WHITE PAPER 6

ECONOMIC COMPARISON OF THE ALTERNATIVES FOR TOLLING PROJECTS

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Executive Summary

Benefit-cost analysis (BCA) is a widely used tool that will allow Oregonians to improve decision-making for prioritizing a variety of tolling project alternatives and in comparing tolled alternatives against untolled alternatives. BCA is a technique for comparing two or more projects by comparing benefits and costs that are realized and expended in different years.

Tolling introduces new concepts or issues to the 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 in turn, may 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 the motorist 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 toll proposals. BCA provides a transparent analysis to the public for evaluating benefits and costs of potential tolling projects.

The framework of BCA includes three major components:

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 discounting rate is the annual rate at which future dollars lose value compared to present value. Accordingly, the value of future benefits is lowered as:
    - A discount rate is increased; and
    - Years elapse from the start a project.

BCA can only reflect benefits to the extent that all costs and benefits can be "monetized" into dollar terms, including converting a benefit or cost not in monetary form, such as personal time savings, into a monetary equivalent. Factors that cannot be monetized must be considered separately. 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).

In particular, benefit-cost literature recommends that toll revenues *not* be considered in benefit-cost analyses. From this perspective, tolls are simply payments made by users to transportation providers in exchange for the travel time, safety, and operating cost benefits received.

BCA compares the net value of monetized benefits to users of a highway facility (a new roadway, new lane, or reconfigured lane) to the value of building and maintaining the facility. The most common highway-related benefits considered in a BCA include: 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. The following are some typical benefits and costs that must be considered in evaluating transportation projects.

Net User Benefits

- Value of time saved
- Lower costs due to increased safety
- Lower vehicle operating costs

Costs

- Construction costs, including costs associated with toll collection, if applicable
- Annual operating costs
- Routine maintenance costs
- Capital rehabilitation costs

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 do not equal costs, this ratio is less than 1.0.

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 toll or untolled roadway or bridge. Increased access potentially improves cost-competitiveness for businesses, changes patterns of household spending, and leads to more personnel 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.

Chapter 1. Introduction

Tolling technology has changed dramatically in the last few decades, and these changes have enabled a broader range of possible tolling applications. Toll booths that require vehicles to stop for toll payment, interrupting the flow of traffic, are no longer the only way to collect tolls. Advances in electronic tolling technologies now make it possible to toll an entire roadway or single lanes by use (general use, truck-only, high occupancy), vary toll costs by time of day, even recover toll revenues by electronic means (e.g., credit-card billing)—all without creating undue delays or inconveniences for the user (see Exhibit 1.1).

These new technologies have opened discussions of the ways in which the Oregon Department of Transportation (ODOT) may use tolling to help achieve a variety of policy objectives. A recent Department report, *The Future of Tolling in Oregon: Understanding How Varied Objectives Relate to Potential Applications* (Cambridge Systematics 2007), surveys a number of transportation, environmental and economic development objectives that can be achieved in part through tolling.

The 2007 report also provides a typology of tolling applications. This typology specifies three major categories that pertain to individual roadways and bridges: new facilities, converting existing facilities from freeways to tollways, and establishing toll-managed lanes. Exhibit 1.1 shows the tolling typology from the 2007 ODOT study; applications addressed in other white papers are noted.

Most tolling applications are new to Oregon; previously only Columbia River bridges have been tolled. Further, tolling introduces five new concepts or issues to the transportation planning process:

1. *Motorists' reactions to the presence of tolls.* White Paper 3 examines the capability of existing transportation models in Oregon to predict this behavior.

2. *Traffic diversion created by motorists avoiding paying the tolls.* This behavior may be less predictable than the behaviors experienced on today's untolled system.

3. *The economic benefit to motorists of improved reliability.* Improving travel reliability is a primary motive for some tolling applications, such as toll managed lanes, yet little attention has been paid to how to quantify its value. White Paper 4 specifically addresses this issue.

4. *Properly framing non-tolled alternatives to tollway proposals.* Tollways, other than bridges, must be of a sufficient size to offer the motorist enough improvement in travel time or reliability to merit paying the toll. This means toll projects will be relatively expensive, and may be too costly to be financed solely with toll receipts. Improvements to parallel free facilities may be able to be done in an incremental fashion requiring a series of smaller investments, a significant consideration in times of tight budgets.

5. *The public's acceptance of tolling.* Some public questioning of the introduction of tolling, particularly on facilities constructed with public funds, should be expected. On the other hand, tolled facilities can offer some clear benefits in improved travel time and reliability, which are important considerations in achieving acceptance of toll proposals. Public response to any given proposal, however, is difficult to anticipate in advance.

In combination, these factors suggest the need for a more deliberate and transparent analytical approach for potential tolling projects. In order to properly judge the relative merits of tolled and non-tolled alternatives, the public will need a sound understanding of the different effects of considered options. Tolling adds certain complexities to the planning process that should be met by public agencies through improved analytical capability and more transparent decision-making.

This paper is an initial attempt to respond to this challenge. It does so by positing the requirements and attributes of benefit-cost analysis (BCA), a long-standing approach for analyzing and prioritizing transportation projects, as they apply to tolling applications. The limitations of BCA are identified, and analytical means to compensate for them are discussed.

Exhibit 1.1. Typology of Toll Applications

Traditional Projects

- New toll road
- New toll bridge or tunnel

Tolled Managed Lanes

(See White Paper 5, Congestion Pricing, and White Paper 7, Truck-Only Toll Lanes)

- HOT lane
  - Convert existing high-occupancy vehicle (HOV) to HOT
  - Build new lanes and make HOT
  - Convert existing general purpose (GP) lane to HOT
- Express toll lane
  - Build new lanes as express toll lanes
  - Convert existing GP lane to express toll lane
- Truck-Only toll (TOT) lane
  - Convert existing HOV lane
  - Build new lane(s)
  - Convert existing GP lane

Toll Existing Corridors or Systems

- Replacement bridge as toll bridge (potentially with expansion)
- Convert existing freeway to tollway
- Cordon or area pricing around or within a defined area (e.g., a CBD)
- Convert system of freeways to tollways within a defined area

Source: *The Future of Tolling in Oregon: Understanding How Varied Objectives Relate to Potential Applications* (Cambridge Systematics 2007).

Chapter 2. Benefit-Cost Analysis – An Overview

What is Benefit-Cost Analysis and What Does It Do?

Benefit-cost analysis (BCA)[1] is a method for comparing project benefits and costs over time.[2] It is designed for evaluating the investment efficiency of public investments.

Benefit-cost analysis is meant to answer the following questions:

- *Do the benefits of an action justify its cost?*
- *Which, among a number of scheduled projects, should be completed first?*
- *When should a project be undertaken?*

BCA first determines if a proposed project is worth undertaking—i.e., whether the benefits of the project exceed the costs—and second, which project among several alternatives will generate the greatest social return on investment. This social perspective provided by BCA is very important, and distinguishes it from other methods of project analysis (discussed later in this chapter).

Benefits and Costs – Basic Concepts

The concepts of *benefit* and *cost* are commonly understood, and their use in a BCA is similar to common usage but not exactly the same.

BCA does not consider how money is raised, saved, or spent. Instead, it addresses the total cost of a project and the total benefit it generates, without regard for funding sources or beneficiaries. In particular, benefit-cost literature recommends that toll revenues *not* be considered in benefit-cost analyses. From this perspective, tolls are simply payments made by users to transportation providers in exchange for the travel time, safety and operating cost benefits received. The following are some typical benefits and costs that must be considered in evaluating transportation projects (a more detailed breakdown is given in Chapter 3).

User Benefits

- Value of time saved
- Lower costs due to increased safety
- Lower vehicle operating costs

Costs

- Construction costs, including costs associated with toll collection, if applicable
- Annual operating costs
- Routine maintenance costs
- Capital rehabilitation costs

[1] Much of this immediate discussion is drawn from the NCHRP *Guidebook for Assessing Social and Economic Impacts of Transportation Projects*, David Forkenbrock and Glen Weisbrod, 2001.

[2] BCA is also referred to as cost-benefit analysis (CBA).

For a well-rounded perspective, "hard-to-quantify" impacts such as social equity, environmental considerations, and land use impacts also should be considered. Although many analysts have attempted to quantify one or more of these measures and to include them in calculations, they fall largely outside the monetized framework of a benefit-cost analysis.

How Does Benefit-Cost Analysis Work?

Although the process of conducting a project BCA is complicated to set up and conduct, it is built around a few simple calculations:

A. First, identify and add up all of the benefits and costs of the project in monetary values for each year of the expected useful life of the project.

B. Then, translate both benefits and costs into a common numerical language called *present value* (PV). PV measures the time-value of money under the principle that one dollar in the future will be worth less than the same dollar is worth today. This is done by applying a *discount rate* that reduces the value of money each year. Using this method, $1.00 of benefit in Year 20 is worth substantially less than $1.00 of construction cost in Year 1.

C. Finally, calculate the project *benefit-cost (b/c) ratio* by dividing PV benefits by PV costs.

Subtracting the present value of expected costs from the present value of expected benefits produces the net present value (NPV) of a proposed project. When there is a positive NPV, the benefit-cost ratio will be greater than 1.0. Exhibit 2.1 compares benefit-cost ratios and net present value calculations for three simple projects.

Exhibit 2.1. Net Present Value and Benefit-Cost Ratio Calculations

Project	PV of Benefit	PV of Cost	NPV (Benefit – Cost)	Benefit-Cost Ratio (Benefit/Cost)
A	36 million	30 million	+6 million	1.2
B	3 million	1 million	+2 million	3.0
C	8 million	10 million	-2 million	0.8

As demonstrated above, any project for which benefits exceed costs will have both a positive net present value and a benefit-cost ratio greater than 1.0. However, depending on budget conditions, benefit-cost calculations may be different. For example, in Exhibit 2.1, Project A has three times the net present value of Project B, while Project B's benefit-cost ratio is nearly three times that of Project A.

For a government agency, one problem with basing decisions on net present value is that it tends to favor large-scale projects over smaller ones, even if the smaller projects have a better return on investment. For this reason, agencies generally use benefit-cost ratios to inform funding decisions among projects.

Overall, however, BCA should not be seen as the sole basis for project decisions, but as one tool among several. There are two reasons for this:

1. BCA measures the efficiency but not the equity of investment decisions. In other words, BCA aggregates all benefits and costs associated with a project, without regard for who pays the costs and who reaps the benefits. Yet there is a real public interest in equitably distributing both costs and benefits of public investments.

2. BCA can only reflect benefits to the extent that all costs and benefits can be "monetized" into dollar terms and included in the BCA calculations.[3] Any factors that cannot be monetized must be considered separately. Consequently, there may be cases where a project with a low NPV or a low B/C ratio is nevertheless funded because it has additional, hard-to-quantify benefits (e.g., reduced noise to properties abutting the roadway).

Understanding Benefits and Costs

Accurately identifying the benefits and costs for a BCA can be challenging. The analyst must first decide what benefits and costs will be included in the calculations.

Types of Costs

In BCA, costs include the development and construction of a facility as well as the operation, maintenance and rehabilitation expenses incurred over its useful life. In some cases these resources may be wholly controlled by a government agency, perhaps with some distribution between federal/state/local shares. In other cases, the resources may be split between public and private sources. This private money may be considered a public resource when its availability is contingent upon the government contribution.

About Toll Revenues

From a pure benefit-cost standpoint, toll payments do not enter into benefit-cost calculations because they are considered to be transfer payments from users to transportation providers in exchange for benefits already measured in BCA calculations, such as values of time, safety, and vehicle costs.

Costs typically fall into four categories:

- *Investment costs*. These can include right-of-way purchases, construction costs, and equipment purchases.
- *Operations and maintenance (O&M) costs*. These can include labor, materials, supplies, and equipment.
- *Anticipated major capital rehabilitation*. These costs include capital outlays for reconstruction activities that preserve existing capacity, and are in addition to O&M costs.
- *Termination costs and residual value costs*. These include the costs of dismantling and restoring a site, as well as the site's salvage value if the benefit-cost analysis period ends before the useful life of the applicable facilities and equipment.

[3] Monetization refers to the process of converting a benefit or cost that is not in monetary form, such as personal time savings, into a monetary equivalent.

Types of Benefits

User Benefits. Benefits are defined as the sum of all direct impacts accruing to users or other parties as a result of project improvements, compared to what would otherwise occur under "base case" conditions (i.e., if the project is not funded). *User benefits* typically do not include indirect benefits that result from improvements. Generally, indirect benefits occur away from the project and require additional action, other than using the project, to realize indirect benefits. For example, time savings as a result of a project is a benefit within the BCA, but economic development impacts occurring as a result of increased speed and access (e.g., additional investment to take advantage of the improved conditions) are outside of the BCA. The major BCA user benefits are:

- *Reduced travel time*. This broad category of benefit can result from a variety of factors, such as improvements in travel speeds and reductions in travel delays. Travel time savings, in turn, may affect the cost of auto and truck travel.
- *Reduced operating costs*. If an investment reduces both travel time and travel distance, there may be additional savings in fuel and maintenance costs. In other cases, a project may create more efficient travel conditions or enable more efficient vehicles to use the system, thereby reducing operating costs and maintenance costs for operators and users.
- *Induced travel*. Time and cost improvements may also induce new trips that would not have otherwise occurred. Economists agree these travelers comprise another group of beneficiaries. Their benefit is calculated using the concept of *consumer surplus*.

Consumer Surplus

"Consumer surplus" is the difference in value between the maximum price a person is willing to pay for a good or service and the price actually paid. For example, if a driver is willing to pay $5.00 to save 15 minutes on a trip, and the toll is $2.00, there is a resulting consumer surplus of $3.00.

- *Improved schedule predictability*. Travelers' ability to predict departure, travel, and arrival times is an added benefit over simple travel time reductions. This benefit can result from improvements that enable better operation in inclement weather and night conditions, or congestion relief. (See White Paper 4, which analyzes the economic benefits of improved reliability.)
- *Improved Safety*. Reductions in the incidence of property damage, injury, or death may be monetized and included as project benefits in a BCA.
- *Improved Network Efficiency*. In some cases, improving the efficiency of one part of a transportation network can have wide-ranging consequences for travelers at distant locations. For example, eliminating a highway bottleneck could reduce delays on surrounding roads.

Non-User Benefits. Some BCA studies include benefits accruing to third parties, or non-users. These benefits can include:

- *Environmental benefits*. These may include reductions in air, water, or soil pollution, habitat loss, noise levels, and other quantifiable environmental impacts.

- *Land use impacts*. Most often, land-use impacts are outside of a BCA framework. An exception to this occurs when a new highway configuration creates new developable parcels. Then, the difference in land value between the new parcels and previous parcels (which could be $0) can be attributed to the project within a BCA. However, improvements on the new parcels are not counted. The speed and efficiency improvements listed above are the benefits that would provide support for these improvements. More discussion of land use is presented in Chapter 6.

- *Increased business productivity*. Improvements in accessibility can promote more desirable and effective services for visitors and for freight deliveries, all of which can provide economic benefits beyond the direct benefits for travelers and shippers.

- *Option value*. Adding new transport modes and services may provide residents and workers with greater flexibility to adjust to unanticipated events. Option value reflects the importance people place on having a wider choice of travel alternatives and the availability of backup options.

Negative Benefits (Dis-Benefits). Implementing tolling on a previously untolled facility can add traffic to nearby roads and bridges (or lanes) that remain untolled, as drivers change routes to avoid paying the toll. This diverted traffic may result in reduced speed for drivers who had previously used the (still) untolled facility, as well as for drivers who are avoiding tolls. The outcome of reduced speed is an increase in travel time, and is a cost to users. In BCA, any costs to users should be treated as negative benefits and not as positive costs. Before calculating a benefit-cost ratio, negative benefits need to be subtracted from the sum of positive benefits.

A Note on Negative Benefits

Negative benefits (also known as dis-benefits) occur when a project causes a loss of income (out-of-pocket cash or monetized equivalent). In this case, negative income should not be treated as a project cost. Instead, negative benefit should be counted on the numerator side of the benefit/cost equation. As a negative number, the negative benefit is subtracted from anticipated positive benefits. The final numerator is the sum of all positive and negative benefits.

Other Economic Assessment Methods

BCA takes a wide view of welfare while other types of analysis take a narrower view by considering only one aspect of welfare, such as improving air quality. While BCA takes a societal viewpoint for measuring all benefits and costs, other, more focused methods are sometimes used to assess particular aspects of alternative actions. These methods all involve some elements of comparing benefit and cost streams outside of a standard benefit-cost analysis, and include the following:

- *Cost-effectiveness analysis* (CEA) is a method for rating or ranking competing projects or policies when the desired benefit can be measured as a mixed monetary/non-monetary ratio of costs against program or project effects. It is most often used for ranking alternatives aimed at achieving environmental, health or safety improvements. Common CEA applications include the measurement of alternative policies or projects in terms of cost per ton of pollution reduction, or cost per injury reduction.

- *Life-cycle cost analysis* (LCCA) is used to identify the costs of alternative investment options required to achieve a pre-determined objective, such as maintaining a given level of pavement quality or safety. LCCA is not concerned with the benefits of spending or whether to conduct a project, but rather how and when to do it to minimize total costs over the long run. By conducting an LCCA, an agency can determine an optimal facility management schedule.
- *Financial analysis* is similar to BCA in that both compare the benefits and costs of alternative actions. However, financial analysis takes a narrower, organizational viewpoint and focuses on annual cost and revenue flows to determine if a project is affordable at the time of construction, during a foreseeable operational period, and in relation to other potential investments. Financial analysis can be used to assure that a project has an annual positive cash flow (to pay for project construction and projected annual operating costs) and maintains adequate margins for debt service coverage, if applicable. Accordingly, this method is applicable to feasibility studies of toll roads to compare the expected stream of toll revenues to debt coverage service for bonds and/or the annual cost of operation and maintenance of the proposed toll facility.

Economic impact analysis includes two distinct types of studies.

- The most common type measures just the current economic role, contribution, or significance of a highway to its local or regional economy. It does this by measuring the amount of direct jobs and wages generated in the economy by operation of the highway, including highway-dependent land uses near interchanges and the activity of highway-dependent businesses (such as shippers and third-party truckers). It also counts the indirect multiplier effects generated by these dependent business activities, and the induced multiplier effects of workers re-spending their incomes in the community. The objective of these studies is to gain an understanding of how proposed transportation improvements affect local, regional and/or state economies.
- *Incremental economic impact.* A second type of economic impact study calculates the incremental difference between how the local or regional economy would look in a future year with and without a proposed highway improvement (or new highway). Sometimes an economic impact analysis can be used to show how highway policies or tolling applications can affect local economies. This form of analysis is similar to BCA in that both comparative analyses calculate the difference between a future with and without a particular highway improvement. In their application, however, they are quite different. BCA identifies the net benefits (direct and indirect) of a project; these benefits represent both actual economic transactions (actual flows of money) and valuations of non-monetary transactions, such as placing a value on the time consumed for making personal trips. Economic impact analysis, in contrast, is *only* concerned with economic transactions within a given region, estimating what the economy of a region will look like with and without a particular project (FHWA 2003; Weisbrod and Alstadt 2008). In addition, economic impact analysis does not consider whether project benefits exceed project costs or are affordable.

Exhibit 2.2 gives an overview of the differences and similarities between BCA and economic impact analysis.

Exhibit 2.2 Difference in Coverage of Benefit-Cost and Economic Impact Analysis

Form of Impact	Counted in Benefit-Cost Analysis	Counted in Economic Impact Analysis
Business cost savings	Yes	Yes
Business-related time savings that generate cost savings	Yes	Yes
Personal and household out-of-pocket cost savings	Yes	Yes
Attraction (relocation) of business activity into the area	No	Yes
Income generated by off-highway businesses and their suppliers, and by the re-spending of workers' wages	No	Yes
Value of personal time (no expense to employers)	Yes	No

Chapter 3. Benefit-Cost Analysis – A Detailed Explanation

A. Three Steps Toward Setting Up a Benefit-Cost Analysis

Step 1: Define the Analysis Period

Typically, the analysis period in BCA is equal to the expected life of the investment. It is important to use an evaluation period that allows for realization of both the costs (some of which, such as construction, are near-term) and the benefits (many of which may take several years to realize). Electronic toll collection equipment has an expected life of about 10 years, which means the cost component of the analysis must include a recurring capital cost for new equipment every 10 years (Burris and Sullivan 2006).

The time frame should be consistent among all alternatives. The standard length of time in a BCA framework is 20 years, although lengthier analyses are seen. In general, the time frame should be consistent with traffic demand modeling (see White Paper 3) and with other analyses being used for the project. All anticipated benefits and costs within the established timeframe should be included in the BCA.

Step 2: Define a Base Case

In BCA, one or more transportation system improvements are compared to a base case. Best practice is to create the most realistic base case possible, which is almost never "do-nothing." A realistic base case will include actions that can still be taken within the bounds of existing local funding levels, even if new project funding is unavailable.

The base case should be an estimate of current and future expected conditions, and may be defined as no build, system degeneration, or some build (CalTrans, no date). Under the no build scenario, no improvements are made to the existing facility, although routine maintenance and rehabilitation are assumed.[4] A build alternative will incorporate any system improvements expected to be made in the future if none of the proposed project alternatives are built.

This guidance for defining the base case should be applied to all tolling projects under review. For example, if a toll project includes construction of new lanes or a new road, the base case should reflect what is likely to be built if no toll facility is implemented. If no road or new lanes will be built without the toll facility, then the base case should be a no build option. However, if new lanes or a new road is planned to be built regardless, the base case may be a new, untolled facility. If the tolling option converts lanes of an existing facility to a tolled road, the base case may be defined as a no build scenario or, alternatively, as a limited build scenario if physical improvements are anticipated. It also may be appropriate to use a toll facility as a base case, with various tolling strategies as the alternatives.

[4] As an extreme case, a system degeneration alternative assumes no new construction and limited or no upkeep of the existing system.

Step 3: Set a Discount Rate

As discussed in Chapter 2, discounting converts future benefits and costs into "present value." A discount rate reflects the "time value of money," in that money in hand today is more valuable than the identical amount of money received in the future. Discounting decreases the value of money year by year, so that a dollar of benefit realized 20 years in the future will have a substantially lower value in PV terms than a dollar of benefit gained four years after the project begins.

When discounting, future benefits decrease in value as the discount rate increases. Though this also true of costs, most substantial project investments are close to the current year; therefore, discounting affects capital investment less severely than downstream benefits and relatively minimal operation and maintenance expenses. The effects of varying discount rates on benefit-cost ratios are illustrated in Exhibit 3.1, below. By discounting and normalizing benefits and costs to present value, decision makers have a common basis to compare projects or project alternatives even when costs and benefits are spread out over 20 or more years.

The choice of discount rate used in a BCA is a heavily debated issue in the professional and theoretical literature. This is, in part, because small changes in the discount rate can translate into large changes in BCA results. Three core issues to consider when deciding on a discount rate are:

1. **Inflation.** For BCA, costs and benefits are usually defined in constant values, and therefore a real discount rate (one that does not account for inflation) is appropriate. However, a nominal discount rate that includes expected inflation should be used in circumstances when benefits and costs are reported in nominal terms (OMB 1992).
2. **Risk-free discount rate.** The risk-free rate is used when the expected return on investment is guaranteed and the prospect for default on the debt is non-existent. One standard approach is to base the risk-free rate on long-term U.S. Treasury notes.[5] A similar approach, yielding a slightly higher discount rate (due to slightly more risk of default), is to base the rate on the interest earned by deposits of public money in bank accounts. Both

Higher Discount Rates Require More Benefits

The following simple example illustrates that the higher a discount rate is set, the less value is assigned to future benefits. All dollars for benefits and costs in this example are in present-year values.

Assume that the nominal cost of a tolled project is $12 million, including $10 million for construction. The project will require 2 years to build at $5 million per year, and $100,000 annually for operation and maintenance over the next 20 years. Assume also that for each of the 20 years after construction, the project will generate an equal level of nominal benefits.

If the BCA is based on a 7% discount rate, the project would need to generate $1.08 million annually before discounting to achieve a discounted benefit-cost ratio of 1.0. Over 20 years, this is a nominal total of $21.6 million. However, if the analysis uses a 5% discount rate, only $923,000 per year is required to achieve a 1.0 b/c ratio, or a total of $18.5 million over 20 years.

[5] 2008 20-year discount rates from OMB based on projected treasury notes were 4.9% (nominal) and 2.8% (real) (OMB 2008).

cases reflect alternative revenue streams that could be expected by foregoing a tollway investment and safely investing the money. This comparison is called the "opportunity cost," which is the next best investment that can be made.

The interest paid by the US Treasury or by Oregon banks reflects the risk-free (or extremely low-risk) time value of money. It is the practice of ODOT to set discount rates by the cost of borrowing to the state. The logic here is that by having a constrained trust fund that is not sensitive to inflation, the nominal interest rate is also the real rate, and project alternatives are always other highway projects.

3. **Risk**. Projected benefits over time are estimates that are not guaranteed, and cost projections are subject to over-runs. Accordingly, "risk premiums" are added to a discount rate to account for the contingency of net present value not being as strong as forecast in the BCA.[6] Exhibit 3.1 illustrates net present values and benefit-cost ratios of the same cash flow with four different discount rates.

There are several ways to approach risk in a public investment. First is the deconstruction of costs and benefits, as uncertainty is associated with every aspect of the cost and benefit streams. This type of analysis can be calculated but only with significant effort, particularly for benefit streams. The history of ODOT's estimated and actual construction project investments can provide a reasonable basis for risk associated with "costs." For benefits, however, a similar analysis would require examining projected benefits of past BCAs and actual benefits realized from projects.

Time Value of Money

If ODOT invested $1.00 today at 3% annual interest (the approximate value of a long-term inflation-free return on a treasury note), 20 years from now the Department would have $1.81. Therefore, $1.81 of expected benefit 20 years from now equals $1.00 in present value.

A more practical approach is to assume that the risk of an ODOT project reflects the spread between the risk-free interest rate of a long-term Treasury bond and Oregon's cost of long-term debt. This is already incorporated in the Department's practice of using the cost of borrowing to the state, and adding the "spread" above this would be double counting.

Lastly a number of transportation agencies encourage evaluating projects with multiple discount rates as sensitivity tests. Stronger projects can achieve a benefit-cost ratio of 1.0 with higher discount rates than those available to other more marginal projects.[7]

The choice of discount rate is critical, for it can have a dramatic effect on both Net Present Value measures and benefit-cost ratios measured for tolled and untolled facility investments. This is because the capital cost of a new project occurs largely as an "up front" cost associated with paying for materials and the construction process. On the other hand, the benefits occur sometime later, starting after the construction is finished and continuing into the future. A higher discount rate has

[6] For private sector projects, risk premiums are calculated on the basis of expected volatility of return on investment.

[7] For example, the Federal Aviation Administration mandates a 7% discount rate, but encourages analysts to test other rates for sensitivity. Transport Canada recommends a 10% real discount rate, with 5% and 15% sensitivity tests.

the effect of reducing the present value of benefit streams extending into the distant future, while having relatively less impact on cost streams that are mostly incurred up front. As a result, a higher discount rate has the effect of making fewer projects appear to have benefits exceeding costs, while a lower discount rate has the opposite effect.

Exhibit 3.1. Benefit-Cost Ratio Varies by Discount Rate

Example: Sum of Nominal Costs equals $13,900,000 and sum of nominal benefits equals $28,000,000.

Discount Rate	PV Costs	PV Benefit	NPV	BC Ratio
10%	$10,925	$7,346	($3,579)	0.67
7%	$11,700	$10,549	($1,151)	0.90
5%	$12,267	$13,368	$1,401	1.11
3%	$12,881	$17,985	$5,104	1.40

Note: All dollars are in thousands.

Example based on 4 years of construction, and 20 years of benefits and marginal operation and maintenance costs. Timing for incurring costs and realizing benefits is the same among each of the four examples.

B. Identifying and Measuring Benefits and Costs

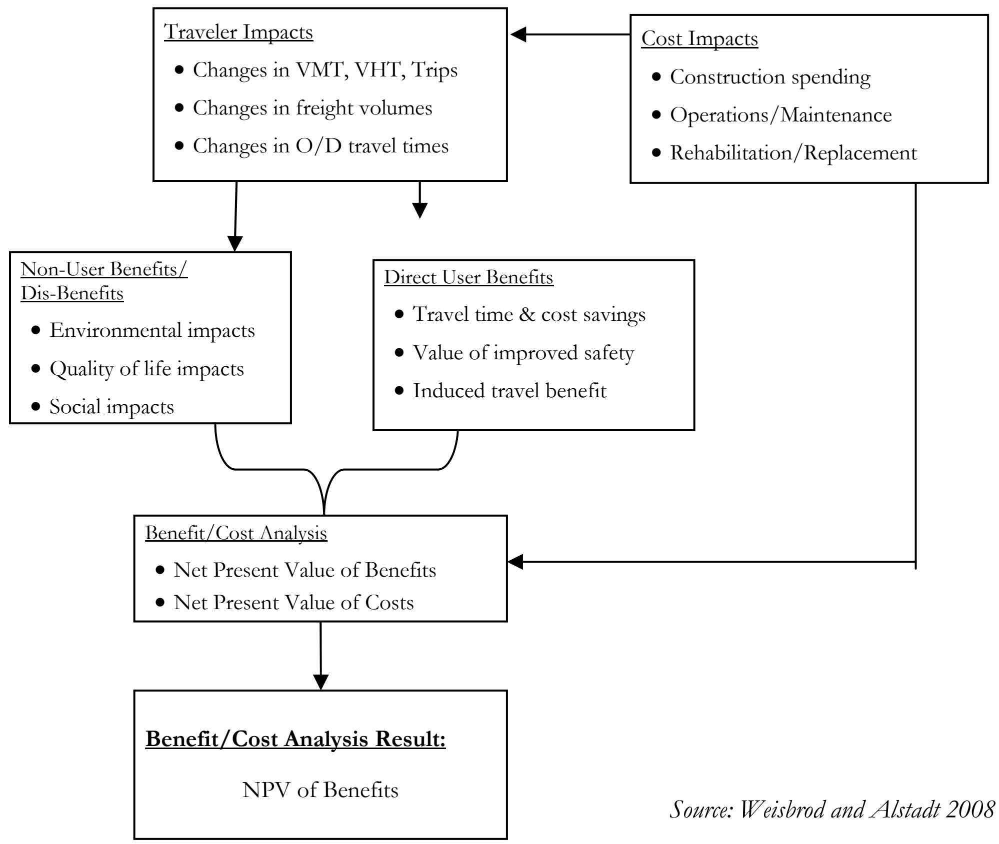
With the framework for BCA in place, we now review how to account for benefits and costs. Costs, simply, are calculated from the direct expenditures required to build and operate the proposed facility.

Benefits are two-pronged, those attributed to users of the proposed project and those attributed to non-users. User benefits are derived from traveler impacts, such as changes in vehicle hours traveled (VHT), vehicle miles traveled (VMT), safety improvements, and other direct travel impacts forecast as result of the proposed project.[8] Non-user benefits include impacts such as emissions reductions that can affect more people than just users of the proposed project. A “dis-benefit” is a negative benefit; for example, traffic diverted to nearby untolled roads or bridges may slow traffic flows on these other roads, and thereby negatively affect travel times.[9] The interrelationships of these core BCA components are illustrated in Exhibit 3.2.

[8] These travel impacts are usually calculated through travel-demand transportation modeling. The monetization of these impacts is then calculated during the BCA.

[9] As discussed earlier, it considered a dis-benefit or negative benefit because the value of time lost due to increased congestion on these nearby untolled facilities is subtracted from the value of time saved as a result of implementing the toll project.

Exhibit 3.2. Investment Drives the Scale of Travel Impacts and Resultant Benefits



Source: Weisbrod and Alstadt 2008

Cost Impacts[10]

The major costs for highway development are the initial capital costs for construction, anticipated rehabilitation during the useful life of the project (if any), and annual O&M expenses.[11]

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 or electronic tolling mechanisms), hardware, software, and labor.[12]

[10] Identifying costs is usually straightforward, as costs are limited to construction, anticipated O&M, and any rehabilitation costs anticipated during the specified analysis period. Identifying and measuring benefits is significantly more complex. Also, calculating, or at least estimating, a project cost is usually the first step in the sequence of BCA. For these reasons, we begin this review with the cost component of BCA.

[11] Bond financing, or debt service, does not factor into the benefit-cost calculation, and is properly part of a financial analysis.

[12] Within BCA, projected costs of the base case are subtracted from the cost of each build alternative. In this way, the "cost" component of a BCA represents net additional costs required to construct and operate the build alternatives.

Travel Impacts

Travel impacts are the data derived from a state or regional travel-demand model. Unit costs are applied to these metrics to derive direct user benefits. Examples of unit costs are vehicle operation expenditures per mile or hour, value of time per hour, and cost of accidents per incident.

Data needed from the regional demand model include changes in VMT, VHT, and volume/ capacity ratios (along with current/ predicted non-recurring incidents to calculate reliability). Note that the same data are required for measuring truck travel and passenger vehicle travel. In general, travel-demand modeling assumes that for each travel decision (mode and destination), a person will choose the route that offers the lowest trip cost. In this case "trip cost" is a melding of time, reliability, personal comfort, and roadway tolls or transit fares.

Currently there is no standardized practice for representing toll roads in travel-demand modeling, and modelers in different locales address this issue in different ways (Spear, no date). White Paper 3 discusses how accurately the current practice of travel-demand forecasting in Oregon can model tolling.

Value of Time (VOT)

For transportation, VOT refers to the amount of money a traveler: (a) would be willing to spend to save time; or (b) expects to be paid to make up for lost time. In most circumstances, benefit streams increase as the value of time increases. Time values vary by types of highway users and would need to be established in the analysis.

Valuing the per-mile or per-hour operating cost of a vehicle increases with the vehicle's weight, but valuing time varies by trip purpose. Time consumed for personal trips or commuting is typically valued less than on-the clock trips, which are valued at hourly expense to employers (wages plus benefits plus employer-paid payroll expenses).

Different values assigned to time can skew the relative valuation of projects. Valuing "on-the-job" travel is usually based on payroll costs to employers in a target region. This can differ if national or regional averages are applied or if methods to value time have not caught up with technology changes. For example, laptop computers and cell phones enable work on trains or in airport terminals or on airplanes. Thus, actual lost value of time for these modes may be less than for highways.

Valuing personal travel is estimated in varying ways. Commuting may have a productivity value for a person's job—for example, better reliability may reduce tardiness. Hence, some approaches value commuting time higher than other personal travel. Other approaches, however, simply count all not-working time as personal time and assign a value. Notably, federal modal agencies offer differing guidance in assigning an average value of time.

The values most widely used in the United States come from the Federal Highway Administration's Highway Economic Requirement System, a program developed specifically to calculate measures of travel time for highway benefit-cost analysis. The most recent model presents values of time for work trips ranging from $27.99 per hour for a small automobile to $31.58 for a large truck (1995 dollars) (Weisbrod et al. 2007).

Current methods for valuing time ignore differences among motorists such as income and personal values (Wallis and Hamilton 2005). To address this, some researchers have estimated a measure for the relationship between increases in income and increases in the value of time.[13] One group estimated this value to be 0.5, meaning that for every 100 percent increase in income, value of time would increase 50 percent. In the United Kingdom, analysts estimated that the value of time for non-work trips increases at 80 percent of the rate that income increases (Cambridge Systematics 2007).

As an example of how sensitivity to income levels affects the value of time, a review of alternative road pricing studies in New Zealand found the average value of time was $14.40 (in U.S. dollars) per vehicle hour of travel, but when segregated by different income levels, the average value of time was $1.22, $7.77, and $31.76 per vehicle hour of travel for the low, medium, and high thirds of the income spectrum, respectively. This study found that benefits were underestimated by not using a value of travel time savings segmented by user markets (Wallis and Hamilton 2005).

Reliability is a critical component for the value of time. Measuring time savings, if any, which result from changes in reliability requires analyses of likely impacts on major highways and arterial roads, which may become less reliable due to traffic diversions (see White Paper 4).

Vehicle trips should be segmented into "on-the-clock" and "personal trips," at a minimum. Personal trips can be divided into "commuting" and "other personal trips." In addition, types of vehicles can be identified (trucks, buses, passenger cars, etc.). Sources for these data are usually output from a regional traffic demand model, surveys, and trustworthy studies and averages. Truck traffic and crew trips are always on-the-clock, while other vehicles and passengers are a mix of on-the-clock and personal travel. VOT is adjusted depending on trip purpose, with on-the clock trips being valued at regional industry wages (plus employer-paid benefits), and commuting trips and personal trips reduced, respectively, from the on-the-clock values. These trips then need to be classified as through-trips and those with a trip-end in the corridor. This is done for two purposes: as a means of evaluating VHT and value of time on the corridor, and to help determine land use benefits and additional economic activity along the corridor.

Within the on-the-clock trips segment, the market can be further segmented by occupation and by business travel and freight shipments, although collecting data on the occupations of travelers is difficult (Weisbrod et al. 2001). For freight shipments, the value of time includes not only the wages paid to the operator, but also costs related to missed shipments, loss of sales, the need for additional fleet, and spoilage, as well as whether or not a firm can use technology to track congestion and avoid costs (Cambridge Systematics 2007). These costs have been valued from a conservative 2.5 times the value of the driver's time, to as much as $371 per hour for the value of avoidance of scheduled delays (Weisbrod et al. 2007). These values further differ based on the commodity being shipped. A number of recent studies have examined issues of the value of time delay and reliability changes for trucks. These values may depend critically on freight mix, in order to account for issues of spoilage and requirements for just-in-time deliveries.

[13] In economic jargon, these measures are called "elasticities."

For freight deliveries, drivers' time, vehicle costs, and an empty truck start at about $38 per hour. Additional values can be assigned that reflect productivity benefits associated with timely deliveries. These hourly rates have been valued from $66 for durable manufactures to $40 for drayage and warehousing (Cambridge Systematics, EDR Group, et al. 2005). The mix of vehicles and trip purposes can skew the relative valuation of projects that involve multiple modes, such as airport access improvements.

Dis-Benefits

Dis-benefits occur when a project imposes costs on users or non-users. These may be actual costs, such as business disruption due to project construction, or monetized costs such as increased travel time for drivers who divert to a local road to avoid paying a toll. This is likely to be an important consideration where an existing untolled facility becomes a tolled lane or toll road and diversion is high. When dis-benefits are found, net benefits for a project are reduced accordingly.

Non-User Benefits

Non-user benefits may be positive or negative. Positive benefits include savings costs associated with:

- Environmental impacts (such as air quality improvement), and/or
- Other economic efficiency benefits that accrue to "downstream" beneficiaries, such as those associated with new markets. These benefits include travel efficiency or "full" user benefits. Travel efficiency benefits include time savings and operation cost savings; full user benefits; and broader measures such as time savings to freight shippers (as distinguished from the carrier).

Non-users can bear dis-benefits as well. Notably, users of local roads can endure congested conditions from drivers changing their trips to avoid paying tolls. This added congestion will not only lengthen trip times for current users of local roads, but may require more frequent and expensive maintenance, worsen safety conditions, degrade the immediate environment through increased emissions and noise, affect access to local businesses, and cause the value of housing abutting the roadways to fall.

Interpretation of Benefit-Cost Calculations

BCA presents the present value of all estimated benefits compared to all estimated costs. However, it is important to point out that certain underlying features can affect benefit estimates, as discussed below:

- *Aggregation issues*. As an example, consider a project that saves 1 million people one minute of travel time each versus a project that saves 10,000 people each 100 minutes (1-2/3 hours). It is unlikely the projects would be valued similarly, because one extra minute is worth very little, whereas 100 extra minutes are more useful to each of the beneficiaries. In weighing different alternatives, it is advisable to ensure that: (a) key aggregations are arrived at in similar ways, and (b) the decision over which alternative to pursue is made by understanding the aggregation differences and weighing the importance of each.

- *Distribution of benefits*. Benefits may be distributed differently among user types (for example, freight vs. passenger), traveler types (for example, business vs. personal), income groups, or special populations (elderly, minorities, or disabled). While the distribution of impacts does not change the resulting BCA metrics, it can be an important consideration in project selection.
- *Spatial perspective*. By definition, BCA should count all costs and benefits. However, in practice, the measurement of benefits is frequently limited by political boundaries (city, county, state). Moreover, the public may have a reasonable desire to know if there is a spatial mismatch between who benefits and who bears the costs.
- *Risk analysis*. BCA is typically prospective, meaning it makes predictions about future events. Risk analysis provides methods for incorporating the uncertainty inherent in all predictions into the practice of BCA. There are three methods for doing this:
    - Sensitivity analysis, which observes variations in the results by changing one or several input variables at a time.
    - Probabilistic methods, which apply distributions to some or all input variables, and use sampling techniques to determine distributions surrounding the resulting BCA metrics.
    - Scenario-based methods, which use "low," "medium," and "high" scenarios that incorporate varying degrees of pessimism or optimism about growth in demand or savings associated with future projects.

Chapter 4. Market Segmentation

Market segmentation is the act of categorizing the total market for a good or service into groups of prospective customers who have similar preferences and/or behaviors. For roadway and bridge projects in general, and for tolled facilities in particular, the "market" is generally segmented into household (or personal) users and commercial users. This is an important distinction, as each of these groups may need very different things at different times, may have varying abilities to respond to changes in the transportation system, and may have varying abilities to pay for transportation services.

In tolling applications, users can be segmented by type of vehicle (cars, vans, pick-up trucks, buses, and trucks) and purpose of trip (business, personal, commuting, and on-the-clock). Users can be further categorized according to the types of toll facilities they use and by times of use.[14] This chapter presents a detailed typology of tolling applications and discusses current research on the relationship between transportation services and times of use of those services.

Typology of Tolling Applications

The different types of tolling applications complement user-market segmentation. Exhibit 1.1 provides the typology of tolling applications.[15] We suggest adding to this typology: (1) toll interception methods and (2) tolling technology.

Toll Interception and Technology

Toll interception refers to how and where motorists are required to pay a toll. Traditional toll methods intercept traffic on roadways using barrier plazas, forcing vehicles to stop and pay the toll. This, clearly, can add to congestion on busy roads. At the other extreme, on Highway 407 in Ontario, Canada, license plates are photographed as vehicles enter and exit the highway,[16] and monthly bills are mailed to motorists. Alternatively, vehicles can be equipped with transponders that allow electronic detection of entrances and exits on tolled roadways,

Tolling technology is the means of collection, which ranges from cash payment at barriers to automatic photography, address lookups, and invoicing by mail or by billing credit card accounts. One method combines elements of both technologies, placing barriers at the entrances and exits of limited access highways for cash collections, along with electronic detection and billing.

Implementation of varied interception techniques and technologies results in different capital and operating costs. In addition, revenue generation (and costs to businesses and households) may differ with associated policies. Some states offer a discount for use of a transponder because collection costs are cheaper, or—from a different perspective—charge a penalty for use of cash.

[14] A consideration of time of use raises the issue of congestion pricing, which is discussed in White Paper 5.

[15] HOT lanes are addressed in detail in White Paper 5, which discusses congestion pricing.

[16] EDR Group is currently working on a transportation/congestion management plan in Ontario, Canada.

Exhibit 4.1 below presents an outline of tolling techniques, including interception technologies and applications. The different types of toll roads and toll technologies shown there affect benefit-cost ratios, because different capital investments are required, and affect vehicle operating speeds on highways and bridges.

Exhibit 4.1. Tolling Techniques and Technologies

Toll Means	Plaza (barrier) located on highway	Pay at entrance/exit (barrier plazas off-road)	Toll collected off-highway (technology, no plazas)
	Compounds congestion	*Flows expedited on highway; slows at entrances and exits*	*Maximizes mobility*
Technology	Cash – compounds congestion on highways with barrier toll or at entrances/exits. Extends travel time.	Transponder or other technologies – electronic “smart roads”; raises questions of equity if equipment purchases are required.	
Types of Applications	Traditional Projects	Tolled Managed Lanes	Apply tolls to existing highways/bridges/tunnels

Source: Cambridge Systematics 2007.

Value of Time

Value of time provides another way of segmenting the market for toll road BCA. Various studies have demonstrated that factors such as age, gender, income, status of work and education influence the willingness to use toll facilities. Most notably, full time employment and income level are positively related to toll road usage.

Summary of Market Segmentation

For the purpose of benefit-cost analysis, market segmentation requires categorizing by multiple factors in order to effectively measure operating costs and benefits to users.[17]

The major factors are listed below, and are illustrated in Exhibit 4.2:

- Reason for travel and persons per vehicle – to calculate the value of time.
- Type of vehicle – to calculate operating costs.

[17] It is important to consider drivers who pay tolls only in cash. Depending on the technology used, drivers may be concerned about privacy, may not want to acquire transponders for limited numbers of trips (if a transponder-technology is used), or may not be able to afford initial payments for an electronic toll account. A system that collects tolls only by electronic means may exclude people who do not have credit cards, checking accounts or email access. These exclusions could result in higher rates of diversions to untolled roads than would be anticipated by assumptions related to the value of time. Such exclusions could be mitigated by a system that captures license plate numbers and bills users by post, although this would incur higher operating costs than electronic collection methods.

- Time of travel – to calculate incidence of roadway congestion and reliability (see White Papers 4 and 5).
- Type of tolling (facility, lane characteristics, and technology) – to calculate cost of operating speed.

Exhibit 4.2. Market Segmentation for Tolling

Categories	Segments		
Reason for Travel	Business – *on-the-clock*	Commuter	Personal
Persons per Vehicle	Truck – n/a	Other vehicles: 1, 2 or 3+	
Vehicle Use and Occupancy	Truck	Auto	Bus or Van
	Use: Freight Occupancy: Crew	Passengers	Passengers Driver
Time of Travel	<u>Time of Day</u> *Examples:*	<u>Day</u> *Examples:*	<u>Season</u> *Examples:*
	Morning Peak Evening Peak Mid-day Mid-night	Weekday Weekend	Spring Summer-Fall Winter
Toll Development	New Road/Bridge	New Lane	Converted Lane or Road/Bridge
Lane Characteristics	General Purpose	Auto Only	HOV/HOT
Tolling Technology	Electronic	Intercept	Combination of Intercept and Electronic

Chapter 5. Calculating Benefits and Costs for Highway and Bridge Projects

Costs

Benefit-cost analyses for transportation projects typically recognize the following project costs:

- Facility construction costs (right-of-way acquisition, planning, design, engineering, construction of roadway elements, and construction materials).
- Facility operating costs (including liability insurance, police, roadside assistance, snow removal [if applicable] and annual maintenance).
- Rehabilitation costs (pavement rehabilitation, structure rehabilitation, and sign replacement).

Two additional costs are worth noting: interest costs (if bonding was used to finance the facility) and end-of-project costs (residual value, salvage value, and close-out costs). Both costs are valid, but neither is appropriate in the context of a public benefit-cost analysis. First, interest payments reflect the time-value of money and are properly reflected in the discount rate within the structure of the analysis. Second, end-of-project costs are relevant if the intent is to calculate the potential sale value of the facility at some future point to augment the project's returns on investment. However, these costs are not germane for choosing among projects, because it is unlikely a public highway will be sold after 20 or 30 years, as may be the case with a private sector investment.

Traveler and Economic Development Benefits

Traveler benefits of a transportation project include:

- Travel time savings
- Safety benefits
- Vehicle operating cost savings
- Improved reliability

In addition to these traditional user benefits captured by traveler impacts, policy makers are increasingly interested in economic development benefits projected as a consequence of transportation investments.

Travel Time Savings

Reduction in travel time is generally the most important benefit of a highway BCA, which is why it is discussed throughout this paper. To include travel time savings in a benefit-cost framework: (1) monetary values of time for each category of users of the transportation facility are determined; (2) the value of total project time savings is calculated by multiplying those values by the time savings that would accrue to users of each segment compared to a base case scenario derived from a transportation demand model; and (3) the total time savings of all user segments are summed to arrive at a total time savings benefit. If applicable, the same process is followed to calculate negative benefits.

For commercial vehicles, the value of reliability depends on the commodity being shipped, inventory impacts, the potential for lost sales, potential spoilage costs, and the ability of firms to use new technology to track congestion and avoid costs (Cambridge Systematics 2007). Improvements in reliability are a component of time savings, and are particularly important for commercial vehicles. Issues of reliability and how it is measured are discussed in more detail in White Paper 4.

Safety Benefits

Safety benefits include values for property damage, personal injury, or deaths due to accidents on the transportation facility. To monetize these impacts, analysts calculate an average cost of property damage per accident, based on different travel speeds and highway geometrics, and then apply values for injuries sustained and for lives lost.

As some analysts have noted, however, tolling facilities that reduce congestion may reduce the number of deaths from accidents because emergency vehicles can reduce response times. At the same time, faster speeds on a free-flowing toll road may result in more severe accidents (FHWA 2003). In addition, the accounting of safety benefits must include impacts on the surrounding transportation network. Studies have shown that tolling strategies that divert traffic to arterials or parallel roads may cause more congestion (CSI 2008; Gupta et al. 2004) and increased accident rates (Wallis and Hamilton 2005) on these roads.

Vehicle Operating Cost Savings

Operating cost savings include reductions in vehicle wear and tear, vehicle maintenance, and fuel cost savings. With the addition of toll lanes to manage congestion, fuel costs may increase or decrease, depending on the level of congestion relief, the level of congestion on alternative roads, the use of traditional or electronic tolling, and the number of trips diverted.[18]

If a toll facility allows for vehicles to travel faster than optimal fuel efficiency speeds, fuel usage could be higher than on an adjacent untolled facility, particularly if congestion is not notably affected on the untolled facility (Wallis and Hamilton 2005). Conversely, if the toll facility allows for travel at optimal fuel efficiency levels on the tolled facility and reduced congestion on the non-tolled alternative (thus improving fuel efficiency), a reduction in fuel usage and fuel costs will result (Cambridge Systematics 2007). Of course, this benefit could be offset by induced demand, as more trips are attracted to the facility due to its increased capacity, thereby leading to higher fuel usage (although potentially a lower per vehicle usage).

[18] For more information, see White Paper 5.

When Toll Revenue Should be Included in BCA

As stated in Chapter 2, tolls are a tradeoff for the benefits associated with time and cost savings gained by the toll road and therefore, are not usually included in BCA. An exception to this treatment of toll revenues occurs when there is only one, tolled road available. In this case, the transportation provider is acting as a monopolist and extracting money from travelers who have no other option but to pay. In this unlikely scenario, tolls may be considered as costs if there are no other practical means to get to a destination.

Economic Development Benefits

In addition to the traditional user benefits included in a highway BCA, transportation agencies may be interested in accounting for economic development benefits. These can occur as a result of:

- Reduced travel costs (reducing the cost of doing business)
- Expanded geographic markets (freight deliveries and regional retail)
- Wider access to labor and jobs
- Improved reliability

These improvements result in production efficiencies, or increased productivity, and are measured in terms of gross regional or state product, or income (Cambridge Systematics 2007).

Improved reliability means businesses know they can meet shipment schedules for just-in-time deliveries and intermodal transfers. This may affect logistics, including how many trucks companies need, locations of warehouses, and the number of drivers needed. Moreover, improved reliability and access also may result in expanding a firm's market reach, such as the geographic area reachable by an eight-hour truck delivery.

Chapter 6. Hard-to-Quantify Benefits

Societal benefits are usually included as "project impacts" in an environmental impact analysis, but are rarely included in the calculation of a benefit-cost ratio in the United States. These impacts include (but are not limited to):

- Air quality
- Water quality
- Noise
- Energy consumption
- Social and environmental considerations (including habitat loss, community cohesion, and equity and environmental justice)
- Land use

In the United States, many societal/external benefits are not included in benefit-cost models because: (a) there is no agreed-upon or well understood method for monetizing the impact; (b) they are not recognized as true benefits or costs (usually because the impacts are not well understood); or (c) they are not considered central to the goal of the analysis.

In Europe, transportation agencies are working to better account for a wider set of impacts in their analysis of project costs and benefits, while recognizing they all cannot be included in a benefit-cost ratio. These agencies have developed "appraisal tables" that allow for a listing of unquantifiable costs and benefits, and consider these impacts as well as the benefit-cost ratio in selecting projects for implementation (UKDT 2004).

Air Quality

Air quality is most often considered for inclusion in an analysis of project costs and benefits. Interest in measuring the air quality changes resulting from transportation projects is increasing as concerns increase about the impacts of emissions on climate change. Tolling does not provide a single answer regarding improvement or degradation of air quality. For example, while tolling may reduce congestion and thus reduce emissions on the tolled facility, increased congestion on arterials and parallel roads due to diversion may lead to increased emissions.

Air quality impacts are generally measured in kilograms of emissions per mile by type of vehicle, which are calculated for alternative transportation facilities using an emissions model. Conversion of kilograms of emissions into a monetary measure for BCA has been an area of much research. The most widely accepted approach has been to estimate the health costs of treating illnesses associated with different types of motor vehicle emissions (Wallis and Hamilton 2005). Values have been estimated for nitrous oxide, volatile organic compounds, carbon monoxide, and particulate matter, although the values vary considerably between research efforts and urban areas. More recently, there has been interest in valuing the cost of emissions using the market value of emissions trading credits

(Weisbrod et al. 2007). This is an attempt to assign a monetary value to the cost of greenhouse gas emissions. See White Paper 1 for a detailed discussion of tolling and emissions reductions.

Water Quality

Water quality could be affected by tolling strategies in two distinct ways. The addition of new lanes as well as limited access ramps and toll plazas will result in more impervious surface and, as a result, more runoff into the water system. This impact will be less for electronic tolling systems, as these can process toll collection through fewer collection lanes than manual systems. Tolling strategies that reduce VMT may reduce water quality impacts by lowering both the emission of pollutants and leaking vehicle fluids (ECONorthwest et al. 2002). There have been some efforts to monetize these impacts at the national level (Weisbrod 2006), but findings differ substantially among studies and are difficult to apply at the local level.

Noise

Noise is a function of multiple factors, including speed, traffic volume, mix of vehicle types, and how well the ground and the surrounding natural and built environment absorb noise. The cost of noise has been calculated by identifying changes in housing prices or rents based on differences in noise levels (CalTrans, no date; ECONorthwest et al. 2002). Another suggested approach is to value the cost of noise at the cost of any steps used to mitigate the impact (e.g., the cost to erect noise barriers or to soundproof homes). Neither of these techniques has been widely used in project BCAs, although differentials in housing prices have been reported in project impact analyses. Methods for measuring the noise impacts of toll facilities should not differ substantially from other transportation facilities.

Toll facilities that decrease the number of vehicle trips or reduce the vehicle hours of travel on a road system should result in a reduction in noise (Cambridge Systematics 2007). However, since noise impacts increase with vehicle speed, tolling strategies that increase speeds without significantly reducing the number of highway trips may not realize substantial noise reductions. Furthermore, if substantial diversion of trips occurs, it may be necessary to pay special attention to noise impacts along the diversion routes.

Energy Consumption

Impacts related to energy consumption are usually discussed in two ways. First, is consumption based on optimizing miles per gallon and lowering overall consumption? These beneficial impacts are indicated by fewer delays and less fuel-inefficient stop-and-go traffic. These measures are complemented or balanced by changes in expected VMT and VHT. It is possible a new roadway will lead to a decrease in one or both of these, resulting in further fuel savings. On the other hand, an improved roadway may increase one or both of these measures by inducing additional travel and negating some or all of the savings realized by delay reduction.

Social and Environmental Disruptions

Other impacts often included in transportation investment analyses include disruption or loss of natural habitat, neighborhood cohesion, community disruption, visual impacts, civic pride, and social equity or environmental justice (CalTrans, no date).

Tolling strategies that create new roadways or divert traffic onto existing local roads may have any number of possible effects on adjacent communities or the natural environment, and these must be considered.

Land Use

Land use analysis cannot be folded into BCA and must be considered separately. Projected land use impacts attributable to a tolling investment are considered "externalities," i.e., "external" to the direct costs and benefits of constructing and using the tolled (or untolled) facility. Another term for this effect is "spillover" benefits.[19] This is not to say that land use or economic impacts should not be considered. A qualitative or quantitative side analysis can be used in combination with BCA. For example, comparative land use impacts may be a deciding factor when evaluating alternatives with BCA ratios greater than 1.0, or may function as a tipping point for deciding whether to go forward with a project.

Tools are available to estimate land use and economic development impacts of tolled and untolled facilities. For example, MetroScope is a set of analytical techniques used by Portland Metro to model changes in measures of economic, demographic, land use, and transportation activity. The Transportation Economic Development Impact System (TREDIS) has been developed by EDR Group to report both economic impacts and BCA for transportation projects.

[19] In addition, the interpretation of land use impacts as positive or negative is often contentious.

Chapter 7. Conclusions and Recommendations

BCA is an effective tool for analyzing and comparing alternatives for specific projects and corridor improvements, and for assessing a portfolio of projects competing for limited funds. The BCA framework weighs benefits and costs in terms of net present value to allow the economic efficiencies of alternatives to be compared.

A benefit-cost framework can be used to help determine which option will return greater benefits relative to costs, over time. In particular, BCA can be used to determine which among competing tolling options will provide the most direct benefits compared to the cost of investment, as well as to compare tolled and non-tolled project alternatives.

Driver decisions affect the efficiency of tolled facilities. Tolls can be a catalyst for improving safety, reducing vehicle operating costs, reducing emissions, and/or improving the efficiency of a wider transportation network by reducing congestion. On the other hand, diversion of traffic to untolled roads can lead to increased congestion and associated problems.

Benefit-Cost Does Not Answer Every Question

BCA should not be considered as the sole determinant of decisions on tolling/pricing. Although BCA helps evaluate projects and alternatives by demonstrating which among them are the most efficient, it does not address all issues that concern decision-makers. BCA does not address social equity issues, nor does it address possible inequities between who pays the tolls and who benefits of a project.

In addition to the traditional user benefits included in highway benefit-cost analyses, more and more transportation agencies are interested in accounting for the economic development benefits due to transportation investments. These impacts are defined in terms of added gross regional or state product, jobs, or wages; are appropriately measured by economic impact studies; and are measured through economic impact analyses, not through a BCA.

As a tool to answer questions about operating efficiencies, we recommend ODOT develop and adopt a BCA methodology as a basis for comparing alternatives on a local, corridor or portfolio scale. In this context, the methodology should retain flexibility to consider factors that fall outside of the BCA, as well as other hard-to-quantify impacts.

Implementing a Benefit-Cost Analysis Program for Oregon

We recommend ODOT develop a benefit-cost guidance document as a first step in implementing a BCA for tolling in Oregon. Even if the state is the only entity performing benefit-cost analyses for toll facilities, published guidance will provide transparency to the public on how these analyses are conducted. It also will assure that over time, all staff use consistent approaches to conducting analyses for identified problematic roadway segments and bridges, as well as for choosing among alternative solutions to problems. Moreover, the process of establishing such guidance can help involve the public and stakeholders in the design of the BCA. Topics generally included in a BCA guidance document include the following.

- **Discount Rates.** Discount rates provide an effective tool to evaluate the risk associated with future benefits. Regardless of what rate or series of rates are incorporated, the state should review and (if warranted) revise the rates on an annual basis to ensure they remain relevant.

- **Length of a Benefit-Cost Analysis.** A standard time frame for the analysis needs to be established. The time frame analyzed in a BCA is usually 20 to 30 years, based on the useful life of a project. Generally, this is a reasonable approach for tolled and untolled public-sector highway projects. However, some tolling projects involve long-term leases between departments of transportation and private sector operators, leases that often run 30 to 40 years and have been known to run as long as 99 years. However, this is not good BCA practice, because the time frame of a BCA should not exceed the capacities of modeling and demographic projections to develop useful traffic forecasts.

- **Time Values.** Time values should be supplied in a guidance document, segmented by trip purpose (at least by on-the-clock, commute, and other). Values could be set by Oregon for the state, could vary by intra-state region, or could be taken from national guidebooks (e.g., the FHWA guidebook). We recommend Oregon update these values annually or specify an index that can be used for such updates (such as the consumer price index).

- **Other Values.** Other common benefit values, such as safety and vehicle operations, may vary case by case. It is important to specify the methods used to derive these benefits so analyses can be traced and verified.

- **Freight Benefit.** We recommend ODOT's guidance specify methods of specifying cargo benefits, and define both direct freight benefits for BCA and indirect benefits that are appropriately part of economic impact analyses.

- **Base Case.** Identification of a base case is a critical step in a benefit-cost analysis. For example, if the base case includes needed safety improvements, then the capital cost of the toll facility would be calculated as:

  [Cost of New Facility – Cost of Needed Safety Improvements].

- **Externalities or "Expanding the Toll Community."** Most federal transportation funding agencies, with the exception of the Federal Aviation Administration (FAA), do not acknowledge that indirect activities may be a valid basis for benefit calculations. Indirect benefits depend on improved services provided by tolled and untolled highway and bridge projects. Even though externalities generally fall outside the BCA framework, ODOT may choose to follow the FAA example and consider such dependent impacts if a nexus can be established to the facility being evaluated. Usually, however, benefits external to the facility are considered in economic impact analyses.

- **Using Survey and Interview Data to Document Benefits and Costs.** There are two types of surveys/interviews: those that simply collect data on expenditures or time delays, and those that attempt to predict behavior given new circumstances, such as construction of a new toll lane, based on responses to interview questions. The first type is usually incorporated in a travel-demand modeling system. The second type requires interviewing or surveying the general public or business community about projects that may be constructed. This type of interview often yields statements from responders about what might be done if certain improvements are made at some time in the future. Given that investment decisions may rest on data gleaned and interpreted from these surveys, hard commitments by interviewees are considered more important than statements of intention. Commitments, however, may be more relevant to an impact analysis than a BCA. For example, a manufacturer might commit to locate a plant near an interchange for a proposed toll facility.

It is always advisable to develop benefit-cost analyses with full disclosure and transparency of data, but this is not always practicable. For example, in benefit-cost studies, interviewees are often asked about business plans, including information about mode shifts or new market potential, given the expected time savings due to a highway improvement. Businesses often do not want to disclose this competitive data, and insist on confidentiality if they do disclose.

ODOT should consider providing guidance for handling confidential data. Benefit-cost studies address confidentiality issues in various ways: by merging data, hiding business names, or providing side memos to the funding agencies outside of the benefit-cost document.

Appendix A: Literature Summary

A wealth of literature exists describing how to conduct benefit-cost analysis (BCA) for transportation projects, the pros and cons of alternative approaches, and how to measure a wide variety of potential costs and benefits. In recent years, as more and more transportation agencies have begun considering and implementing tolling and variable pricing strategies for revenue generation and congestion management, researchers and practitioners have focused attention on how to conduct benefit-cost analyses for these projects. This section summarizes the literature on transportation project benefit-cost analysis in general, and for tolling and pricing projects in particular.

Benefit-cost analysis has been used for decades by transportation agencies as a tool to help prioritize projects for construction. Traditionally, transportation benefit-cost analysis has focused on the efficiency (or user) benefits of project alternatives, and compared these benefits to the costs of construction and operations. User benefits were narrowly defined to include travel time savings, safety benefits (reductions in accidents), and operating cost savings (reduction in fuel usage and vehicle maintenance costs). Costs included construction costs to build the facility, operations and maintenance costs to run the facility, rehabilitation costs, and end of project costs.

In the 1980s, some transportation agencies began to recognize that transportation investments (including highways, transit, and airports) might also create economic development benefits for a region or state by improving travel times for business travel and freight shipments, expanding the market area businesses could serve, and improving the reliability of the transportation network. Beginning with the Wisconsin Department of Transportation's Highway 29 corridor study in the late 1980s (Cambridge Systematics 1988 and 1989), several state and regional transit agencies began including economic development benefits, measured in terms of either gross regional (or state) product (a measure of productivity) or personal income, in project benefit-cost analyses. The addition of economic development benefits to the analysis meant the traditional goal of prioritizing projects based on their impact on system efficiency was changed to include consideration of how a project boosted the economic competitiveness of its service area (Weisbrod 2006).

Transportation agencies recognize that the many additional impacts of transportation projects include societal benefits or dis-benefits. These include environmental impacts such as air and water quality; quality of life issues such as noise and visual impacts, community cohesion, neighborhood disruption, environmental justice, and security; and land use impacts. While the environmental review process for major transportation investments has required these impacts to be measured and mitigated, they have not been included in benefit-cost analyses because it has been difficult to assign a monetary value to these impacts. However, in recent years, as more attention has been paid to the environmental consequences of fossil fuel consumption, and as transportation investment strategies that reduce dependence on fossil fuels have become more important to decision-makers, some transportation agencies (primarily abroad) have begun including air quality, noise, land use, and sustainability factors in benefit-cost analyses and in the decision-making process (Wallis and Hamilton 2005; Lobe et al. 1998).

Current State of BCA Guidance

This section reviews published guidance that explores the different ways in which benefit-cost analysis can be applied and interpreted. The guidance reviewed here is limited to BCA for transport projects, but it spans many modes and includes several international guides:

- **US Highway Guidance:**
  - Federal Highway Administration (2002). HERS-ST v2.0: *Highway Economic Requirements System-State Version Technical Report.*
  - Federal Highway Administration (2003). *Economic Analysis Primer.*
  - American Association of State Highway and Transportation Officials: A Manual on User Benefit Analysis of Highway and Bus Transit Improvements, 1977, *AASHTO Red Book.*
  - National Academy of Sciences' National Cooperative Highway Research Program, *Development of an Update to the 1977 AASHTO Redbook User Benefit Analysis for Highways*, 2002
- **European Guidance:** European Commission (2002). *Guide to Cost-Benefit Analysis of Investment Projects.*
- **Canada Guidance:** Transport Canada (1994). *Guide to Benefit-Cost Analysis in Transport Canada.* Report TP11875E, Economic Evaluation Branch.
- **UK Guidance:** UK Department of Transport (2000). "Cost Benefit Analysis," in *Guidance on the Methodology for Multi-Modal Studies Volume 2.*

The Role of BCA in Project Appraisal

The Federal Highway Administration (FHWA) encourages use of BCA as a tool for state agencies to maximize the use of scarce resources. Transport Canada also encourages use of BCA. Other U.S. federal transportation agencies require BCA in some circumstances for funding capital projects, including the Federal Aviation Administration, the U.S. Army Corps of Engineers, and the Federal Transit Administration. The U.K. Department of Transport and the European Commission do, also. In Europe, BCA and financial analysis are performed side by side. This approach has the benefit of: (1) determining private return-on-investment, (2) explicitly stating which benefits are external and which are not, and (3) identifying all revenue sources.

Defining Costs

Recommendations for quantifying project costs are very similar among the guidance documents surveyed here. All recognize capital spending and operations and maintenance, although some explicitly define the detailed categories of each, as listed in Chapter 2.

Defining Benefits

Guidance for highways is narrowly defined on this topic. While FHWA's Primer (FHWA 2003) acknowledges network and corridor effects, the FHWA-sponsored models for benefit-cost analysis only incorporate mode-switching behavior to the extent that it is included in "induced" travel. This lack of a multimodal perspective was seen as a major shortcoming by an expert panel reporting to the Government Accountability Office (GAO 2006).

Appendix B: Glossary of Terms, Abbreviations, and Acronyms

Amortization – A financial term referring to terms of a loan where the provision is made in advance for the gradual reduction of an amount owed over time.

Area pricing – A tolling approach where vehicles are charged a fee to travel within a high activity center, such as a downtown or business district. Prices may vary by time of day to encourage motorists to enter the zone during less busy times or to use transit. An example is Fareless Square in Portland, where transit is available for free to discourage short-term and short-distance auto travel within the business district.

Bus rapid transit (BRT) – High-frequency bus service on dedicated lanes that are separate from general travel. BRT combines the advantages of rail transit – exclusive right-of-way to improve punctuality and frequency – with the advantages of a bus system – low implementation costs and flexibility to serve lower density areas.

Congestion pricing – An overarching term used to describe measures that reduce congestion by charging drivers tolls that vary by time of day or traffic volumes.

Consumer surplus – In economics, the difference between the price a consumer pays for an item and the price she would be willing to pay rather than do without it.

Cordon pricing – A pricing scheme whereby vehicles entering a high activity area are charged a fee when they cross the boundary line into the activity center. Motorists are charged each time they cross the cordon line. Prices could vary by time of day, to encourage motorists to enter the cordon zone during non-peak periods or to make peak trips using transit. This is similar to area pricing, distinguished by the toll being charged for crossing the cordon line rather than for driving within the cordon zone.

Cost-benefit analysis (CBA) – An analytic technique used in determining the economic value of a project or plan. Costs and benefits are typically denominated in dollars and include the money, time, resources, and consequences associated with a project or activity.

Distance-based tolls – Fixed toll rates based on distance traveled and vehicle type.

Diversion – The result of people making different travel choices, in this case as a result of a toll. Diversion can refer to taking different routes, or changing modes, travel time or destination.

Dynamic congestion pricing – Tolls that change based on real-time travel conditions. For example, when traffic volumes go up, so do the tolls. Rates are lowered as demand eases.

Economic impact analysis (EIA) – A comprehensive assessment of direct, indirect and induced economic impacts that takes into account the system-wide, sectoral effects of productivity improvements, expanded access to jobs and markets, and effects of improved reliability on business operations.

Elasticity – The price elasticity of demand measures the nature and degree of the relationship between changes in quantity demanded of a good and changes in its price. High elasticity implies high sensitivity to changes in price while low elasticity, often referred to as inelasticity, means low sensitivity to price changes.

Electronic toll collection (ETC) – Using technology to collect tolls from drivers without requiring them to stop and make cash payments.

Equity – The idea that all travelers are of equal standing, and should be considered in the development of toll policy. Social, geographic and income equity are examples of equity issues that arise in toll policy development and implementation.

Express toll lanes – Limited access, normally barrier-separated highway lanes requiring drivers of all vehicles to pay toll in order to use the facility. All tolls are collected electronically.

Fixed tolls – Toll rates that don't change. They are typically used to pay for the bridge or road on which they are charged. Trucks pay more than cars.

Fixed-schedule congestion pricing – Tolls charged at predetermined rates reflective of demand levels at different times of day; rates can be based on hour of the day, day of the week, direction of travel and vehicle type.

Gas tax – A state levied tax on the consumption of gasoline. Currently the primary means of financing highways in Oregon.

Greenhouse gas emissions – The generation and emission of gases, such as carbon dioxide, methane, nitrous oxide and halocarbons, which accumulate in the atmosphere and have a long residence time, leading to a surface warming of the land and oceans.

High occupancy vehicle (HOV) – A vehicle containing more than one person.

High occupancy vehicle (HOV) lane – A travel lane restricted to transit and carpool vehicles meeting occupancy requirements of two or three people per car. HOV lanes are meant to carry more people in less space than general purpose lanes.

High occupancy toll (HOT) lanes – Travel lanes restricted to either qualifying HOVs or solo drivers willing to pay a toll. The toll typically varies by time of day or traffic levels and is collected electronically.

Investment grade – The top four rating categories for bonds. Important to tolling, as special, independent analysis of the revenue generating capacity of a particular toll project may be required for bond issuance.

Managed toll lanes – Any toll lane that uses variably priced tolls to maintain superior, less congested travel conditions.

Mileage-based fee or mileage tax – A tax on vehicle use based upon miles driven rather than fuel consumption.

Non-recurrent delay – A type of travel delay that occurs because of incidents, and is therefore not as predictable as recurrent delay caused by traffic exceeding capacity, bottlenecks, or other infrastructure problems.

Open road tolling – Use of electronic toll collection methods to keep traffic moving, as opposed to making people stop at toll booths to pay the toll.

Opportunity cost – In economics, the value of the next-highest-valued alternative use of a given resource.

Parking policies – Adopted means of managing access to a particular locale by changes in the price of parking.

Peak period – The busiest travel time of the day, also known as commute time or rush hour. There are typical two peak periods each weekday – the morning and afternoon commute times.

Public-Private Partnerships (PPPs) – Contractual agreements formed between a public agency and private sector entity, which expand on the traditional private sector role in the delivery of transportation projects. PPPs are particularly prevalent for tolling projects.

Pricing – A tolling concept where the level of toll (price) is used to change travel behavior.

Public good – In economics, a good that is non-rival and non-excludable. This means consumption of the good by one individual does not reduce the amount of the good available for consumption by others, and no one can be effectively excluded. A non-congested public highway can be considered a public good.

Recurrent delay – A type of highway delay that occurs regularly due to too much traffic and/or geometric constraints.

Single occupancy vehicle (SOV) – A vehicle containing only one occupant.

State Infrastructure Bank (SIB) – An ODOT-managed revolving loan fund available for transportation projects.

System-wide tolling – Implementing tolls on highways and major arterials to reduce congestion, minimize route diversion and increase transportation revenues.

Theory of the Second Best – In economics, a theory of what happens when one or more optimality conditions are not satisfied in an economic model. It implies the need to study the details of a situation prior to assuming theory-based conclusions, because improvements in market performance in one area may not mean an overall improvement. This is significant in congestion pricing schemes where theoretically optimal conditions are likely to be unachievable.

Time-of-day pricing – A tolling approach that varies by the time-of-day in order reduce congestion at peak hours; rates are higher at peak hours than at off-peak.

Tolling – Charging a price to use a road, bridge or tunnel.

Toll Revenue Bonds – A type of municipal bond where the principal and interest are secured by tolls paid by the users of the facility that is built with the proceeds of the bond issue.

Travel-demand forecasting – The analytical estimation of future travel volumes and patterns, typically performed with computer models. There are four basic components: (1) trip generation – predicting the number of trips that will be made; (2) trip distribution – determining where the trips will go; (3) mode usage – how the trips will be divided among available modes of travel; and (4) trip assignment – predicting which routes the trips will take, resulting in highway system and transit ridership forecasts.

Travel demand management – The application of techniques that affect when, how, where, and how much we travel, done in a purposeful manner by government or other organizations. The techniques include education, policies, regulations, or other combinations of incentives and disincentives.

Truck only toll (TOT) lanes – Limited access, normally barrier-separated toll lanes available only to trucks for a variably priced toll. All tolls are collected electronically.

Value of time (VOT) – One of the most important benefits of road pricing, as well as other transportation projects, is travel time savings. What these savings are worth to motorists can vary by income, gender, age, trip purpose, mode used, length of trip, uncertainty of travel time, and other factors. This in turn implies analytical difficulties in applying values to given situations.

Value pricing – Toll rates that vary in direct proportion to travel demand or congestion on alternative free routes.

Variable toll – A toll that changes by time of day, traffic volumes or other factor.

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Appendix D: Tolling and Pricing Policy Development White Papers

Advances in electronic technology enable the tolling of highways to be done in a variety of ways and for a variety of public policy objectives. To date, tolling in Oregon has been limited to a few Columbia River bridges. In response to new opportunities for tolling, the Oregon Transportation Commission established several strategies in the 2006 *Oregon Transportation Plan* for examining the applicability of tolling in Oregon.

As part of this effort, a series of White Papers has been commissioned to explore a variety of policy and methodological issues unique to tolling or congestion pricing. These White Papers are intended to provide discussions of particular issues that are accessible to both policy-makers and the general public. Because of the relative unfamiliarity with tolling and pricing, coupled with the immediacy of our current transportation challenges, discussions about putting tolling and pricing policies in place can be confusing to the public. Because public attitudes and acceptance of tolling are also evolving, ODOT policy development needs to be sensitive to the potential effects of tolling on public attitudes. The white papers are intended as a mechanism for soliciting public comment and not as statements of OTC policy.

White Paper #1 – Air quality/greenhouse emissions

In order to improve air quality or to reduce greenhouse emissions, tolling/pricing must induce changes in the use of motor vehicles, such as fewer "cold starts," reductions in vehicle miles traveled (VMT), or decreases in vehicles hours of delay (VHD). The white paper discusses the relative efficiency of various tolling applications as a strategy for reducing greenhouse gas emissions.

White Paper #2 – Geographic & Situational Limits

Highway tolling or pricing may have limited applicability in parts of Oregon. Much of the state is rural and possesses highways with neither the traffic volume nor levels of congestion typically required for successful tolling/pricing applications. Further, Oregon has little experience with tolling, a fact reflected in the relative lack of consideration of the topic seen to date in transportation planning throughout the state.

It is ODOT's desire that the planning process be better equipped to consider tolling/pricing applications, when appropriate, while being relieved of the need to consider tolling in circumstances with little or no chance for success. Additionally, the relatively low traffic volume on many state highways implies that most potential toll projects are unlikely to be financially self-sustaining. The resulting requirement for state or local financial contributions raises, in turn, a series of finance and project programming issues.

White Paper #3 – Demand Projection Sufficiency

Technological enhancements enable highways to be tolled or variable-priced in a number of ways. The evaluation of tolling applications is dependent upon accurate projections of resultant travel behavior that predict not only facility usage but also the level of expected toll receipts, the amount of traffic diversion around the tolled facility, and changes in relative levels of accessibility to different locales in the area served.

This white paper assesses current modeling practices in Oregon. It explains how new methods of travel demand modeling address the analytic requirements of tolling and dynamic pricing, evaluates the effectiveness of existing models across a range of tolling applications and offers a set of general recommendations for improving model performance.

White Paper #4 – Economic Evaluation of Improved Reliability

A major benefit of some highway pricing applications is improved reliability for motorists. The application of variable prices, dynamically in certain cases, can reduce traffic volumes sufficiently to ensure free flow conditions and to guarantee the motorist a "time certain" trip over the affected roadway. Beyond the travel time savings a tolled facility provides, the guarantee of reliability can be expected to have an economic value in and of itself. This is a new consideration in transportation planning. The paper discusses the challenges to quantifying the economic benefits of improved reliability.

White Paper #5 – Assessing the Economic Effects of Congestion Pricing

Congestion pricing is being considered in some locales for entire parts of an urban area. Pricing schemes cannot be expected to affect all motorists or locales evenly; there will be winners and losers and a unique set of economic consequences for each potential application.

Given the indeterminate nature of broad congestion pricing schemes coupled with expected analytical challenges, it may be necessary to develop one or more methodologies for determining expected economic outcomes. This white paper is intended as a first step in this process, and provides a general discussion of the potential economic effects of system-wide congestion pricing that frames the problem in terms of its theoretical, analytical, and institutional parameters.

White Paper #6 – Economic Comparison of Alternatives

Since most potential tolling are new to Oregon, attention may need to be paid to the analytical methods for assessing the relative economic efficiency of tolled and non tolled highway improvement alternatives.

Tolling presents some unique challenges to traditional methods for evaluating alternate transportation improvements, such as benefit/cost analysis or cost effectiveness comparisons. Constant value-of-time assumptions have been challenged by observed motorist behavior in toll managed lanes. There is also the need to consider the "consumer surplus" a motorist enjoys in a tolled lane rather than simply straight time savings. Freight movements demonstrate variable elasticity to tolls, which could alter analytical conclusions.

The analytical challenges and lack of public familiarity with some of these issues suggests the need for increased analytical rigor and transparency for potential tolling projects. This white paper is intended as an initial consideration of how this can best be done.

White Paper #7 – Truck Only Toll Lanes

There has been a recent surge in national interest in truck only toll lanes (TOT lanes), and a variety of proposals are in some stage of consideration. In varying degrees this reflects the growing economic cost of congestion, lagging investment in highway capacity, and a desire by some to privatize portions of the highway system. This growth in national interest implies a need for ODOT to consider the utility of TOT lanes before embarking on future freeway corridor studies. This white paper provides an introduction to the subject intended for enhancing state policies and the transportation planning process.