Benefit-Cost Assessment Guidance for Evaluating Proposed Highway Tolling and Pricing Options for Oregon

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Introduction

The 2007 Oregon legislature directed the Oregon Transportation Commission (OTC) to develop tolling policy recommendations so that, if the state decides to pursue tolling, it will have a consistent framework and foundation on which to develop, implement, and evaluate potential projects.

In response to this direction, seven white papers were commissioned to evaluate and understand a series of technical tolling issues and their implications for motorists, the transportation system and communities in Oregon. The papers, completed in 2009, discuss the following issues:

1. Tolling and reductions of greenhouse gas emissions
2. Geographies and circumstances where could tolling work
3. Incorporating tolling and pricing into Oregon's regional transportation models
4. Economics of transportation system reliability
5. Effect of "pricing" urban highway networks on transportation, people, and businesses
6. Determining if tolling a project is a better alternative than other non-tolled options, and choosing between a number of tolled alternatives
7. Determining if truck-only toll lanes are a viable option for Oregon

White Paper 6, *Economic Comparison of the Alternatives for Tolling Projects*,[1] describes how benefit-cost analysis can be applied to tolling projects, and discusses how a benefit cost analysis (BCA) approach can determine if the anticipated benefits of tolled projects justify their costs. That paper also discusses the limitations of BCA.

The purpose of developing this BCA guidance document is to provide a *systematic and transparent approach* that can be used by ODOT staff for conducting a BCA of alternative options for highway tolling. The document lays out a verifiable methodology that is capable of identifying economic consequences of the imposition of tolling schemes in terms of their positive and negative consequences for the economy of the Portland region and elsewhere in the state. This guidance provides transparency to the public on how these analyses are conducted. It also ensures that consistent approaches are used to conduct analyses for identified tolling projects, as well as for choosing among alternative solutions for a given project.

This document describes the methods and identifies the data sources needed to prepare BCAs. The tolling projects discussed include: (1) removing a single general use lane from a freeway and tolling it; (2) tolling a bridge (including tolling of an existing bridge to pay for a new bridge); (3) tolling at ramp meters; (4) tolling an entire freeway or a freeway segment; (5) developing high occupancy toll (HOT) lanes; and (6) developing new tolling facilities.

[1] Prepared by Economic Development Research Group, Inc. and Parametrix, Inc. for the Oregon Department of Transportation, February, 2009. Available at: http://www.oregon.gov/ODOT/TD/TP/docs/LRPU/twp6.pdf.

What Is Benefit Cost Analysis?

Benefit cost analysis (BCA) is a technique for comparing two or more projects by comparing the project's benefits and costs that are realized and expended over several years. BCA can only reflect benefits to the extent that all costs and benefits can be "monetized" into dollar terms. This includes converting a non-monetary benefit or cost or benefit, such as personal time savings, into a monetary equivalent. Factors that cannot be monetized must be considered separately from the BCA. Consequently, there may be cases in which a project looks unfavorable from a BCA perspective, but is viewed favorably because it has additional, hard-to-quantify benefits (e.g., reduced noise to properties abutting the roadway).

The benefit-cost ratio is the value of all discounted benefits divided by discounted costs. When benefits exceed costs, the benefit-cost ratio is greater than 1.0; conversely, when benefits are less than costs, this ratio is less than 1.0. The most common highway-related benefits considered in a BCA include the value of time saved by drivers, savings due to increased safety, and lower vehicle operating costs as a consequence of the project. Costs are usually the sum of construction, annual operating, routine maintenance, and scheduled capital rehabilitation costs. Benefits and costs are organized in a framework that includes three major characteristics:

1. A *specified analysis period*, usually 20–30 years, which should be consistent among all alternatives being compared.
2. A *realistic base case*, that is, an estimate of future expected conditions and costs (such as increased roadway maintenance or anticipated rehabilitation) if a build alternative is not constructed.
3. A *discount rate* that reflects the "time value of money," in the sense that money in hand today is more valuable than the same amount of money received in the future. "Present value" represents the value of money at the beginning of a project. The discount rate is the annual rate at which future dollars lose value compared to present value. Accordingly, the value of future benefits is lowered as:
    - The discount rate is increased; and
    - Years elapse from the start a project.

BCA does not specify whether a project or particular alternative is affordable to construct, it does not fully address environmental issues (unless these impacts are monetized), and it does not address equity issues. Moreover, BCA does not consider the impacts of changing access to multimodal facilities, delivery markets, labor markets, or customers that can be attributed to a proposed tolled or untolled roadway or bridge. Increased access potentially improves cost-competitiveness for businesses, changes patterns of household spending, and leads to more personal and business income for Oregon's economy. These latter benefits, however, are economic impacts and fall outside the benefit-cost framework.

Although BCA effectively measures whether the benefits of a project will exceed its construction and operating costs, it should not be the sole analytical tool used to make decisions. A package of analytical methods is required to fully evaluate the costs and benefits of transportation projects, including economic impact analysis, environmental analysis, and financial analysis, as well as equity considerations.

Purpose of this Guidance Document

As stated above, the purpose of this BCA guidance document is to provide a systematic and transparent approach that can be used by ODOT staff for conducting a BCA of alternative options for tolling transportation facilities. This document addresses the task of comparing an untolled "base case" against one or more proposed tolled "build alternatives." The document frames the overall task of a BCA and provides common sources of data for evaluating tolling projects in Oregon.

Tolling introduces new concepts or issues to the state's transportation planning process that can be addressed through BCA, including:

- *The economic benefit to motorists of improved speed and reliability.* Improving travel reliability is a primary motive for some tolling applications, such as toll-managed lanes.
- *The reaction of motorists to the presence of tolls, particularly when diverting their trips to untolled roads.* Such traffic diversions may increase congestion on these untolled facilities and may, in turn, result in lower speeds, decreased safety, and other negative impacts. The negative impacts of these diversions are counted in BCA by subtracting them from the positive impacts found in other parts of the analysis.
- *Properly framing non-tolled alternatives to tollway proposals.* Tollways, other than bridges, must be of a sufficient size to offer motorists enough improvement in travel time or reliability to merit paying the toll. Non-tolled alternatives may be phased in smaller increments.

The public may question the need and appropriateness for tolling, particularly on facilities constructed with public funds. Tolled facilities can offer some clear benefits in improved travel time and reliability, which are important considerations in achieving general public acceptance of tolling proposals. BCA provides the public with a transparent approach to evaluating the benefits and costs of proposed or potential tolling projects.

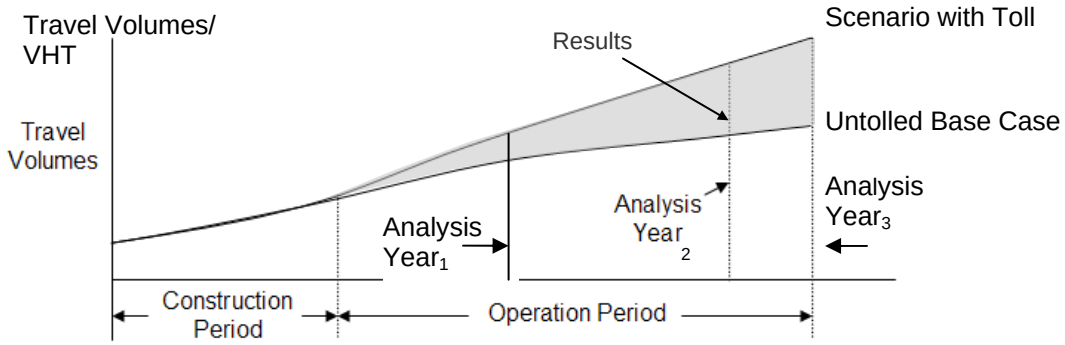
1. BCA Development

Benefit-Cost Analysis (BCA) aids in making capital investment decisions by determining whether the benefits of a proposed action justify its costs. BCA is a tool to aid agencies in project selection and prioritization. At its core, it is a computational tool to determine whether an investment will generate benefits that will exceed its costs. This analysis is accomplished by expressing all current and future benefits and costs on an equivalent basis, which is their "present value" (PV). A project is economically efficient if it has a positive "Net Present Value" (calculated as the PV of benefits minus the PV of costs), and hence also a "Benefit-Cost Ratio" exceeding one. The use of BCA has significant limitations, which are fully recognized by the Oregon Department of Transportation (ODOT). For instance, BCA measures only aggregate benefits and costs without considering who incurs them or the form in which they occur. Thus, it does not address issues of impact distribution, such as when one party gains at the expense of another. It also does not address issues of equity, such as the distribution of who pays and who benefits or the fairness of how funds are allocated. In addition, some types of benefits are hard to quantify in monetary terms, which is required for BCA.

The initial steps in the benefit-cost analysis should capture the appropriate benefits and cost differences between the base case and the identified alternatives. Benefits of a project are derived from comparing the base case highway user data (travel time, operating costs, and safety) that occur within the study area to those of the alternative scenario(s). These comparisons are built around one or more specific future snapshot year(s) , or "analysis year(s) ", that are used to project differences in benefits, costs, and economic activities in that year. While the common approach to BCA is to project a single benefit horizon, it is acceptable to include multiple analysis years in a single BCA. A multiple analysis year approach is warranted if investments will be staggered in phases and/or if significant "bumps" (or declines) of trips are expected to occur at different times in the project's life.

The comparison will be between two policy options such as "build a tolled facility" or "don't build the tolled facility, but account for what will happen without it." This approach means that results are shown as differences in benefits and costs between the "build" and "base case" scenarios in a given year. Figure 1 demonstrates this concept applied to tolled vs. untolled project scenarios.

Figure 1. BCA Overview: Comparing Toll Build Alternative to an Untolled Base Case



Source: TREDIS Users Guide. Note, the shaded area represents the accrual of project benefits over time.

This guidance document builds on the discussion of benefit-cost analysis in White Paper 6, *Economic Comparison of the Alternatives for Tolling Projects* (February 2009), which is one of seven white papers on tolling policy commissioned by ODOT. White Paper 6 reviews the pros and cons of BCA and discusses different BCA components. The purpose of this guidance is to: (1) illustrate how a BCA is brought together; and (2) outline the core data and recommend data sources required for each component of BCA. This document is applicable for the following types of projects: (1) removing a single lane from a freeway and tolling it; (2) tolling a bridge (including tolling of an existing bridge to pay for a new bridge); (3) tolling at ramp meters; (4) tolling on a freeway (entire freeway or a freeway segment); (5) developing high occupancy toll (HOT) lanes; and (6) developing new roads that are tolled.

1.1 Initial Setup Requirements

An analysis period of 20 – 30 years is typical for transportation improvement projects, because traffic and demographic forecasts are generally available and manageable for this time frame. The general principles for selecting an analysis period are:

- The time frame should be long enough to capture the majority of benefits, but not so long as to exceed capabilities to develop good traffic information. So, for ODOT projects, it needs to be governed by the modeling span of ODOT's transportation demand models, as well as the demographic projections that are used by the modelers.
- The time frame should be the same for all alternatives.
- All benefits and costs within the time frame should be included in the analysis.

Note: the Federal Transportation Plan requirement is 20 years.

Generally, BCAs are evaluated for the end of the modeling period – for example, Year 20. However, more than one evaluation year may be used if ODOT wants to look at intermediate benefits, say, in Year 10, as well as Year 20. This approach is valuable when alternatives have different investment and phase-in schedules.

1.1.1 Days in a Year

For BCA, the number of days in a year may be 365 for all year or 260 for week days.[2] Typical capacity improvement projects associated with tolling should use 260 days, and exclude weekends. In cases where Saturdays show a similar pattern of vehicle miles traveled (VMT) as weekdays, weekday traffic (260 days) and Saturday traffic (52 days) should be analyzed separately if the profile for Saturday shows a shorter peak period and less extreme congestion than observed for weekday traffic. If, however, a tolling facility serves to shorten the length of a trip – reducing mileage between two points – then benefits should be considered for the full calendar year. Another alternative is to separate weekday and weekend traffic. This latter approach is appropriate when the route incurs substantial recreational traffic. The number of days assumed in a year should always be noted in BCA documentation and analysis documentation and should be consistent for the base case and all build alternatives.

1.1.2 Defining the Problem

It is best to explicitly define the problem that a tolling project proposes to address. The problem usually involves severe congestion due to demand that overwhelms a roadway capacity (now or anticipated by some future year), or poor reliability of a current roadway due to disrepair that causes backups and safety concerns. Tolling options may be motivated to improve traffic flows, achieve greater system reliability, and/or raise revenue.

The second step is to identify potential solutions to the problem, which are the steps in the development of build-alternatives. After the set of alternatives has been identified, the benefit-cost framework allows the public to compare possible solutions to the defined problem.

1.2 Base Case

Every analysis requires a definition of a base case. Establishing a realistic base case provides a reference point against which the incremental benefits and costs of alternatives are measured. If, for example, a base case for a given project shows 1000 vehicle hours traveled (VHT) and a proposed toll facility shows 800 VHT, then the BCA assesses the savings of 200 VHT.

To develop the base case, we realistically represent current and expected future conditions if the proposed project is not undertaken. The base case can represent a combination of "no build," “operations and maintenance,” "some build," and/or "investment to avoid failure.” According to

[2] For commuting traffic corridors, guidance from a wide variety of state DOTs suggests using the number 260 (52*5) to extrapolate from a typical workday to an annual total for traffic impacts during commuting periods (examples include Minnesota, Florida and Texas). This is the most widely used value in transportation studies across the nation. However, an argument can be made for using 250, recognizing that there are 10 federal holidays per year. On the other hand, many private sector businesses do stay open on at least some of those federal holidays, and in the retail sector, many stay open on all but two of those holidays. For general daily traffic, it is common to also consider weekend days, and assume that they average roughly half of a weekday traffic level, in which case the multiplier would be 312 days (52*6). It is rare for 365 to be used. Finally, for specialty corridors such as those serving sports and recreation facilities, it is necessary to adopt custom extrapolation factors representing seasonal traffic or event frequencies.

FHWA guidance, the base case is the best course of action that would be pursued in the absence of a major initiative to meet the investment objectives identified.[3]

The base case should include allowances for changes in levels of population and employment, traffic patterns and congestion.

1.2.1 Costs

The base case should be constrained to foreseeable revenues. Within those constraints, the base case needs to assume operation and maintenance of existing roadways, incorporating improvements that are currently underway and/or funded, and adding reasonable expectations of corrective actions (for example, safety improvements that will be required if a build alternative is not enacted). This approach reduces the likelihood of overestimating benefits from reduced congestion.

1.2.2 Safety

Accident rates are often higher on older roads than on newer facilities with less congestion. BCA can capture the benefits of the improved safety of a toll facility over the base case due to reduced accident rates or accident severity. Accident rates, as usually calculated, are categorized by severity:

- Fatality Accident
- Personal Injury Accident
- Property Damage Accident

Accident rates and costs can be derived from local knowledge and be factors that are used in ODOT or regional MPO analyses, or can be derived from national sources and studies.[4]

[3] See *Toward the Evaluation of Value Pricing*. Lee, Douglas Jr., November 2007. Lee discusses the automatic tendency to regard high occupancy vehicle (HOV) lanes as a base case for evaluating HOT lanes, and argues that the untolled general traffic lane should be the base case for HOT lanes because "excess capacity in HOV lanes is used by toll payers, who probably came from the general purpose lanes."

[4] Data sources will be presented in the draft of Section 2.2. Because sources on safety benefits were discussed in the process of reviewing the outline for this paper, the sources are presented here. Generalized accident factors can be derived from the following sources: total fatality cost, including both money costs and social value of lost life and lifetime earnings, from "Treatment of the Economic Value of a Statistical Life in Departmental Analysis – 2009 Annual Revision," USDOT, Memorandum to Modal Administrators, March 18, 2009, at: (http://ostpxweb.dot.gov/policy/reports/VSL%20Guidance%20031809%20a.pdf). Values for injury and property damage are drawn from Blincoe, L. et al. (2002). *The Economic Cost of Motor Vehicle Crashes, 2000* (Table 2). These values need to be updated from 2000 dollars to current year dollars by the CPI. Available at: (http://thedesignstate.com/wp-content/uploads/2009/04/economicimpact2000.pdf) The Bureau of Transportation Statistics maintains a tabulation of accident rates in its national transportation statistics publication.

1.3 Approach to Build Alternatives

The proposed alternative(s) are a specific and discrete set of tolled highway/bridge improvements that can be undertaken. These improvements generally change travel times, vehicle operating costs, and/or safety characteristics from the base case. To be meaningful, proposed alternatives must also be reasonably distinct from one another. Slight alignment shifts or changes that have little to no impact on travel times, safety, or operating costs need not be considered as separate alternatives from the benefit-cost analysis standpoint. The alternative should be specified in as much detail as possible for purposes of estimating costs (capital and maintenance) and effects on travel time, operating costs, and safety.

The benefits of a transportation investment are typically estimated by comparing travel time, vehicle miles traveled, and expected safety improvements for the base case to each build alternative. The base case is treated an alternative for the purposes of data entry and modeling.

1.3.1 Travel-time Savings

Travel-time savings between an untolled base case and one or more tolled alternatives typically generate the greatest amount of benefit. Travel time is usually expressed as vehicle-hours traveled (VHT) and is estimated from travel demand models of appropriate metropolitan planning organizations (MPOs) in Oregon.

Estimates of travel time should include times for both the driver and passengers in the vehicle (i.e., vehicle occupancy rates). In many cases, vehicle occupancy rates vary between peak and off-peak hours as well as between alternatives. Several vehicle occupancy rates may be used to represent different conditions, including the effects of diversion onto other roads or untolled lanes in circumstances when proposals to convert a single freeway lane to a tolled facility are being studied.

1.3.2 Capital Costs

Capital costs make up the total investment required to prepare a highway improvement for service, from engineering through landscaping. When possible, capital costs should be grouped into similar life-cycle categories to facilitate comparisons among alternatives and updating of cost assumptions. Such categories include: engineering, right of way, major structures, grading and drainage, surfacing, and miscellaneous items.

Estimates of capital costs range from detailed engineer's estimates to planning-level costs. This is the denominator of the benefit/cost calculation, so it is important to be as realistic as possible. Costs are defined in a constant dollar value. ODOT's engineering section is the preferred developer of cost estimates for build alternatives, as well as for the base case. If ODOT is unable to provide cost estimates, then other reliable sources could include an MPO staff engineer or a certified Professional Engineer. In addition to these options, professional planners and transportation experts can estimate costs as a final option, if necessary.

Base case and alternative costs should be developed in parallel to ensure consistency. This will help when checking costs for accuracy or making changes as needed. If certain costs are not relevant to the base case or to a build alternative, enter $0 when appropriate. For example, it is

likely that there are no costs projected for tolling electronics in an untolled base case, but it would be an expense in a contrasting tolled alternative. These costs need to be placed in an annualized context appropriate for discounting.

The major costs for highway development are the initial capital cost for investment, anticipated rehabilitation during the useful life of the project (if any), and annual operating and maintenance expenses. In addition to the costs of adding highway lanes or building a new roadway or bridge, tolling costs include capital costs and operating and replacement expenses associated with toll collections, including construction (tollbooths, if tolling is not entirely electronic), hardware, software, and labor.

Figures 2 and 3 sketch out a spreadsheet for comparing the base case and build alternatives. Figure 2 illustrates how the base case and build alternatives are compared for determining cost of the build alternatives.

Figure 2. Summary of Capital Cost Comparison of Base Case and Build Alternative(s)

	Cost	
Category	**Base Case**	**Alternative**
Property Acquisition		
Engineering and Design		
Grading & Drainage		
Wet Lands Replacement		
Paving/Road Construction		
Transport Structures (bridges)		
Vehicles		
Tolling Electronics and other Equipment		
O&M		
Rehabilitation/Safety Improvement		
Total Cost		

The base case should include expenditures that would be superseded by a build alternative. The marginal cost of a build alternative is: *Alternative – Base Case*.

Figure 3 shows these costs placed in an annualized spreadsheet, which is necessary to discount costs over time, and illustrates capital costs arranged in an annualized spreadsheet. A spreadsheet needs to be developed for the base case and each tolling alternative that is being compared to the base case. Although the cost difference in each category by year could be compared, the only critical comparison is the difference in the "Totals by Year" column (shown in the red circle) for the base case and each build alternative.

Figure 3. Annualized Spreadsheet to Facilitate Capital Cost Comparison of Base Case and Alternative and Discounting for the Benefit Cost Analysis

Year	Property Acquisition	Engineering and Design	Grading & Drainage	Wet Lands Replacement	Paving/Road Construction	Transport Structures (bridges)	Vehicles	Tolling Electronins and other Equipment	O&M	Rehabilitation/ Safety Improvement	Totals by Year
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
Totals											

1.3.3 Benefits are Compared in a Similar Fashion to Costs

Net benefits of project alternatives are based on changes in VMT, VHT, trip demand, and reliability forecast for an alternative when compared to the base case forecast. The applicable travel demand model will be the primary source for these data.[5]

Project costs and benefits are phased in for build alternatives. Figure 4 provides a schematic of how to approach a build alternative phase-in. These steps usually follow in a logical sequence. Planning and engineering and land acquisition precedes construction. Project benefits cannot begin until after the facility opens. Benefits usually increase based on increased demand for transportation. Maintenance costs are usually minimal for a new facility just after opening, and then increase as the facility ages and requires increased levels of service, until capital rehabilitation and/or tolling equipment needs to be replaced (illustrated under "Construction/Other" in Figure 4). Then the cycle beginning with low maintenance cost begins again.

[5] Net benefits include changes in "reliability," discussed in Chapter 2.

Figure 4. Illustration of Project Phase-In Timing

Year	Property Acquisition	Engineering	Construction/ Other	O&M	Project Benefits
1	x	x			
2		x	x		
3			x		
4			x		Benefits Begin & Grow Over Time
5				Minor	
6				Minor	
7				Minor	
8				x	
9				x	
10				x	
11				x	
12				x	
13				x	
14			x	x	
15			x	x	
16				Minor	
17				Minor	
18				Minor	
19				x	
20				x	

1.4 Travel Benefits

Benefits are derived from travel impacts, which are developed by the travel demand model. Measures for both the base case and build alternatives generated by the model include travel time, VMT, trips, and passengers. After both the base case and build alternatives are so modeled, results are monetized. Then the incremental monetary benefits realized by build alternatives over the base case are compared to incremental costs, as shown in Figure 4.[6]

[6] Factors and methods for monetization are discussed in Section 2.2.

Traveler benefits, or direct user benefits, are the traditionally used measure of benefits in BCA, and are defined to include benefits accruing to drivers and passengers and savings in vehicle costs as a result of improvements in travel times; travel expenses; and travel safety. Benefits associated with switching modes of travel, origin-destination patterns, and "induced" additional travel is also counted.[7]

Figure 5 shows a basic matrix needed to begin the process of monetizing benefits.

Figure 5. Transportation Modeling Output

	Average Annual Daily Traffic[1]	
	Base Case	**Build Alternative**
Commuting vehicle trips		
Commuting average vehicle trip time		
Commuting average vehicle trip length		
Non-commute vehicle trips		
Non-commute average vehicle trip time		
Non-commute average vehicle trip length		
Congested miles (volume/capacity > 0.90)		
Congested % of VMT		
Passenger occupancy		

Notes:

[1] The time frame needs to be specific. Three options for setting the daily time frame are (1) Differentiating among AM peak hour/s, PM peak hour/s, rest of day – in this case all traffic is counted in the model; (2) AM peak hour/s with factors supplied to increase data to daily or annual totals; or (3) total average annual daily traffic – not recommended because differences between time periods are significant and spreading VMT over 24 hours will under-represent peak hour even under extremely congested conditions. In addition, options for days in a year vary by the problem being addressed and the nature of the existing or planned roadway; these options may be: (1) every day, (2) weekdays, (3) weekdays and Saturdays calculated separately, or (4) weekdays and weekends calculated separately.

Safety is usually expressed and calculated as factor (e.g., accidents rate per thousand VMT) and is discussed in Chapter 2.

[7] This is the concept of "consumer surplus." For projects with no induced travel, the change in direct travel impacts between two scenarios can simply be calculated as the difference between the two scenarios. However, for projects with induced travel, this "simple" difference must be adjusted to account for travelers' and shippers' economic response to travel cost changes. A new tolling application may increase speed and thus reduce cost measured by travel time. Over time, firms and households recognize this lower price as an opportunity to decrease production costs or satisfy new trips. In both cases, the total number of trips (or miles traveled) may increase in the long term. If direct impacts are calculated as the "simple" user cost difference between scenarios, then overall benefit might be underestimated because the new (induced) trips are tallied as having costs but no benefits. In reality, induced trips are made *precisely because they have value* which outweighs the cost of making the trip.

2 Data Sources and Calculations

2.1 Discount Rate

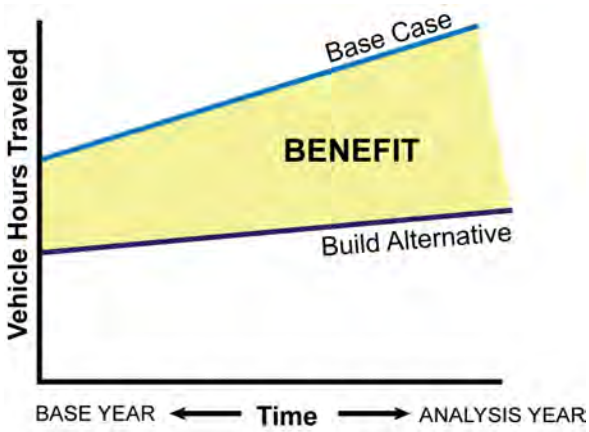
The discount rate for tolling BCA should be 4.73%, which was the fully loaded interest rate on 25-year bonds from ODOT's last bond sale in 2009. The discount should be re-established each time ODOT sells long-term bonds of 20 years or more. A discussion of setting a discount rate for BCA is found in White Paper 6.[8]

2.2 Benefits

Toll road user benefits are dependent on the differences between the base case and the build alternative(s) in the number of trips, the distribution of trip purposes, vehicle hours traveled (VHT), and vehicle miles traveled (VMT).

As described in Section 1, highway user data developed from peak period transportation demand models need to be multiplied by the appropriate number of days in the analysis year to reflect annual totals.[9] Figure 6 shows a simple example where projected VHT is less than the forecast VHT for the base case. The benefit in terms of VHT, as shown, is the difference between the build alternative and base case from the base year to the analysis year (typically Year 20).

Figure 6. Benefits are calculated as the difference between a base case and one or more build alternatives.



The basic metrics required for a BCA are value of time saved, savings related to reduced (or increased) distances traveled, less congestion measured by faster drives during peak periods and a decrease in volume/capacity ratio, emissions reductions, and savings attributable to reduced crashes and associated fatalities. In BCA, these are translated into automobile passenger time costs, vehicle operating costs, and safety costs (e.g., costs of crashes and fatalities, increased reliability, and emissions savings), and are applicable to automobile and truck traffic, freight delivery benefits, and crew cost savings for trucking.

[8] Alternatively, many states use the rate of long-term private bonds signifying the displacement of private capital. The difference in the rates is the taxable portion of the private bonds.

[9] For AM peak period model, it would be appropriate to double the results to reflect both AM and PM peak. Peak period analysis should be sufficient for tolling projects intended to provide congestion relief. If, however, ODOT wants to look at benefits on a 24 hour basis, then the Department will need to estimate the percent of average daily traffic (ADT) in relation to peak periods. As an example, if a morning peak period travel demand model accounts for 40% of ADT (2/5 of ADT) that multiply the results by 5/2. This will increase benefits of the BCA, but ODOT will need to determine if it is warranted to assume benefits accruing outside of peak periods.

For BCA, the value of VHT savings, as well as differences in vehicle miles traveled and the number of trips made, need to be monetized according to: (a) type of vehicle (passenger car, truck—including truck type, such as delivery, long-distance haul, etc.); (b) purpose of trip (on the job, commuting, or personal travel); and (c) type of benefit (generally, value of time, vehicle operating cost, safety, freight delivery, reliability). These core dimensions for calculating benefits in BCA are summarized in Figure 7, below.

Figure 7. Dimensions of Benefit Calculations

Factor	On the Job Value	Commuting Time Value	Personal Time Value	Multiplier		
				VHT	VMT	Trips
Auto						
Average Passenger Occupancy						X
Passenger Time Cost	X	X	X	X		
Auto/Truck						
Safety					X	
Vehicle Operating Cost				X	X	
Congestion/Reliability/Delay	X	X	X	X		X
Truck						
Freight Delivery	X			X		
Crew Costs	X			X		

2.2.1 Vehicle Occupancy

The BCA should use the most recent vehicle occupancy rates published by the National Household Travel Survey. The 2009 rate for passenger cars is 1.59 and 1.71 for all vehicles (see Figure 8).[10]

[10] Alternately, vehicle occupancy rates can be found ODOT, *Oregon Passenger Vehicle Occupancy Rates for Urbanized Highways and City Streets, by Functional Class*. The most current rates as of this writing are based on 2006 data, issued August 30, 2007 (http://library.state.or.us/repository/2007/200711010921074/index.pdf). Vehicle occupancy rates are computed by region and statewide. For the 2006 study, occupancy rates are equivalent among the Portland area and the sum of all of Oregon's urban areas, and among the types of roadways that may be tolled (interstate freeways, and other freeways and expressways). Passengers per automobile for each segment range between 1.32 and 1.35. The values in the table are from the August 30, 2007, report and should be changed to incorporate ODOT updates of vehicle passenger occupancy rates. However, the source of these data is accident reports of crashed vehicles; therefore, the data may not be as reliable as survey data. This is a final determination that ODOT will make.

Figure 8. Average Vehicle Occupancy Rates

Vehicle	Average Occupancy
Car	1.59
Van	2.35
SUV	1.92
Pickup truck	1.49
Other truck	1.12
RV	3.76
Motorcycle	1.18
All	**1.71**

Crew Size per Truck. ODOT calculates crew size estimates for truck drivers and will provide its latest estimate.[11]

2.2.2 Value of Time

Faster speeds from the base case realizable through build alternatives are monetized through the value of the time being recouped by users of toll alternatives. Prior to calculating the value of time benefit, users need to be segmented into the following classifications:

- Truck drivers and crew
- Automobile drivers and passengers on the job
- Automobile drivers and passengers commuting
- Automobile drivers and passengers on personal trips

The value, or cost, of time spent traveling is separately defined for each mode (truck or auto) and each trip purpose. For each mode-trip purpose combination, driver, crew and/or passengers' total time cost is calculated as total vehicle hours traveled (VHT) times a specified cost rate per hour (CostPerHr), multiplied by the number of drivers/passengers (DPperVeh) per truck or automobile. Scenario totals are summed over modes and trip purposes.

$$ValueofTime = (VHT) * (DPperVeh) * (CostPerHr)$$

The opportunity cost (value of time) for on-the-job travel is the employer's cost, and therefore truck and auto on-the-job travel (OJT) should be inclusive of personal fringe benefits and employer-paid benefits. Monetized values for different classifications of roadway users are summarized in Figure 9 and discussed following the table.

[11] Alternately, a factor of 1.3 is drawn from typical values for New York City, San Francisco and Chicago, as reported in Chester, Mikhail, Institute of Transportation Studies, UC Berkeley, 2008. This value may vary for Oregon by region and by industry. For projects involving high-intensity truck corridors, this and other operational information about commercial vehicle costs and operations should be assessed.

Figure 9. 2009 Values of Time

Crew Time Cost ($/hr per crew member) – the business cost of labor for professional drivers and paid crew (including cost of wages plus fringe benefits).	**Car:**	**$21.60**
	Truck:	**$23.03**
	Bus:	**$27.33**
Passenger Time Cost ($/hr per occupant) – the business opportunity cost, or user valuation, of the average passenger's time. This is in addition to the passenger vehicle operating cost per hour.	**On-the-Clock:**	**$28.00**
	Commute:	**$21.60**
	(=user benefit	*$10.80*
	+wage premium	*$10.80)*
	Personal:	***$10.80***

Values for truck drivers', truck crew, and bus drivers' wages are statewide 2009 values drawn from the Oregon Labor Market Information System: Occupational Information Center. The truck value of $23.03 represents the weighted median wages for drivers of heavy trucks and tractor trailers; light trucks or delivery services; and company-owned sales trucks, with 42% added for fringe benefits (national average in those occupations).

Values of time for automobile drivers and passengers are generally consistent with methods for valuing *user travel time benefits* as recommended USDOT guidance and followed by HERS and the Center for Urban Transportation Research (CUTR) and. Values have been updated to reflect current wage rates, based on BLS data.[12] Also, *additional long-term business costs* (beyond the user value of travel time) have been added in the form of fringe benefit costs for "on-the-clock travel" and wage premiums paid by employers for commuting in higher-cost congested areas. As a result, "on-the-clock" travel time is calculated as a business cost valued at 100% of the national average wage rate plus 30% fringe.

[12] May 2008 National Occupational Employment and Wage Estimates for Oregon. 2008 data are the most current as of this writing. Data should be updated with each new data release.

Both commuting and personal travel times are treated as a non-money user values set at 50% of the wage rate (no fringe added), but higher commuting cost also brings an additional employer cost in the form of a wage rate premium valued at another 50% of the wage rate per hour without fringe (per research by Carlson, Zax and others).[13] The application of commuting value is illustrated in Table 2, above.

Value of Time for Logistics Improvements. Broader "User" Benefit measures are now becoming more common in BCA. All BCAs include traveler benefits, but analyses may also add logistics benefits. These are freight distribution system efficiencies that increase productivity for shippers and consignees, who, after all, are the true "users" of the freight transportation system.

Economists define productivity as the amount of output produced by a firm or industry per unit input (typically defined as labor or capital). There is general consensus among modal guidance documents that transportation projects can have the ability to stimulate increased productivity at varying geographic levels. In the context of airport improvements, the primary mechanism for productivity improvement occurs as freight shippers respond to lower transportation costs by adjusting inventories or shuffling logistical activities (FHWA 2001). However, no clear consensus has emerged as to how to measure such benefits in BCA, presumably because productivity impacts can vary among project types and modes, and such impacts can be difficult to measure.

Generally, three types of logistics benefits can be realized from a highway project:

- Benefits to shippers for freight travel should be picked up through transportation demand modeling and subsequent calculations, as long as the travel demand model (TDM) used for the BCA includes truck-mode.
- Shipper/consignees productivity gain, which is defined as the additional net income produced through cost savings or scale or production economies for shippers.
- Connectivity improvements to other highways, intermodal freight yards, marine ports and/or airports.

Commodities have varying cost sensitivities to delay, accounting for spoilage, just-in-time manufacturing processes, and time-sensitive retail items. The cost of freight delays can be estimated without purchasing expensive data or surveys. Typical cargo loadings for trucks come from the USDOT Comprehensive Truck Size and Weight Study. Moreover, freight logistics cost per ton can be estimated on the basis of values assigned for recurring travel time delay from HEAT documentation, based on literature review and additional research by Cambridge

[13] Carlson, William E.: The Spatial Variation of Wages in U.S. Cities and States, Wesleyan University, October 2009. *"By paying premium wages, firms can increase the sizes of their labor pools. The wage premium attracts workers who must commute from further away. Willingness to commute as a function of the wage offered defines the labor supply curve. Hence, in the inverse labor supply function, the proxy for labor quantity is commuting time" ... "The urban economics explanation is that one worker commutes further, or pays a higher rent to live close to the job, and must be compensated for those costs."*
A preponderance of literature that supports this, including Zax, J.S.: *Compensation for Commutes in Labor and Housing Markets*, Journal of Urban Economics Vol. 30, 1991; and Darren Timothy, and Wheaton William C., *Intra-Urban Wage Variation, Employment Location, and Commuting Times*. Journal of Urban Economics, vol. 50, 2001.

Systematics and EDR Group. These logistics cost values, when added to crew cost and vehicle operating cost, yield total freight costs per hour in line with Texas Transportation Institute congestion studies. These data are summarized in Figure 10.

Figure 10. Value of Time for Transport of Freight

	Non-Manufactured Goods	Manufactured Goods		
		All Manufactured Goods	Durables	Non-Durables
Average Freight Tons per Truck	1.0	17.5		
Freight Logistics Time Costs ($ per ton)	$0.75		$2.50	$1.50

2.2.3 Vehicle Operating Costs

The change of total vehicle operating costs between the base case and build alternative(s) is a benefit in BCA.[14] These costs include depreciation, fuel, and maintenance costs.[15] Operational costs can be measured either by unit time (for example, $ per hour) or unit distance (for example, $ per mile) and the value of reduced delay and improved reliability on in-vehicle cargo.

It is important to be able to calculate operating cost on a per-mile or per-hour basis for several reasons. First, across modes, operating costs may be known more precisely by mile (for example, passenger car) or by hour (for example, operations in congested conditions). Accommodating both therefore leads to more accurate overall cost estimates.

Second, depending on the nature of the project, either VHT or VMT may remain constant across scenarios. For example, a new toll lane added to an existing freeway (or adaptation of a freeway lane to a tolled lane) might reduce VHT by increasing travel speeds without changing VMT. Calculating operating costs using VHT only would yield no difference between scenarios in this case. Alternatively, a new toll road might: (1) increase VMT and decrease VHT due to greater speeds and less congestion; (2) decrease *VMT as well as VHT*; or (3) increase both VMT and VHT due to diversions. The first example might yield additional cost using VMT and show cost savings using VHT. In the second case, the benefits of both measures should be represented. In the third case, both the volumes and routes for diverted traffic need to be assessed in travel demand models developed and calibrated to address these issues—especially where tolling is being introduced on untolled, non-HOV (high occupancy vehicle) roadways. These possible permutations necessitate a sophisticated approach to calculating operating costs:

- *Vehicle Operating Cost ($/mile, free-flow)* – the average per-mile cost of vehicle operation for uncongested network travel.

[14] In most cases, it is expected that build alternatives will incur less operating costs than the base case; therefore, the differences between base case and alternatives show a savings of operating costs. In circumstances when operating costs of alternatives are greater than the base case, the resulting "negative benefit" is also included (as a negative number) as a benefit.

[15] Other costs such as insurance, finance, and storage are explicitly excluded either to avoid double counting (insurance), or because they do not explicitly vary with distance or speed traveled. In addition, as discussed in White Paper 6, out-of-pocket toll payments are transfer costs and do not enter into BCA calculations.

- *Vehicle Operating Cost ($/mile, congested)* – the average per-mile cost of vehicle operation under congested conditions. For highway travel, congestion is defined as a volume-to-capacity ratio greater than 0.9.

- *Vehicle Operating Cost ($/hr, congested or idle)* – the per-hour cost of a vehicle sitting at idle, in a queue, or traveling in highly congested conditions (volume-to-capacity ratio greater than 0.9).

As a simple calculation, the cost of most road modes is easily estimated on a per-mile basis because both mileage and volume-to-capacity ratios are known. In cases when a tolled build alternative is being proposed to relieve highly congested conditions, it may be appropriate to base the measure of vehicle operating cost savings on VHT reductions. Also, the *per hour operating cost* measure is to be used when a project speeds up travel time but does not reduce mileage traveled. The larger of the VHT and VMT calculations may be used in the BCA.

From Figure 11, below, the per mile operating cost measure is to be used when the savings in travel time is due to a reduction in route mileage. Operating cost/mile for cars is an average of small, medium, and large cars, SUVs and light trucks ranging from $1.03–$1.38, depending on speed (based on FHWA Truck Size and Weight Study).

Figure 11. Vehicle Operating Costs

Vehicle Mileage-based Operating Cost: Free Flow ($/mile) – the average per-mile cost of vehicles' fuel, tires, maintenance, and depreciation for travel in free-flow conditions.	**Car/light truck:**	**$ 0.58**
	Heavy Truck:	**$ 1.18**
	Bus:	**$ 1.45**
Vehicle Mileage-based Operating Cost: Congested ($/mile) – the per-mile costs of vehicle operation under congested conditions.	**Car/light truck:**	**$ 0.64**
	Heavy Truck:	**$ 1.46**
	Bus:	**$ 1.55**
Vehicle Operating Cost based on Congested Conditions ($/VHT)	**Car/light truck:**	**$ 2.00**
	Heavy Truck/Bus:	**$ 4.50**

Source: U.S. EPA, AAA *Your Driving Costs,* 2008 Edition, Berwick and Farooq (2003), adjusted to 2009 dollars. Subsequent years should be adjusted by using the U.S. Consumer Price Index.

2.2.4 Safety Benefits

The National Highway Traffic Safety Administration (NHTSA) estimates costs result from property damage, personal injuries, as shown in Figure 12.

Figure 12. Safety Values

$ per Accident	**Prop Damage**	**$ 3,200**
	Pers. Injury	**$ 84,000**
	Fatality	**$ 6,000,000**
	- econ cost	***$ 1.2 million***
	- social value	***$ 4.8 million***

Total fatality cost including both money costs and value of lost lifetime earnings is from "Treatment of the Economic Value of a Statistical Life in Departmental Analysis – 2009 Annual Revision," USDOT, Memorandum to Modal Administrators, March 18, 2009. Detailed values for injury and property damage are drawn from Blincoe, L. et al. (2002). *The Economic Cost of Motor Vehicle Crashes, 2000* (Table 2), and then updated from 2000 dollars to 2009 dollars by the CPI change.

The difference between total fatality valuation and fatality cost is attributed to social valuation of lost life.

2.2.5 Environmental Benefits

Environmental impacts are most often measured in terms of tons of pollution emitted in a given study area. For transportation analysis, this typically means air pollution emissions, although it can also encompass water pollution emissions or land pollution (such as loss of wetlands or loss of usable land). Environmental impacts are usually calculated on the basis of a "dollars per ton" value of a given pollutant when monetized.

There is substantial precedent for measuring environmental effects as transportation-driven impacts. In 2003, the USDOT identified the agency's strategic outcomes with respect to the human and natural environment. They included enhancing sustainability and livability of communities, reducing adverse effects and improving the viability of ecosystems and the natural environment, and reducing the amount of pollution from transportation sources.[16]

For local air pollution issues, a state can focus the monetization of emissions reductions on the six "criteria pollutants" for which the state (or sub-state area) is out of attainment of the U.S. Environmental Protection Agency's National Ambient Air Quality Standards (NAAQS). The six criteria pollutants are: (1) carbon monoxide, (2) lead, (3) nitrogen dioxide, (4) particulate matter, (5) ozone and (6) sulfur oxides.

Valuing Emissions Damage. The level of monetary benefits associated with transportation emissions reduction is highly sensitive to context, including existing levels of pollution in the affected areas, density of population in an area, time of day (peak vs. non-peak), season, and other factors. As such, general values of monetary benefits should only be used to get a broad sense of the value of emissions reductions and in cases where better information is not available.

[16] USDOT, *2002 Performance Report* and *2004 Performance Plan for the Human and Natural Environment,* http://www.dot.gov/perfacc2002/human.html, http://www.dot.gov/PerfPlan2004/humanperf.html. USDOT's *Performance Report* has also tracked greenhouse gas emissions from transportation sources (USDOT, *2000 Performance Report).*

Figure 13 shows FHWA's national average air pollution in costs per mile driven for four types of vehicles; costs vary from 1.8 cents per mile to 6.4 cents per mile. If a vehicle mix is not available for a BCA, then the overall value of 2.4 cents per mile can be used.

Figure 13. Per Mile Values for Emissions Reductions

Vehicle Type	Per Mile Factor
Automobiles	$0.018
Pickups, Vans	$0.043
Gasoline Vehicles > 8,500 pounds	$0.049
Diesel Vehicles > 8,500 pounds	$0.064
Overall	$0.025

Source: FHWA: *1997 Federal Highway Cost Allocation Study Final Report Addendum*, Federal Highway Administration, USDOT, 2000. Values were updated to 2009 using the US Consumer Price Index.

Additionally, for greenhouse gases, the total cost per VMT is estimated to be 1.7 cents for cars, 2.0 cents for light trucks, and 2.4 cents for trucks, on top of the emissions reduction factors cited in Figure 13.[17]

2.2.6 Congestion and Travel Time Variability & Reliability[18]

Congestion and travel time variability are related but separate concepts.[19] Both congestion and variability can be caused by predictable factors such as weather or special events (concerts or Trailblazers' games, for example), and they can both be caused by unpredictable factors such as crashes or other road closures (rail crossings, for example). Secondly, insufficient capacity on highways exacerbates time lost due to unpredictable factors, even on mildly congested corridors, if crashes or special events are common or if these incidents are not managed well. (Time lost due to congestion conditions, not including unpredictable incidents, should be identified by slow speeds in travel demand model output.) Congested corridors can operate fairly reliably if incidents are minimized and managed well

Beyond creating delay and higher vehicle operating costs, congestion on an untolled facility has the effect of increasing the variability of travel times if there are incidents off-road that might cause a spike in traffic. For example, spikes may be caused by incidents (or even planned

[17] Todd Littman: "Climate Change Emission Valuation for Transportation Economic Analysis," VTPI, 2009 and drawing from *Transportation Energy Data Book*, Oak Ridge National Laboratory, 2008. Also shown in Table 5.10.7-2 of Littman: Transportation Cost and Benefit Analysis II – Air Pollution Costs, Victoria Transport Policy Institute, updated 2009.

[18] Small and Brownstone, and later work by Small and others, have developed the idea that the value of time and the value of reliability are different, and provide estimates of both derived from California SR99 and I-15 tolling studies. These estimates range from higher than the value of time to lower than the value of time. To simplify the BCA process, this guide uses a standard value of time that includes reliability.

[19] Congestion is something experienced on a single day, whereas variability must be measured over time.

maintenance) on other roads that that lead motorist to change their regular driving patterns, by inclement weather, or by temporary problems with transit services. Travel time variability relates to how long it takes to complete the same trip on different days. Consider a morning commute, where a driver makes the same trip roughly 20 times per month. If the driver can make the trip in about 30 minutes almost every day, then that trip is very reliable. If, on the other hand, the same trip on some days takes 45 or even 60 minutes, then the travel time is highly variable, and the driver must budget extra time into commuting. As with in-vehicle travel time, this extra "schedule," "float," or "buffer" time has value because it infringes into work and leisure activities.

Estimating Travel Time Variability for BCA.[20] For BCA, the concept of *buffer time per vehicle* can be used to estimate the impacts of travel time variability. The preferred method for calculating *buffer time per vehicle* for roadways in the BCA (untolled base case, tolled alternatives and primary parallel roads) is based on the capacity of ODOT to develop a distribution of travel times on selected routes by using Intelligent Transportation Systems (ITS) or other methods. The department will then be able to estimate buffer times from the accumulated state and regional data. (See Appendix A for an alternative methodology if locally accumulated travel time distributions are not available.)

Buffer Time Definition. Buffer time is defined by FHWA as the "extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival." The index presents buffer time as a percentage of the average time, so a buffer of 5 minutes on a 25-minute average trip time translates to a buffer index of 20%.[21] In practice, this can be estimated by comparing the worst travel time in a month with the average over that month. A "buffer time index" is the difference in travel time between the worst and average day.[22] Using a month as the basis for this estimate is appropriate because there are about 20 work days in a month, and therefore the worst day approximates the 95th percentile travel time. FHWA defines buffer time as follows:[23]

$$\frac{\text{95}^{\text{th}}\text{ percentile travel time (Minutes)} - \text{Average travel time (Minutes)}}{\text{Average travel time (Minutes)}}$$

[20] The intent here is to present practicable and implementable approach to measuring reliability issues in the context of multiple BCAs. For a nuanced discussion of the economics of congestion and reliability as these concepts pertain to tolling applications, see White Paper 4, *Economic Evaluation of Improved Reliability*.

[21] Definition taken from *Travel Time Reliability: Making It There On Time, All The Time,* USDOT/FHWA website (http://ops.fhwa.dot.gov/publications/tt_reliability/brochure).

[22] Definition by FHWA.

[23] *Travel Time Reliability: Making It There On Time, All The Time,* http://ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm#equation1.

Computing the Buffer Time Index. To compute the buffer time index:

1. Establish the distribution of travel times on a given highway (e.g., ITS/GPS real time driving runs, "driving runs" from regional traffic demand models).
2. Calculate the difference between the 95th percentile travel time and the mean travel time on a given highway.
3. Divide this difference by the mean travel time

For example, the distribution of 2005 travel times on Portland I-5 northbound show that 95% of all trips take 41 minutes or less and the mean travel time is 27.3 minutes. This means that arithmetic average of all trips on I-5 northbound take 27.3 minutes, and 1 of every 20 trips (5%) take 41 minutes or more. To calculate the buffer time index from these data, subtract "27.3" from "41" and divide the difference by "27.3." The product of 0.501 is the buffer time index.[24]

Factoring Reliability into BCA. The BCA analysis can account for reliability by multiplying the buffer time index by the ratio of "VHT to vehicle trips" calculated by travel demand modeling. This concept is called the *Buffer Time per Vehicle Trip*.[25] VHT and trips can be segmented to show reliability impacts on various classes of travelers, such as on-the-job, truckers, commuters, and personal travelers; then, the *Buffer Time per Vehicle Trip* can be calculated with the varied value of time for different segments of travelers.

$$Buffer\ Time\ per\ Vehicle\ Trip = BTI * \left(\frac{VHT}{Vehicle - Trips}\right)$$

By estimating buffer time per vehicle trip as distinct from in-vehicle travel time, the BCA can show monetized effects of time lost due to travel time variability separately, using the value of time inputs discussed above in this guide.

2.2.7 Residual Value

Residual value counts the value of an investment as a benefit after: (1) depreciating the investment to the end of the BCA analysis period, and then (2) discounting the depreciated nominal value. Residual value is routinely used to value the sale price of private sector assets. For public investments, it represents value to taxpayers. This guidance document will include instruction on how to depreciate the toll facility and how to then discount the remaining value.

BCA studies recognize situations in which the investment in land, buildings, or equipment still has remaining value at the end of the analysis period, even after applying the discount rate. This is referred to as the "residual value" or "salvage value" of the asset. The treatment of salvage value in BCA studies is controversial for public sector assets because the concept is derived from estimating the future resale value of an asset. This is clearly applicable for a privatized toll facility or a facility developed through a public-private partnership, but the State of Oregon may not benefit from the "residual value" of a tolling facility asset in the same way that reducing

[24] Example is taken from White Paper 4, *Economic Evaluation of Improved Reliability*. Prepared for Oregon Department of Transportation by Economic Development Research Group, Inc and Parametrix, February 2009.

[25] FHWA.

congestion is seen as a benefit that helps justify project costs. In this regard, residual value may be counted as a project benefit in BCA, but it is suggested that ODOT scrutinize the stated benefit in its reviews of BCAs and use it as a "tie breaker" or when it might be a determining factor in achieving a benefit/cost ratio of 1.0.[26]

The basis for depreciating an asset to recover salvage value should never include land, but should include subsurface, grading, and drainage improvements and selected over-ground improvements.[27]

Methods of Calculating Residual Value. The five steps necessary to calculate the residual value of a project are summarized below and illustrated in Figure 14.

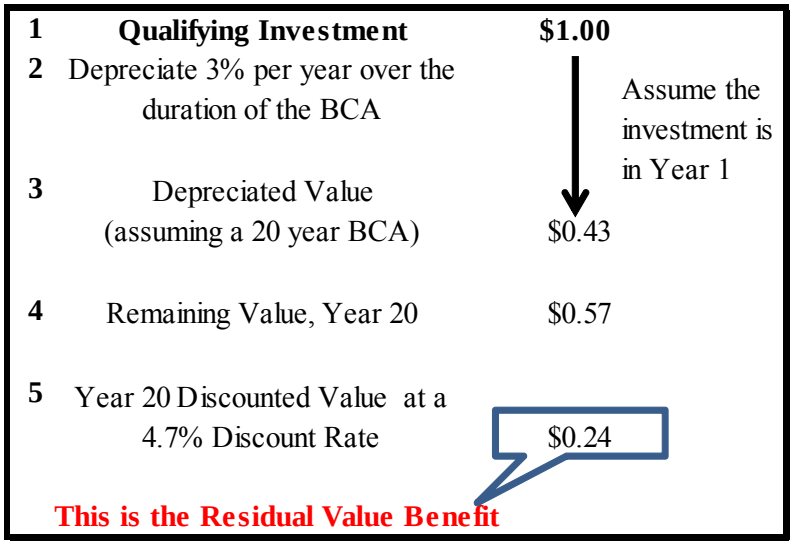
1. Identify the depreciable capital asset(s) and the year(s) that the investment(s) will be made.
2. Depreciate the assets by their useful life per year from the year the assets are constructed through the duration of the BCA (straight line depreciation). The accepted method (by the Internal Revenue Service [IRS]) is to calculate a fixed percentage of the assets' original values each year.[28]
3. Sum the value(s) of the annual depreciation (the value after 3% is deducted per year).
4. Subtract the depreciation from the initial cost of the assets. This is the remaining value.
5. Apply the discount factor for Year 20 (or the final year of the BCA) to the remaining value. (The discount factor is the value of $1 in Year 20 after 19 years of discounting from Year 1. At a 4.7% discount rate, the factor is 0.4178. The factor and discount rate move in opposite directions, i.e., the factor decreases as the discount rate increases and vice versa.) This is the benefit for BCA.

[26] Depreciation expense is the share of the net acquisition cost of an asset allocated to the current period. To calculate the net acquisition cost, the initial cost of the capital asset is determined and then adjusted to reflect the salvage value, or that portion of the initial cost that will remain when the asset is taken out of use. To determine depreciation expense, the net acquisition cost is allocated to each year over the total years of its useful life, usually by dividing net acquisition cost by the estimated years of useful life (e.g., straight line depreciation). "Useful life" is an estimate of how long the asset will be in use. The useful life estimate assumes a given maintenance and repair schedule. Thus, the costs associated with such maintenance and repair activities are reported as expenses when incurred because they do not extend the life of the asset. For example, maintenance only helps ensure that the asset will reach its useful life and provide acceptable service during that period (PRIMER: GASB 34, p.14, US DOT, 2000).

[27] Tolling projects may include land purchases for right-of-way. Project-generated changes to the value of the land will be due to subterranean and aboveground investment.

[28] Do not calculate depreciation by decreasing a continually diminishing asset by 3%. This method can never reach zero mathematically because it keeps dividing a standardized depreciation percent against a steadily declining balance, and is not accepted by the IRS.

Figure 14. Residual Value Benefit



2.2.8 Diversion

Introduction of a tolled facility may lead to increased congestion and less reliability on adjacent lanes or nearby roadways that receive diverted traffic from the tolled facility. Data are available from network modeling to address indirect impacts generated by diversion. BCA-related transportation demand modeling should include lanes that remained untolled (for a single lane-conversion project) and a primary parallel highway, as well as the "project lane/project highway," and traffic changes should be modeled in tandem, i.e., base case and build alternatives.

A positive benefit in a toll facility may be partially or fully offset by slower speeds and degraded reliability on nearby "free" facilities. This occurrence is expected when all or a portion of a freeway is proposed to be converted to a toll application. When converting all or a portion of a bridge to a tolled facility, diversion will be an issue if a nearby untolled bridge is in place. The diversion is a negative benefit (also called "dis-benefit"). The negative benefit will reduce the positive benefits counted in the BCA.[29]

For a new toll highway, diversion may be expected from nearby roads to the new facility. If this is the case, then there likely will be positive benefits gleaned from:

1. The new highway, where drivers who choose to use the toll road will (presumably) enjoy a faster and more reliable trip than by using their previous routes; and

2. Parallel roads, which will be less congested because a portion of the trips forecast under the base case will be diverted to the toll road under a build scenario *if the base case does not include a new freeway alternative*.

If the base case for a new toll road also includes a **new** freeway alternative, then the results may include a displacement-derived negative benefit in that there might be more traffic on primary

[29] A discussion of dis-benefits is included in White Paper 6.

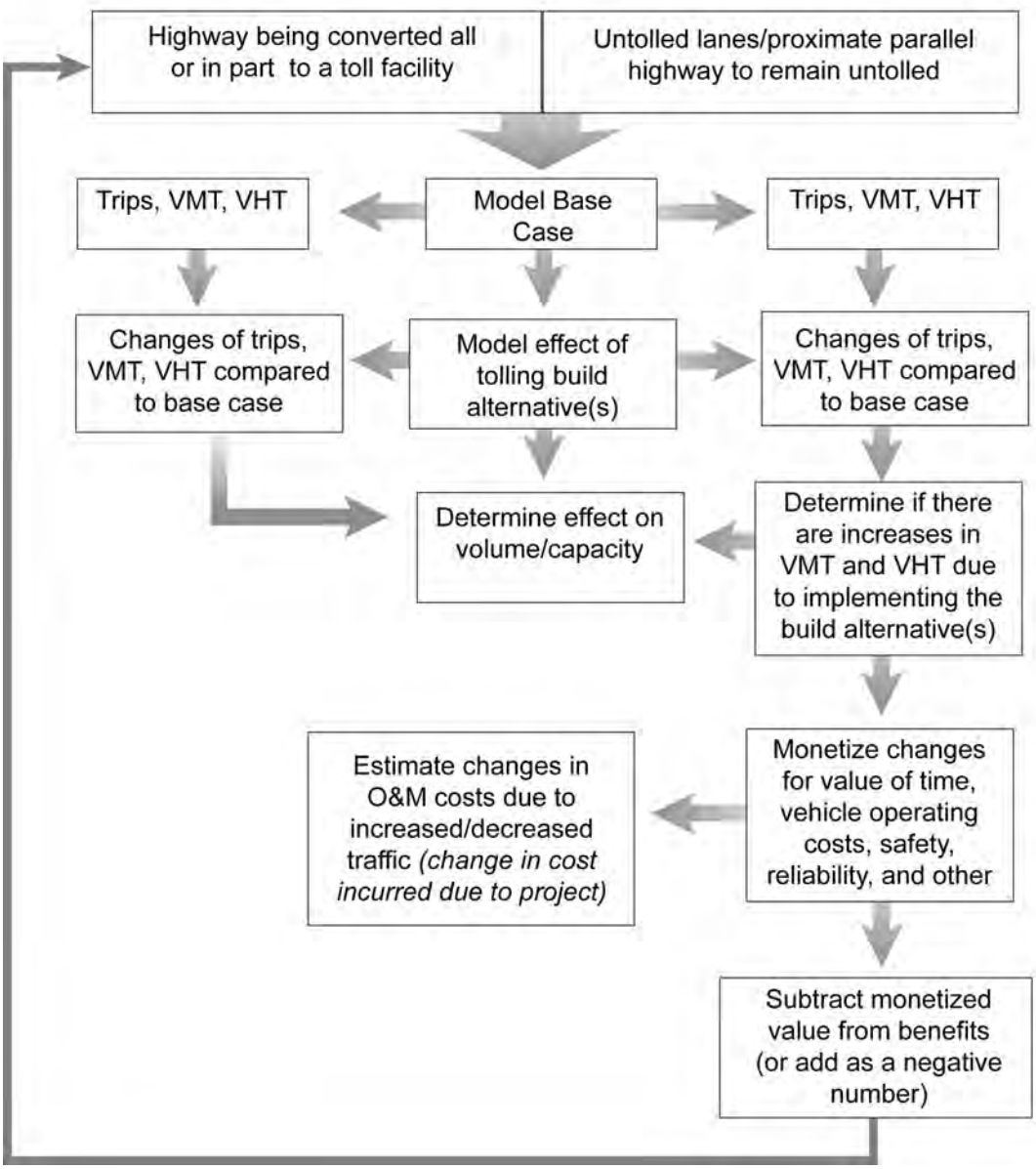
parallel roads (and therefore slower speeds) under build alternative scenarios than under the base case.

The simple formula for the benefit/cost ratio (BCR) to account for effects of diversion totals the sum of benefits from comparing impacts on a tolling alternative to an untolled base case with the sum of negative or positive benefits of parallel roads in proximity to the proposed tolling alternative. This is summarized in the equation below.

$$\text{BCR} = \frac{\Sigma_{Toll} Benefits \pm \Sigma_{Parallel} Benefits}{Cost}$$

Figure 15, below, shows the process for calculating negative benefits and incorporating them into BCA analysis.

Figure 15. Dis-Benefits



3 Other Factors

This chapter reviews irregular measures and methods used in BCA. These include treatment of non-quantified benefits, logistical benefits, use of survey data that cannot be easily replicated, and treatment of uncertainty and risk.

3.1 Non-quantified Benefits

Although BCA studies are focused on numbers, ODOT should look hard at non-quantified benefits, because a 1.0 BCA is a consideration in tolling project evaluation, but it might not be the only requirement. If a BCA is close to 1.0, then ODOT could consider other benefits listed as hard to quantify or non-quantifiable. These could be both positive and negative benefits; for example, a new toll lane could add noise impacts in an adjacent area. Such negative benefits may lead ODOT to disallow the project. However, if a BCA is significantly below 1.0, standard practice suggests that ODOT generally should not rely on non-quantifiable positive benefits to approve the project.

Projects are evaluated on a case-by-case basis, but the more closely related the benefits are to highway transportation and congestion relief, the more weight they should carry. Such benefits include health, noise and certain environmental benefits other than emissions. While these could be measurable, measuring these effects can be data-intensive and expensive. For most projects, it is sufficient to document estimated levels of difference between the base case and build alternatives when the project is completed.[30] However, if there is an issue that requires abatement for anticipated noise or other environmental dis-benefits, then the cost of abatement measures should be included as a project cost.

When a transportation project has the potential to add significant amounts of traffic to an area, a traffic noise analysis may be required to determine the project's noise impact. If the impact is significant, the costs of noise abatement measures, such as sound walls, may need to be included as part of the cost-benefit analysis.

General economic impacts are not influential in the context of BCA, although they are considered in related economic impact studies.

3.2. Interviews and Surveys to Document Benefits

Documenting benefits through interviews and surveys is a frequently used technique in BCA studies, deriving some information from surveys or interviews with potential beneficiaries, such as [potential] toll road/lane users, shippers, and third party truck companies.

In a survey, anyone can say that they will do something (e.g., expand business to take advantage of reduced congestion, switch from a local road to a toll road, opt out of driving to transit usage, switch from the proposed toll facility to a local road, all contingent on a proposed tolling

[30] For example, a hedonic price model may be used for noise impacts, but doing so is expensive. However, the expense may be warranted for major impacts, such as building a new toll-highway next to a residential neighborhood.

investment). These are "stated preference" surveys. Overall, ODOT should grant limited weight to surveys and interviews, particularly those couched in noncommittal statements (e.g., "would consider" or "may").

Revealed preference of similar situations is preferred to "stated preference" and can be used to support findings in surveys. Since toll facilities in Oregon are in limited operation (at this time), analysts should demonstrate that survey findings are reasonable by examining behavior in response to implementation of tolling facilities similar to the type being proposed (e.g., bridge, lane, new road, etc.) in regions that serve comparable demographics to metropolitan Portland (or a different region, if a toll facility is proposed elsewhere in Oregon). Demonstrating that existing toll facilities generate the positive or negative benefits that are reported through "stated preference" is a way to validate survey information.

3.2.1 Confidentiality

When conducting surveys and interviews, analysts are in a position of asking shippers and third-part logistics providers for future business plans and then reporting these results as part of the BCA. The need for confidentiality increases with the level of specificity requested. The conundrum is that companies are hesitant to reveal confidential business planning in competitive business markets. This challenge can be addressed in multiple ways in the BCA. (1) Proponents can represent informants' data in the BCA and orally reveal sources to ODOT without providing these sources in the BCA document. (2) To document future cargo shipping rates, sponsors could average confidential data with published shipping rates. (3) Letters (or e-mail) directly from companies or completed survey forms labeled as "confidential" could be provided to ODOT separately from the BCA document. (4) Information from multiple informants can be consolidated. The latter is interrelated with the point about balancing the consolidated and anonymous survey results with other revealed preference regarding tolling in other regions to show that the information being put forward is reasonable.

3.3 Risk and Uncertainty Associated with Significant Inputs to the BCA

BCA is typically prospective, meaning that it is making predictions about future events. Risk analysis provides methods for incorporating the uncertainty inherent in all predictions to the practice of BCA. Generally, three methods are used: (1) probabilistic/"Monte Carlo" methods, where distributions are applied to some or all input variables, and sampling techniques are used to determine distributions surrounding the resulting BCA metrics; (2) sensitivity analysis, where variations in the results are observed by changing one or several input variables at a time; and (3) scenario-based methods, where "low," "medium," and "high" scenarios incorporate varying degrees of pessimism or optimism about growth in demand or savings associated with future projects. For a basic and practical approach, this guidance document recommends using sensitivity analysis and scenario methods.

Sensitivity tests acknowledge the inexactness of BCA studies, and help view each BCA as a plausible result rather than as a precise number. Generally, sensitivity tests that are most important address changes in projected operations, constraints, and construction schedules, but they depend on the arguments put forward in BCA to justify the project.

The sensitivity tests are expected to address the aspects of BCA studies that carry the greatest uncertainty. For example, sensitivity factors should center on trip volume if a BCA is evaluating congestion relief. Sensitivity scenarios frame these discussions and provide the context for main analyses in BCA studies. It is important that they reasonably represent a range of scenarios and likely outcomes, and that proponents do not simply apply an arbitrary 10% rule. A 10% change shows perfunctory compliance with a requirement. A real and more likely "what-if" situation may involve costs changing as much as 25%.

For tolling applications, risk should be framed by diversion from tolled to untolled alternatives. The BCA should be framed by additional scenarios showing the impacts of high and low rates of diversion on the proposed toll alternative as well as on parallel untolled lanes or roadways. The changes in traffic volumes should be plus or minus 10% -25%, depending on the capacity of the parallel roadways and the nature of the routes. For example, 25% may be appropriate if a parallel roadway is an established four-lane undivided highway or if there are multiple untolled parallel highways. The range would be lower if there are limited practical alternatives to the proposed toll facility. The analyst conducting the BCA should propose the appropriate contextual diversion range for the sensitivity analysis.

Sensitivity analyses are evaluated as an aggregation of scenarios; ODOT looks for plausible scenarios and a preponderance of positive results. Evaluations do not focus on a single sensitivity test, and all scenarios are not necessarily expected to achieve a 1.0 B/C ratio. BCA studies and the review of analyses need to relate outcomes to probabilities of scenarios; for example, a low trip forecast scenario may be expected to fall below a B/C ratio of 1.0. Sensitivity is a final contingency; if a BCA is close to 1.0, a closer review of its sensitivity analysis may be triggered. Moreover, the evaluation of a sensitivity analysis must be sensitive to the cost of the project—that is, the smaller the project, the greater impact a small impact on cost will have on the ratio.

Appendix A

Congestion and Travel Time Variability & Reliability When Actual Distribution of Travel Time Is Not Available

If ODOT is unable to develop a distribution of travel times appropriate for the BCA, then calculating *buffer time per vehicle* will require two intermediate calculations to determine:

1. Travel time index; and
2. Buffer time index for the subject roadways (base case, tolled alternatives' primary parallel roads) based on the travel time index estimated in Step 1, above.

Travel Time Index. The travel time index (TTI) reflects congestion on a roadway; it is estimated from the Bureau of Public Roads' equation shown below. The volume-to-capacity ratio shown in this equation is obtainable from transportation demand models administered by ODOT or applicable MPOs.

$$Travel\ Time\ Index = 1 + 0.15 * \left(\frac{road\ volume}{road\ capacity}\right)$$

Convert Travel Time Index to Buffer Time. Both the following equation for calculating BTI and the accompanying graphic were developed in the FHWA report, *Traffic Congestion and Reliability: Linking Solutions to Problems*. The equation indicates, and the graphic illustrates, that the buffer-time index grows as the travel time index increases. Initially, as shown in the quadratic formula, there is a positive relationship indicating that buffer-time per vehicle trip can grow exponentially with congestion. However, there is a practical limit to that exponential relationship, which is captured by the formula and accompanying line graph. Simply put, buffer times cannot grow infinitely. Faced with overwhelming congestion and delay, drivers will devise alternative travel strategies, including choosing alternative routes, shifting travel hours, changing modes, avoiding trips, and others. Therefore, the equation also includes a negative term that eventually slows down the growth of buffer time as travel delays become extremely high. The regression coefficients draw on data points from FHWA's *Mobility Monitoring Program* for freeway corridors in Atlanta, Minneapolis, Los Angeles, and Seattle.[31]

[31] Source: The regression equation and following graphic originated in the report, *Traffic Congestion and Reliability: Linking Solutions to Problems*, by Cambridge Systematics and the Texas Transportation Institute for FHWA, July 2004. The regression coefficients draw on data points from FHWA's *Mobility Monitoring Program* for freeway corridors in Atlanta, Minneapolis, Los Angeles, and Seattle. These data are the basis for reliability defaults in TREDIS (www.tredis.com).

$$BTI = -0.998TTI^4 + 4.41TTI^3 - 20.5TTI^2 + 25.5TTI - 11.4$$

Where:

BTI is the Buffer Time Index, and

TTI is the Travel Time Index

Figure A1. Relationship Between Congestion and Travel Time Variability

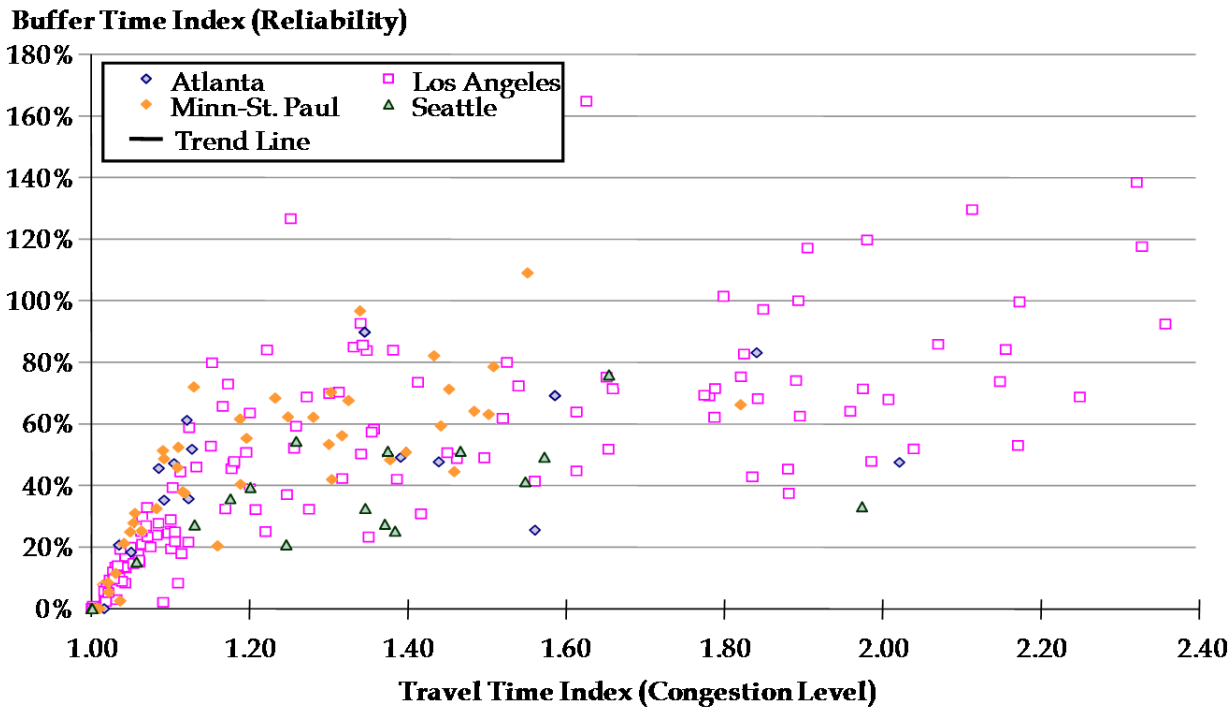


Figure A1 shows a steep increase in the buffer-time index as a function of the travel time index as the TTI increases from 1.0 to slightly past 1.20. As TTI further increases to 2.40, the buffer-time index flattens, with data points concentrating primarily from 60% to 80%, and with a few outliers on either side of the bracket. If the TTI were extended past 2.40 with a fitted line, the slope of buffer-time index would flatten to a greater extent than is shown here for the TTI between 1.25 and 2.40.

Buffer Time per Vehicle Trip. Buffer Time per Vehicle Trip is calculated by multiplying the buffer time index by the ratio of "VHT to vehicle trips" as derived from travel demand modeling.[32]

$$Buffer\ Time\ per\ Vehicle\ Trip = BTI * \left(\frac{VHT}{Vehicle - Trips}\right)$$

[32] FHWA.