SOX	PM	CO2
5	4.454321	4.309995	1.507969	1.000000	1.000000	0.874552
10	1.814762	1.780720	1.119813	1.000000	1.000000	0.874552
15	1.286850	1.274865	1.042182	1.000000	1.000000	0.874552
20	1.060602	1.058070	1.008912	1.000000	1.000000	1.000000
25	0.871080	0.843305	1.019709	1.000000	1.000000	1.093190
30	0.719974	0.655432	1.041521	1.000000	1.000000	1.136201
35	0.615363	0.525367	1.056621	1.000000	1.000000	1.118280
40	0.538647	0.429986	1.067695	1.000000	1.000000	1.111111
45	0.479983	0.357047	1.076163	1.000000	1.000000	1.132616
50	0.429568	0.294365	1.083440	1.000000	1.000000	1.161290
55	0.429568	0.294365	1.083440	1.000000	1.000000	1.161290
60	0.506983	0.429131	1.347020	1.000000	1.000000	1.125448
65	0.584398	0.563896	1.610599	1.000000	1.000000	1.046595
70	0.584398	0.563896	1.610599	1.000000	1.000000	0.960573
75	0.584398	0.563896	1.610599	1.000000	1.000000	0.888889

Speed adjustment factors vary by vehicle class; the above factors are for LDGV - gasoline fueled cars

Speed Adjustment Factors were derived from *Compilation of Air Pollutant Emission Factors*, Volume II: Mobile Sources (AP-42), Appendix H, Office of Transportation and Air Quality, Environmental Protection Agency, November 2000.

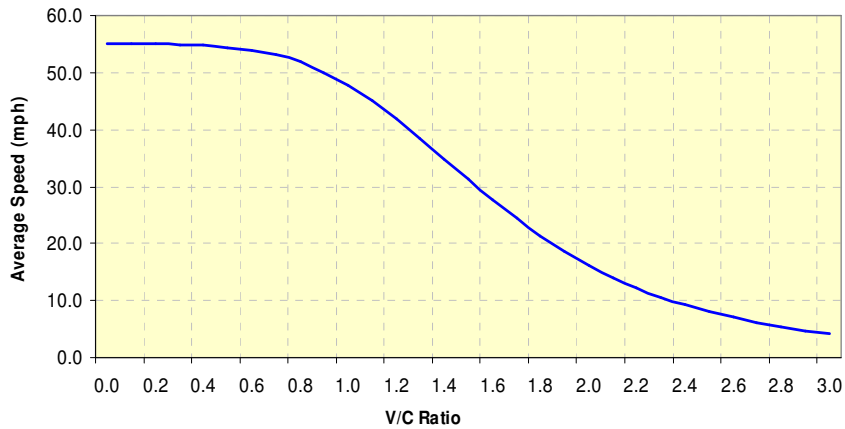
Speed-Flow Factors

To calculate the average travel speed in the peak and off-peak periods, a speed-flow curve, predicting facility speed as a function of traffic flow, was used. Two speed-flow curves were considered (the BPR and MTC speed-flow curves, as illustrated in the figures below) for use in this model.

The BPR speed/flow curve has the following form:

$$\text{Average travel speed} = \frac{FreeFlowSpeed}{1 + 0.15 * (V / C)^4}$$

BPR Speed/Flow Curve

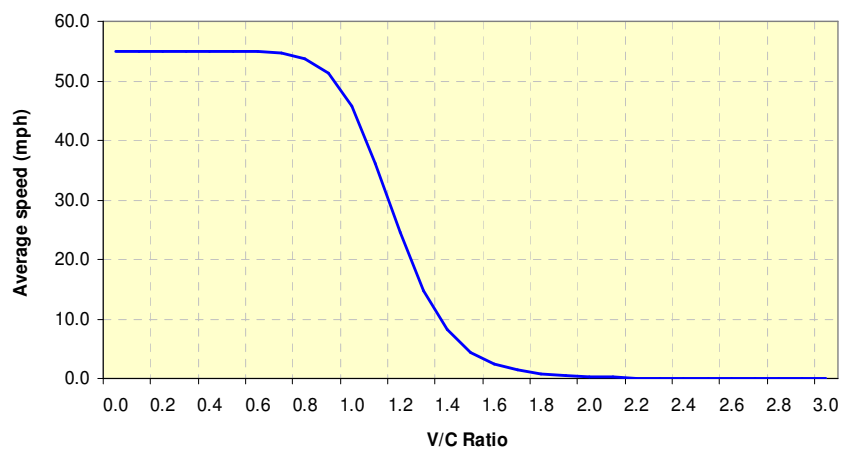


Source: The Bureau of Public Road

The MTC speed/flow curve has the following form:

$$\text{Average travel speed} = \frac{FreeFlowSpeed}{1 + 0.20 * (V / C)^{10}}$$

MTC Speed/Flow Curve



Source: The Metropolitan Transportation Commission

In an effort to closely align the baseline results with the results produced in the Final EIS, the MTC speed-flow curve was chosen. The benefit of this curve is the more gradual decline in the speed as compared to the BPR curve.

Vehicle Operating Costs

The Vehicle Operating Cost (VOC) consumption rates presented in the tables below are drawn from the *Technical Memorandum for National Cooperative Highway Research Program (NCHRP) Project 7-12*, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, January 1990.

The VOC consumption rates are given as: units of consumption (as indicated by the tables) per 1,000 miles:

Fuel Consumption

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	52.17	58.39	74.02	73.99	80.23	120.22	232.62	354.39	407.67	452.27	138.09	220.03	419.94	510.94	589.13
10	39.87	48.92	56.89	59.20	64.20	82.84	168.44	258.96	327.80	380.54	86.75	135.36	306.85	410.84	495.70
15	31.62	40.71	45.29	48.79	52.90	65.59	141.70	217.65	289.96	345.10	58.66	103.96	257.90	363.40	449.53
20	26.03	33.77	37.33	41.41	44.90	54.69	125.10	194.40	267.16	323.08	40.81	88.09	230.36	334.84	420.85
25	22.23	28.09	31.87	36.20	39.26	47.02	112.77	180.01	252.07	308.08	29.09	79.21	213.31	315.92	401.31
30	19.70	23.68	28.17	32.59	35.34	41.61	103.19	170.91	241.70	297.42	21.71	74.30	202.52	302.92	387.42
35	18.11	20.54	25.80	30.23	32.78	38.14	96.25	165.40	234.55	289.77	17.69	72.04	195.99	293.97	377.45
40	17.29	18.66	24.46	28.87	31.30	36.56	92.32	162.59	229.82	284.36	16.44	71.79	192.66	288.04	370.41
45	17.12	18.05	24.02	28.40	30.79	36.92	91.78	161.96	227.01	280.72	17.61	73.27	191.92	284.51	365.67
50	17.59	18.70	24.42	28.77	31.20	39.24	94.76	163.25	225.80	278.57	20.92	76.42	193.45	283.00	362.87
55	18.76	20.63	25.72	30.02	32.55	43.53	100.98	166.32	226.01	277.69	26.20	81.30	197.09	283.26	361.72
60	20.75	23.81	28.06	32.26	34.99	49.63	109.80	171.13	227.50	277.96	33.32	88.10	202.78	285.12	362.07
65	23.83	28.26	31.69	35.71	38.73	57.25	120.25	177.71	230.20	279.27	42.17	97.17	210.58	288.51	363.78
70	28.39	33.98	37.07	40.71	44.15	65.97	131.32	186.17	234.07	281.57	52.68	109.00	220.60	293.37	366.78

Units: Gallons per 1,000 miles

Oil Consumption

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	4.216	4.138	3.817	8.007	9.274	14.024	9.759	8.418	31.103	37.379	27.233	17.574	17.574	65.476	79.373
10	2.486	2.440	2.364	5.944	6.884	7.794	6.330	6.703	17.636	21.195	19.497	13.894	13.894	38.412	46.565
15	1.907	1.872	1.859	4.542	5.261	5.631	4.983	5.501	12.846	15.438	14.507	11.286	11.286	28.118	34.086
20	1.630	1.600	1.612	3.573	4.138	4.561	4.267	4.651	10.367	12.458	11.217	9.418	9.418	22.535	27.318
25	1.478	1.451	1.475	2.893	3.351	3.954	3.841	4.053	8.850	10.635	9.014	8.074	8.074	18.980	23.008
30	1.392	1.366	1.395	2.412	2.793	3.592	3.579	3.639	7.828	9.407	7.528	7.111	7.111	16.496	19.997
35	1.344	1.320	1.352	2.070	2.397	3.384	3.426	3.367	7.096	8.527	6.534	6.435	6.435	14.651	17.761
40	1.323	1.299	1.332	1.828	2.118	3.283	3.351	3.210	6.549	7.870	5.894	5.982	5.982	13.220	16.026
45	1.321	1.297	1.330	1.663	1.926	3.267	3.339	3.153	6.127	7.363	5.525	5.714	5.714	12.075	14.638
50	1.335	1.310	1.342	1.556	1.803	3.324	3.383	3.192	5.795	6.964	5.382	5.606	5.606	11.135	13.498
55	1.361	1.336	1.365	1.500	1.737	3.451	3.479	3.330	5.529	6.645	5.449	5.652	5.652	10.347	12.544
60	1.398	1.372	1.398	1.488	1.723	3.651	3.628	3.579	5.314	6.386	5.733	5.853	5.853	9.677	11.731
65	1.445	1.418	1.440	1.519	1.760	3.931	3.832	3.965	5.138	6.175	6.269	6.228	6.228	9.099	11.031
70	1.502	1.474	1.491	1.597	1.850	4.304	4.098	4.525	4.994	6.001	7.124	6.808	6.808	8.595	10.419

Units: Quarts per 1,000 miles

Tire Consumption

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	0.064	0.000	0.062	0.000	0.111	0.189	0.033	0.109	0.000	0.369	0.213	0.052	0.127	0.000	0.456
10	0.039	0.000	0.068	0.000	0.105	0.161	0.023	0.110	0.000	0.397	0.199	0.038	0.122	0.000	0.476
15	0.022	0.000	0.079	0.000	0.121	0.137	0.018	0.122	0.000	0.443	0.185	0.029	0.126	0.000	0.510
20	0.014	0.000	0.096	0.000	0.158	0.116	0.019	0.141	0.000	0.508	0.170	0.024	0.138	0.000	0.557
25	0.015	0.019	0.117	0.000	0.216	0.098	0.026	0.167	0.000	0.591	0.156	0.024	0.157	0.000	0.618
30	0.026	0.049	0.145	0.000	0.297	0.085	0.039	0.201	0.000	0.693	0.141	0.029	0.181	0.000	0.692
35	0.045	0.087	0.181	0.099	0.398	0.074	0.058	0.241	0.024	0.813	0.127	0.037	0.210	0.000	0.780
40	0.073	0.135	0.227	0.223	0.521	0.067	0.083	0.289	0.163	0.952	0.113	0.051	0.245	0.082	0.881
45	0.111	0.192	0.286	0.367	0.666	0.064	0.114	0.342	0.320	1.109	0.098	0.069	0.285	0.197	0.996
50	0.157	0.258	0.361	0.533	0.832	0.064	0.151	0.403	0.496	1.285	0.084	0.091	0.331	0.325	1.124
55	0.212	0.333	0.457	0.721	1.020	0.068	0.194	0.470	0.690	1.479	0.069	0.118	0.382	0.467	1.266
60	0.277	0.417	0.579	0.930	1.229	0.075	0.244	0.544	0.903	1.692	0.055	0.149	0.437	0.622	1.421
65	0.350	0.510	0.735	1.161	1.459	0.085	0.299	0.624	1.134	1.923	0.041	0.185	0.498	0.791	1.590
70	0.432	0.612	0.935	1.413	1.711	0.099	0.360	0.711	1.384	2.173	0.026	0.226	0.565	0.973	1.772

Units: Percentage of tire wear per 1,000 miles

Maintenance and Repair

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	38.684	42.249	47.635	43.227	44.272	31.337	16.617	46.641	47.070	47.800	32.754	17.973	52.047	38.579	39.850
10	35.999	45.335	46.970	45.989	47.101	30.604	15.867	47.064	48.397	49.856	32.530	17.619	54.577	44.184	46.725
15	36.988	48.421	48.525	48.929	50.111	29.767	15.117	47.914	50.121	52.311	32.259	17.356	58.270	49.788	53.600
20	39.481	51.506	50.988	52.056	53.314	28.829	46.991	49.190	52.244	55.163	31.940	17.131	62.673	55.392	60.475
25	42.799	54.592	53.950	55.382	56.721	27.788	47.632	50.893	54.765	58.414	31.574	15.596	67.681	60.997	67.351
30	46.638	57.678	57.226	58.922	60.346	26.644	48.764	53.022	57.684	62.062	31.161	47.293	73.277	66.601	74.226
35	50.837	60.764	60.721	62.687	64.202	25.398	50.388	55.577	61.000	66.109	30.700	50.826	79.475	72.206	81.101
40	55.300	63.850	64.374	66.694	68.306	24.049	52.503	58.560	64.715	70.553	30.191	54.581	86.309	77.810	87.976
45	59.963	66.936	68.148	70.956	72.671	22.598	55.110	61.968	68.828	75.396	29.635	58.557	93.823	83.414	94.851
50	64.785	70.022	72.019	75.491	77.315	21.044	58.209	65.804	73.339	80.636	29.032	62.756	102.071	89.019	101.726
55	69.736	73.108	75.967	80.315	82.256	53.200	61.799	70.065	78.247	86.275	28.381	67.177	111.113	94.623	108.601
60	74.792	76.194	79.979	85.448	87.513	57.200	65.880	74.753	83.554	92.311	27.682	71.820	121.020	100.228	115.477
65	79.938	79.280	84.045	90.909	93.106	61.200	70.453	79.868	89.259	98.746	60.200	76.684	131.867	105.832	122.352
70	85.159	82.366	88.157	96.719	99.057	65.200	75.517	85.409	95.362	105.578	92.718	81.771	143.740	111.436	129.227

Units: Percentage of average M&R costs per 1,000 miles

Vehicle Depreciation

	Auto					Bus					Truck				
	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%	-2%	-1%	0%	+1%	+2%
5	1.595	1.595	1.595	1.595	1.595	0.743	0.743	0.743	0.743	0.743	0.250	0.250	0.250	0.250	0.250
10	1.340	1.340	1.340	1.340	1.340	0.585	0.585	0.585	0.585	0.585	0.191	0.191	0.191	0.191	0.191
15	1.193	1.193	1.193	1.193	1.193	0.499	0.499	0.499	0.499	0.499	0.159	0.159	0.159	0.159	0.159
20	1.092	1.092	1.092	1.092	1.092	0.442	0.442	0.442	0.442	0.442	0.138	0.138	0.138	0.138	0.138
25	1.015	1.015	1.015	1.015	1.015	0.401	0.401	0.401	0.401	0.401	0.123	0.123	0.123	0.123	0.123
30	0.954	0.954	0.954	0.954	0.954	0.370	0.370	0.370	0.370	0.370	0.112	0.112	0.112	0.112	0.112
35	0.903	0.903	0.903	0.903	0.903	0.345	0.345	0.345	0.345	0.345	0.103	0.103	0.103	0.103	0.103
40	0.861	0.861	0.861	0.861	0.861	0.326	0.326	0.326	0.326	0.326	0.097	0.097	0.097	0.097	0.097
45	0.824	0.824	0.824	0.824	0.824	0.311	0.311	0.311	0.311	0.311	0.092	0.092	0.092	0.092	0.092
50	0.792	0.792	0.792	0.792	0.792	0.299	0.299	0.299	0.299	0.299	0.088	0.088	0.088	0.088	0.088
55	0.764	0.764	0.764	0.764	0.764	0.289	0.289	0.289	0.289	0.289	0.085	0.085	0.085	0.085	0.085
60	0.738	0.738	0.738	0.738	0.738	0.282	0.282	0.282	0.282	0.282	0.083	0.083	0.083	0.083	0.083
65	0.716	0.716	0.716	0.716	0.716	0.276	0.276	0.276	0.276	0.276	0.082	0.082	0.082	0.082	0.082
70	0.696	0.696	0.696	0.696	0.696	0.272	0.272	0.272	0.272	0.272	0.081	0.081	0.081	0.081	0.081

Units: Percentage of vehicle depreciable value costs per 1,000 miles

The data tables for speed cycling (number of speed cycles by period) and excess Vehicle Operating Cost components (excess consumption per speed cycle, consumption rate units are defined as before) are based on the empirical relationships developed in the *Technical Memorandum for National Cooperative Highway Research Program (NCHRP) Project 7-12*, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, January 1990.

Speed Cycle Factors

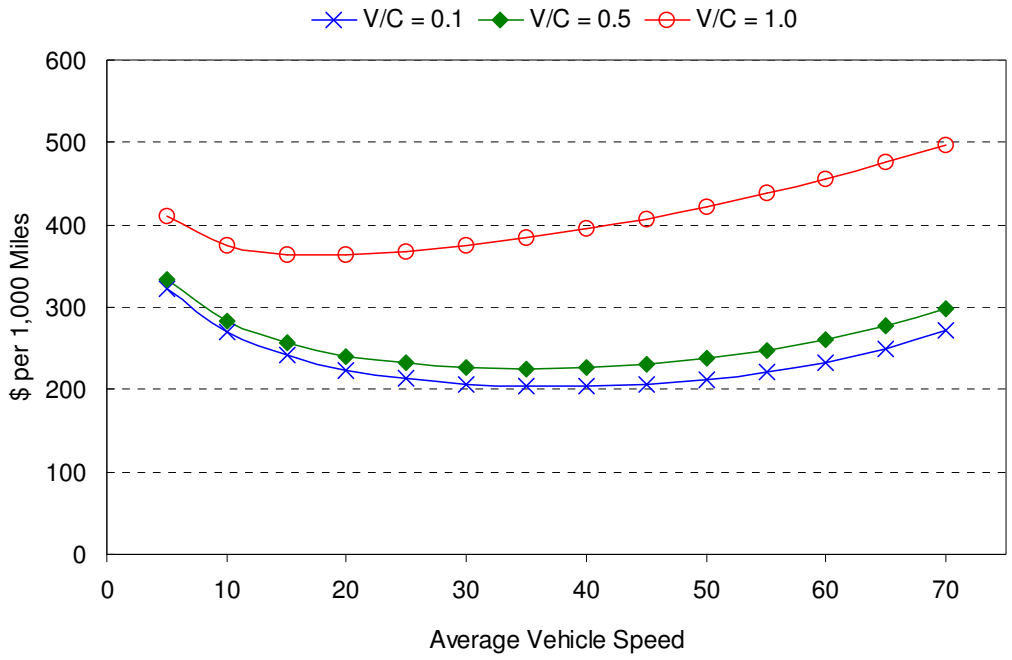
V/C Ratio	Freeways			Expressways			Arterials			Collectors		
	Auto	Bus	Truck	Auto	Bus	Truck	Auto	Bus	Truck	Auto	Bus	Truck
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.2	0.238	0.180	0.166	0.334	0.266	0.178	0.300	0.244	0.216	0.304	0.254	0.226
0.4	0.476	0.360	0.332	0.668	0.532	0.356	0.600	0.488	0.432	0.608	0.508	0.452
0.6	0.714	0.540	0.498	1.002	0.798	0.534	0.900	0.732	0.648	0.912	0.762	0.678
0.8	0.952	0.720	0.664	1.336	1.064	0.712	1.200	0.976	0.864	1.216	1.016	0.904
1.0	3.900	4.650	5.610	3.840	4.600	5.870	3.890	4.650	5.870	4.210	6.430	7.750
1.2	4.106	5.434	7.106	4.602	5.384	7.142	4.696	5.434	7.142	5.148	7.512	9.560
1.4	3.002	4.710	7.080	3.544	4.720	7.028	3.622	4.742	7.028	3.936	6.608	9.436
1.6	2.520	3.480	5.540	2.480	3.560	5.532	2.550	3.558	5.532	2.730	5.042	7.384
1.8	2.520	2.740	4.000	2.480	2.740	4.040	2.550	2.790	4.040	2.730	3.790	5.330
2.0	2.520	2.740	4.000	2.480	2.740	4.040	2.550	2.790	4.040	2.730	3.790	5.330

Excess Vehicle Operating Costs Due to Speed Cycling

Vehicle Speed	Fuel			Oil			Tire			Maintenance & Repair			Depreciation		
	Auto	Bus	Truck	Auto	Bus	Truck	Auto	Bus	Truck	Auto	Bus	Truck	Auto	Bus	Truck
5	0.836	8.004	16.948	0.054	0.054	0.128	0.277	0.277	0.283	0.000	0.000	0.000	0.007	0.007	0.002
10	0.786	7.782	17.081	0.041	0.041	0.101	0.341	0.341	0.351	0.095	0.095	0.024	0.005	0.005	0.002
15	0.942	9.900	19.271	0.031	0.031	0.080	0.399	0.399	0.413	0.229	0.229	0.207	0.004	0.004	0.002
20	1.212	13.300	22.587	0.025	0.025	0.065	0.451	0.451	0.470	0.368	0.368	0.400	0.004	0.004	0.002
25	1.553	17.511	26.616	0.023	0.023	0.057	0.498	0.498	0.521	0.512	0.512	0.601	0.003	0.003	0.002
30	1.944	22.281	31.137	0.025	0.025	0.055	0.539	0.539	0.566	0.660	0.660	0.812	0.003	0.003	0.002
35	2.296	27.167	36.285	0.031	0.031	0.060	0.574	0.574	0.605	0.813	0.813	1.032	0.003	0.003	0.002
40	2.647	32.053	41.433	0.040	0.040	0.072	0.603	0.603	0.638	0.971	0.971	1.261	0.004	0.004	0.002
45	2.998	36.939	46.581	0.053	0.053	0.090	0.626	0.626	0.665	1.133	1.133	1.498	0.004	0.004	0.002
50	3.798	41.525	49.267	0.070	0.070	0.115	0.644	0.644	0.687	1.300	1.300	1.746	0.005	0.005	0.002
55	4.424	44.133	49.336	0.091	0.091	0.146	0.656	0.656	0.702	1.472	1.472	2.002	0.007	0.007	0.002
60	4.878	44.764	46.787	0.116	0.116	0.184	0.662	0.662	0.712	1.648	1.648	2.267	0.008	0.008	0.002
65	5.159	43.417	41.621	0.144	0.144	0.228	0.662	0.662	0.716	1.829	1.829	2.541	0.010	0.010	0.002
70	5.267	40.091	33.836	0.176	0.176	0.279	0.656	0.656	0.714	2.014	2.014	2.825	0.012	0.012	0.003

The figure below illustrates the impact of speed cycling on vehicle operating costs. In the chart, total operating costs for autos are plotted against average vehicle speed, at different levels of congestion (V/C ratio). As shown in the graph, *at any average speed*, the higher the V/C ratio, the higher total vehicle operating costs. The impact of speed cycling is especially large at high congestion levels (V/C ratio close to 1.0).

The Effects of Speed Cycling



APPENDIX D: RISK ANALYSIS PRIMER

The result of a risk analysis is a forecast of future events and the probability, or odds, of their occurrence. Not unlike modern weather forecasting, in which the likelihood of rain is projected with a statement of probability ("there is a 20 percent chance of rain tomorrow"), risk analysis is intended to provide a sense of perspective on the likelihood of future events. Risk analysis is an easily understandable, but technically robust method that allows planners and decision-makers to select the level of risk within which they are willing to plan and make commitments.

Forecasting and the Analysis of Risk

The further into the future projections are made, the more uncertainty there is and the greater the risk is of producing forecasts that deviate from actual outcomes. Projections need to be made with a range of input values to allow for this uncertainty and for the probability that alternative economic, demographic and technological conditions may prevail. The difficulty lies in choosing which combinations of input values to use in computing forecasts and how to use those forecasts to produce a final estimate.

Forecasts traditionally take one of two forms: first, a single "expected outcome", or second, one in which the expected outcome is supplemented by alternative scenarios, often termed "high" and "low" cases. Both approaches fail to provide adequate perspective with regard to probable versus improbable outcomes.

The limitation of a forecast with a single expected outcome is clear -- while it may provide the single best guess, it offers no information about the range of probable outcomes. The problem becomes acute when uncertainty surrounding the underlying assumptions of the forecast is especially high.

The high case-low case approach can actually exacerbate this problem because it gives no indication of how likely it is that the high and low cases will actually materialize. Indeed, the high case usually assumes that most underlying assumptions deviate in the same direction from their expected value; and likewise for the low case. In reality, the likelihood that all underlying factors shift in the same direction simultaneously is just as remote as everything turning out as expected.

A common approach to providing added perspective on reality is through "sensitivity analysis", whereby key forecast assumptions are varied, one at a time, in order to assess their relative impact on the expected outcome. A problem here is that the assumptions are often varied by arbitrary amounts. But a more serious flaw in this approach is that in the real world, assumptions do not veer from actual outcomes one at a time; it is the impact of simultaneous differences between assumptions and actual outcomes that would provide true perspective on a forecast.

The result of a risk analysis is both a forecast and a quantification of the probability that the forecast will be achieved. Thereby, risk analysis provides a way around the problems outlined above. It helps avoid the lack of perspective in "high" and "low" cases by measuring the probability or "odds" that an outcome will actually materialize. This is accomplished by

attaching ranges (*probability distributions*) to the forecasts of each input variable. The approach allows all inputs to be varied simultaneously within their distributions, thus avoiding the problems inherent in conventional sensitivity analysis. The approach also recognizes interrelationships between variables and their associated probability distributions (through the use of correlation factors).

Application of the Risk Analysis Process to Project Evaluation

The Risk Analysis Process (RAP), as applied to project evaluation, involves four steps:

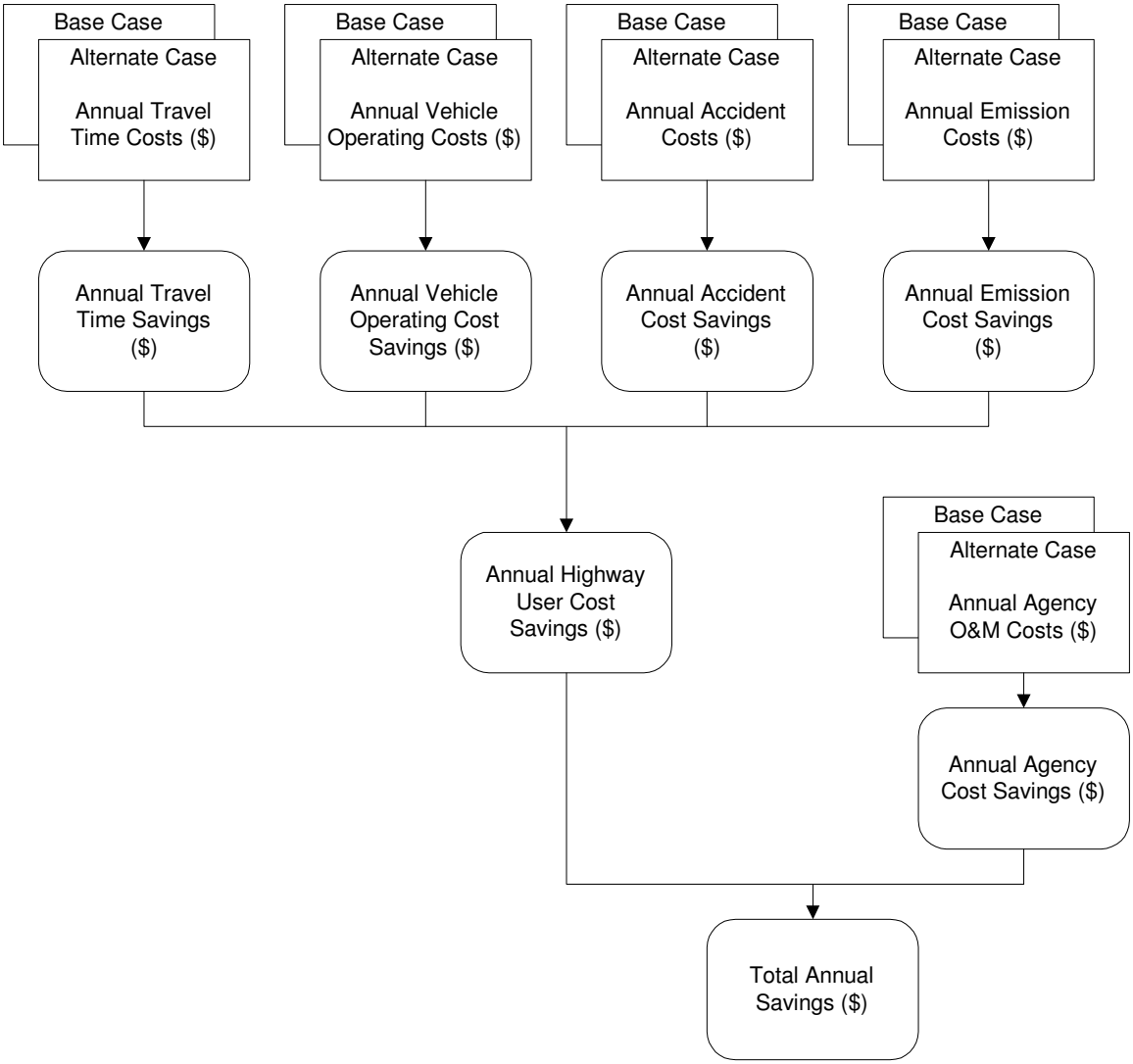
- Step 1. Adaptation of the evaluation steps and procedures into the risk analysis framework;
- Step 2. Assignment of estimates and ranges (probability distributions) to each variable and assumption in the forecasting process;
- Step 3. Expert and public evaluation and involvement, including revision of estimates and ranges developed in Step 2; and
- Step 4. Risk analysis.

Step 1: Structure and Logic Models

A structure and logic model depicts the methodology non-mathematically, indicating how all variables and assumptions combine to yield a forecast. The models provide a clear and uncomplicated means of presenting the evaluation steps and procedures to outside experts, stakeholders and others in an expert panel session. The use of structure and logic diagrams allows all stakeholders, regardless of their familiarity with mathematical modeling techniques, to understand and critique the models.

Once the structure and logic of the model is properly represented, it is programmed into the Risk Analysis software. A sample structure and logic model for the implementation process is shown in the figure below.

Example of Structure and Logic Diagram, Estimation of Transportation Investment Benefits



Step 2: Central Estimates and Probability Distributions

Each variable is assigned a central estimate and a range (a probability distribution) to represent the degree of uncertainty associated with the variable.

Special data sheets are used (see table below) to record the estimates. In this case, the first column provides space for an initial median estimate, and the second and third columns define a range that represents "an 80 percent confidence interval" -- the range within which we can be 80 percent confident of finding the actual outcome. Thus the greater the uncertainty associated with a forecast variable, the wider the range will be (and vice versa). This process ensures that all

risks are properly reflected in the forecasting process and that all stakeholders' views are reflected in the probability ranges.

Data Sheet Example

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Average LRT Fare ($)	$2.50	$2.00	$3.00

Probability ranges are established on the basis of both statistical analysis and subjective probability. Ranges need not be normal or symmetrical -- that is, there is no need to assume the bell shaped normal probability curve. The bell curve assumes an equal likelihood of being too low and being too high in forecasting a particular value. It might well be, for example, that if projected inflation rates deviate from expectations, they are more likely to be higher rather than lower. The RAP process places no restrictions on the degree of "skew" in the specified ranges and thus maximizes the extent to which the risk analysis reflects reality.

Although the computer program will transform all ranges into formal "probability density functions", they do not have to be determined or presented in either mathematical or graphical form. All that is required is the entry of upper and lower limits of an 80 percent confidence interval in the data sheets. The RAP software will then use numerical analysis to translate these entries into a uniquely defined statistical probability distribution automatically. This liberates the non-statistician from the need to appreciate the abstract statistical depiction of probability and thus enables administrators, stakeholders, and decision-makers to understand and participate in the process whether or not they possess statistical training.

Step 3: Expert Evaluation and Consensus Building

Facilitated by the HDR|HLB team, a Risk Analysis Process session is conducted as a structured workshop that incorporates the views of all stakeholders. Participants receive a briefing book and during the session they review the model (via the structure and logic models) and review each data sheet. This approach facilitates consensus building in the underlying assumptions and associated probabilities.

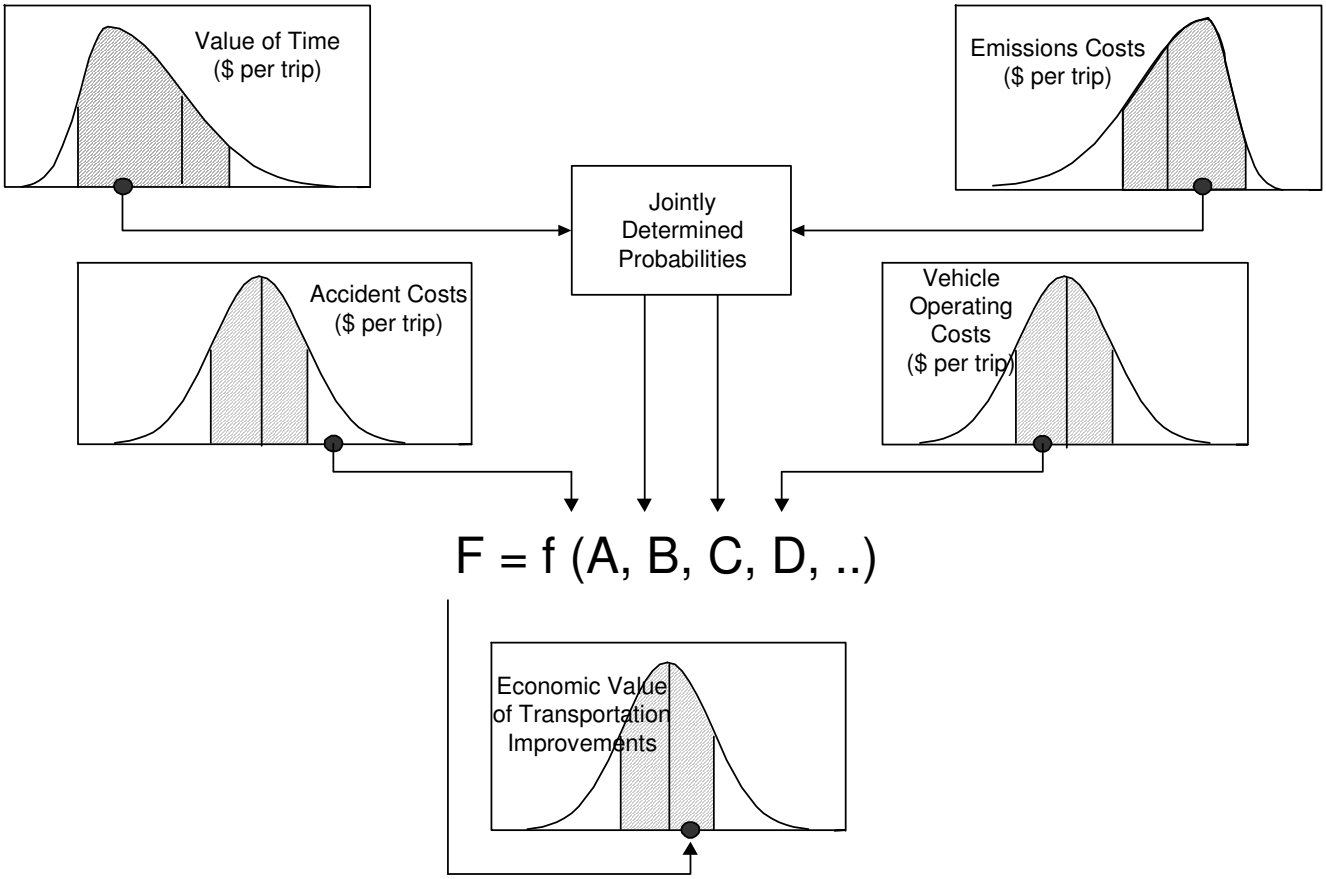
During the panel session, each variable is discussed in-turn. Panelists are asked to record their views on the median forecast -- either quantitatively, qualitatively or both -- in the appropriate data sheet.

Where necessary, changes are made, often consisting of adding variables to the models in order to ensure that they reflect all the factors affecting the outcome. The purpose is to ensure that prior to the transformation of the structure and logic models into RAP forecasting software, the collective vision of the relevant stakeholders is reflected in the modeling and risk analysis results.

Step 4: Risk Analysis

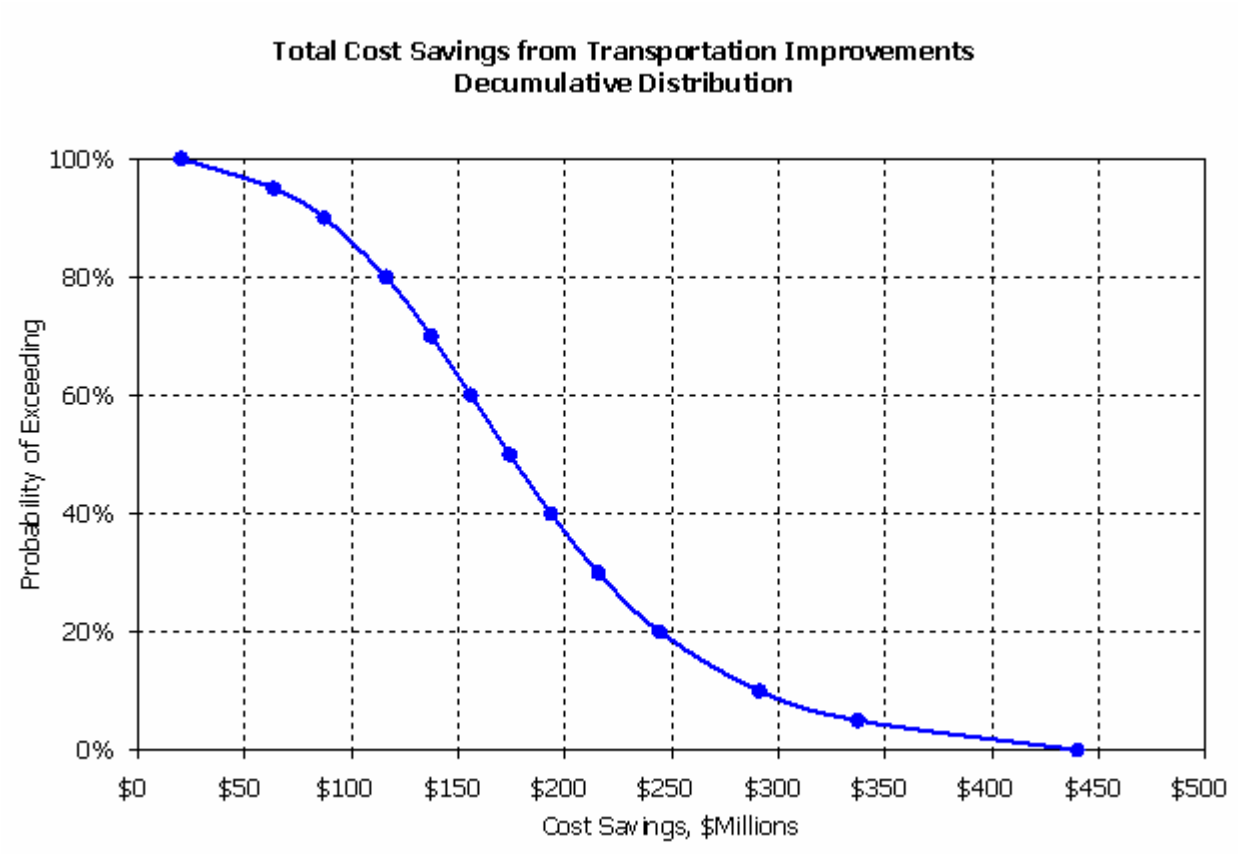
Once the data sheets are finalized, the RAP software transforms ranges given in the data sheets into statistical probability distributions. These distributions are combined using Monte Carlo simulation techniques that allow all variables to vary simultaneously from their expected values. This is illustrated in the figure below.

Combining Probability Distributions, an Illustration



The result of a Monte Carlo simulation is a set of figures together with estimates of the probability of obtaining these different figures given the uncertainty in the underlying assumptions. The table below provides a sample result from the RAP process, and the figure shows a graphical illustration of this output.

Example of Risk Analysis Output

Cost Savings from Transportation Improvements	
Cost Savings ($Millions)	**Probability of EXCEEDING Value Shown at Left (Percent)**
$63.3	95%
$87.0	90%
$115.9	80%
$137.1	70%
$155.8	60%
$174.0	**50%**
$193.3	40%
$215.5	30%
$244.3	20%
$291.0	10%
$337.2	5%
$169.9	**Mean Expected Value**

Example of Risk Analysis Output, Decumulative Probability Distribution