Oregon Transportation Benefit-Cost Analysis
Mode-Based Benefit-Cost Analysis Calculator
PART 2 – Benefit-Cost Analysis Framework

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Abstract

This document is **Part 2 of the Oregon Transportation Benefit-Cost Analysis - Mode-Based Benefit-Cost Analysis Calculator** project, which describes the recommended Benefit-Cost Analysis (BCA) framework. It establishes a standardized methodology for conducting BCA of transportation projects, programs, and policies in Oregon, with detailed steps for equity assessment and sensitivity analyses. It is intended to ensure that evaluations are transparent, consistent, and aligned with both federal guidance and state-specific priorities. Additional information can be found in the companion documents of this project – Part 1 - Literature and Best Practices Review and Part 3 - Oregon Mode-Based BCA Calculator Technical Documentation.

Portland State UNIVERSITY

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Acronyms and Abbreviations

AAA	American Automobile Association
ACS	American Community Survey (U.S. Census Bureau)
AF	Annualization Factor
AT	Active Transportation
ATAP	Australian Transport Assessment and Planning (guidance)
BCA	Benefit–Cost Analysis
BCR	Benefit–Cost Ratio
BEA	Bureau of Economic Analysis (U.S.)
BLS	Bureau of Labor Statistics (U.S.)
CARB	California Air Resources Board
CMF	Crash Modification Factor
CO	Carbon monoxide
CO2	Carbon dioxide
CPI	Consumer Price Index
CRF	Crash Reduction Factor
DDI	Diverging Diamond Interchange
DEQ	Oregon Department of Environmental Quality
DIM	Distributional Impact Matrix
DOT	Department of Transportation
EJ	Environmental Justice
EJSCREEN	EPA EJSCREEN Environmental Justice screening tool
EMFAC2021	EMFAC2021 (Emission FACtors model, California)
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GDP	Gross Domestic Product
GIS	Geographic Information Systems
HUD	U.S. Department of Housing and Urban Development
ICE	Internal Combustion Engine
INFRA	INFRA (the Nationally Significant Multimodal Freight & Highway Projects program)
ITS	Intelligent Transportation Systems
KABCO	KABCO injury severity scale (K, A, B, C, O injury levels)
MOSAIC	ODOT MOSAIC multi-objective decision analysis tool
MOVES	MOVES (Motor Vehicle Emission Simulator) model (EPA)
MPG	Miles per gallon
MPO/RTP	Metropolitan Planning Organization / Regional Transportation Plan
MVM	Million Vehicle Miles
NCTCOG	North Central Texas Council of Governments
NHTS	National Household Travel Survey
NPV	Net Present Value
NZTA	New Zealand Transport Agency

O&M	Operations and Maintenance
ODF	Oregon Department of Forestry
ODOE	Oregon Department of Energy
ODOT	Oregon Department of Transportation
OHAS	Oregon Household Activity Survey
OMB	Office of Management and Budget
PDO	Property Damage Only (crash type)
PM	Particulate Matter
PV	Present Value
QCEW	Quarterly Census of Employment and Wages
ROW	Right-of-Way
SCC	Social Cost of Carbon
SEI	Social Equity Index (ODOT)
SRGP	Seismic Rehabilitation Grant Program (Oregon)
TAZ	Traffic Analysis Zone
USDOT	U.S. Department of Transportation
VMT	Vehicle Miles Traveled
VOC	Vehicle Operating Cost
VOT	Value of Time
VOTT	Value of Travel Time
VSL	Value of a Statistical Life
VTTS	Value of Travel Time Savings
WHO	World Health Organization

Executive Summary

Purpose and Scope

This framework establishes a standardized methodology for conducting Benefit–Cost Analysis (BCA) of transportation projects, programs, and policies in Oregon. It is intended to ensure that evaluations are transparent, consistent, and aligned with both federal guidance and state-specific priorities. The framework applies across a wide range of interventions—including capital investments, operational improvements, and policy measures.

Its primary objectives are to:

- Provide a clear basis for assessing whether proposed investments deliver net social benefits.
- Support defensible and comparable decision-making across projects competing for limited funding.
- Integrate considerations of efficiency, safety, environmental quality, and equity into economic appraisal.
- Establish consistent reporting standards to improve accountability and facilitate communication with stakeholders.

The framework is designed as a practical guide for analysts and decision-makers, balancing technical rigor with usability. While efficiency metrics such as Net Present Value (NPV) and Benefit–Cost Ratio (BCR) remain central, the framework also highlights complementary dimensions—equity impacts, risk analysis, and sensitivity testing—to ensure that project appraisals reflect broader policy goals and societal values.

This six-step sequence shown in Figure 1 represents the Oregon BCA framework's standard procedure for conducting benefit–cost analysis of transportation projects, programs, and policies. It provides a consistent structure for defining projects, establishing baselines, valuing benefits and costs, applying equity and sensitivity analyses, and reporting results in a transparent, comparable format.

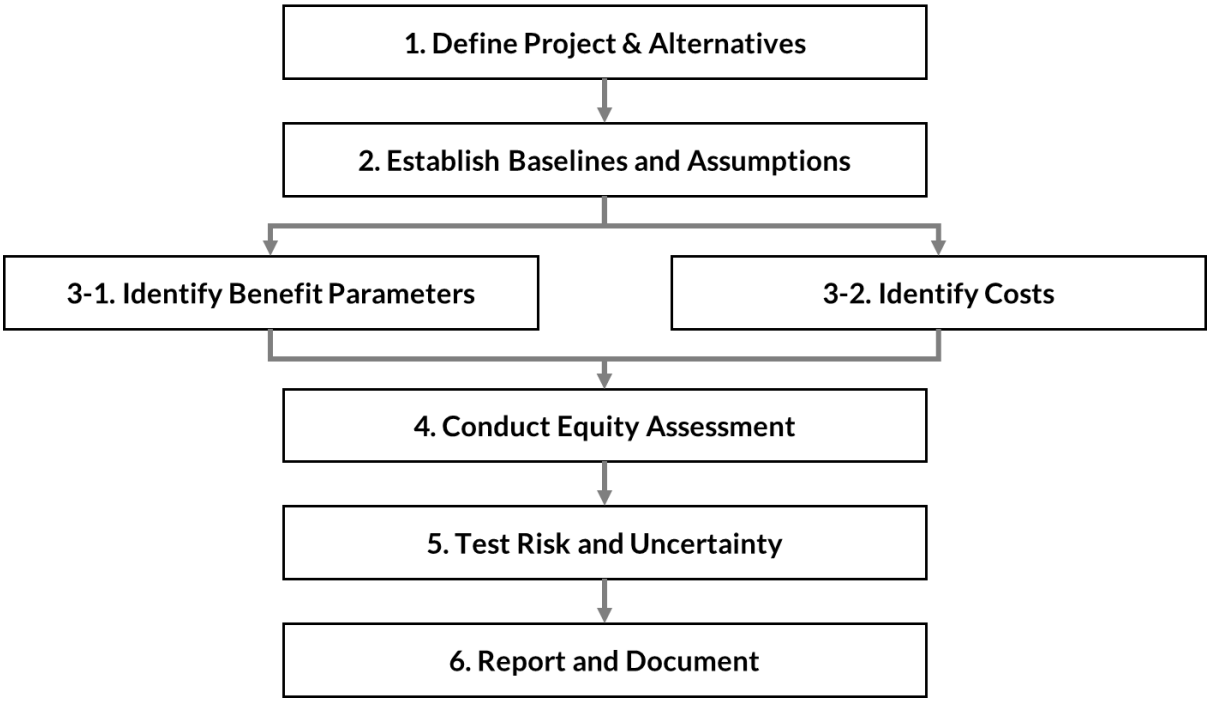


Figure 1 Benefit-Cost Analysis Flowchart

Baseline Parameters

The framework specifies common baseline assumptions that anchor all analyses in Oregon, ensuring consistency across projects and comparability of results.

- **Analysis Period** – Project lifespans are set according to intervention type: typically 20–30 years for most infrastructure and operational projects, with allowance for longer horizons (up to 50 years) where enduring effects justify it. This aligns with federal and international practice while leaving flexibility for Oregon-specific adjustments.
- **Base Year and Deflation** – All costs and benefits must be expressed in constant-dollar terms. Analysts are required to deflate first (using reliable and credible sources such as Bureau of Economic Analysis's (BEA) GDP deflator) before discounting, thereby removing inflationary distortions and preserving comparability.
- **Discount Rate** – Following OMB Circular A-94, a 7% real rate serves as the benchmark, with a lower rate (commonly 3%) applied in sensitivity tests to reflect societal time preference or intergenerational equity. The Oregon framework adopts a flexible range (3–7%), permitting lower rates (2–3%) when long-term public-good benefits are central. Sensitivity testing of discount rates is mandatory.

Together, these baseline conventions—analysis period, base year, deflation, discounting, and residual value—provide a transparent economic foundation for Oregon BCAs, following federal guidelines but adapted for state policy needs.

Benefit Parameters

The Oregon BCA framework establishes a consistent approach for identifying, quantifying, and monetizing the benefits of transportation investments. Benefits are monetized where feasible using standardized methodologies and Oregon-specific parameters. The framework also seeks to incorporate as many travel modes as possible, such as automobile, transit, walking, and cycling, so that multimodal outcomes are fully reflected in the analysis.

Main benefit categories include:

- **Travel Time Savings** — Reduced in-vehicle and out-of-vehicle time from congestion relief, operational improvements, and expanded multimodal options. Time is valued using mode- and purpose-specific assumptions.
- **Safety Benefits** — Lower crash incidence and severity resulting from infrastructure design, operational changes, and mode shifts. Monetization applies Oregon's crash rates and cost factors by severity level.
- **Vehicle Operating Cost (VOC) Savings** — Changes in automobile fuel/energy and non-fuel resource costs, together with relevant transit operating-cost changes that occur when policies shorten travel distances, reduce delays, or improve operating efficiency. Transit operating expenses must not be counted again under project operating costs.
- **Emission Reductions** — Avoided criteria-pollutant and greenhouse gas emissions from changes in motor-vehicle travel. Depending on the analysis, monetization uses emission rates and estimated damage costs per unit of emissions. Social-cost-of-carbon valuation reflects the Oregon framework's analytical assumptions by following the EPA's social cost of greenhouse gases.
- **Health Benefits** — Improved outcomes from increased active transportation (walking, cycling, and transit access). Benefits include mortality risk reduction and lower absenteeism associated with higher physical activity.

Additional benefits include:

- **Ecosystem Services and Wildlife Impact Benefits**— Transportation projects can affect ecosystem services through land conversion, restoration, or habitat protection. They can also affect wildlife mortality through crossings, fencing, or other mitigation. These impacts are monetized when the affected acreage, species, baseline condition, and expected change are reasonably documented.
- **Journey Quality Benefits** — Enhancement in comfort, convenience, and reliability, particularly for walking, cycling, and transit modes.
- **Noise Reduction Benefits** — Reduced noise exposure from mode shifts and traffic flow improvements, improving quality of life in affected areas.

Collectively, these categories ensure that BCA capture both direct user benefits and broader societal outcomes. However, the listed benefits are not exhaustive, as some potential impacts cannot yet be reliably monetized or quantified. The values applied to each indicator should be

updated regularly as new data become available, and they should also be tested through sensitivity analysis to reflect uncertainty.

Costs

The framework distinguishes cost categories clearly to ensure that only relevant, incremental costs are included and consistently reported.

- **Implementation Costs** — All up-front expenditures are expressed in constant dollars and phased according to realistic delivery schedules. Sunk costs and most financing charges are generally excluded, while contingencies must be transparently documented. For reporting consistency, the denominator of the BCR includes only discounted capital costs of an implementation scenario.
- **Operating Costs** — Both Base and Alternative streams are modeled, but only incremental net O&M is recorded on the benefit side to avoid double counting. This includes recurring expenses for programs and policies, which are discounted in real terms.
- **Residual Value** — Where assets extend beyond the analysis period, the unexpired service life is credited as a terminal benefit, typically using straight-line depreciation. This approach prevents undervaluation of long-lived infrastructure, while recognizing that IT-heavy or short-cycle projects often have negligible residuals.

These conventions form the complete cost treatment. They ensure comparability across projects and prevent misstatement of project economics in Oregon's BCA practice.

Equity Considerations

The framework integrates distributional considerations as a structured supplement to efficiency results, ensuring that transportation investments in Oregon are evaluated not only on net benefits but also on who gains and who bears costs.

- **Affected Groups and Geographies** — Analysts must identify relevant populations such as income tiers (using HUD's Area Median Income), racial and ethnic communities, children, older adults, people with disabilities, zero-vehicle households, and other groups (e.g., rural residents). Geographic units are defined at the census tract or block group level, cross-walked to transportation analysis zones, using GIS in order to delineate impact areas.

- **Methods** — Two pathways are recognized, but the primary approach is a welfare-weighted BCA, which applies income-elasticity weights to benefits and costs across income groups within the impact areas. This method leaves the core NPV and BCR unchanged, treating equity as a supplementary indicator rather than altering the core metrics. The second approach applies the Social Equity Index (SEI) to capture multiple dimensions of vulnerability—such as race/ethnicity, vehicle access, disability status, age, and poverty—rather than focusing solely on income. This method allows users to comprehensively determine which geographic regions experience greater positive

impacts from the policy benefits, from an equity perspective.

- **Application** — Both options are applied as companion assessments: analysts report unweighted results alongside equity-weighted or index-based outcomes, without altering the base NPV or BCR. This ensures decision-makers see both efficiency and distributional patterns in a transparent, comparable format.

Equity results are presented alongside core economic indicators, not embedded within them. This approach ensures that Oregon decision-makers can balance efficiency, fairness, and sustainability transparently.

Sensitivity Analysis

The framework requires structured sensitivity testing to account for risk and uncertainty in Oregon BCAs, ensuring that results remain credible under alternative assumptions.

- **Required Tests** — A discount-rate sensitivity test is compulsory. Other parameters—such as benefits, costs, or behavioral responses—are tested at the analyst's discretion, with attention to those most material to risk. For broader policy interventions, analysts are specifically instructed to test scenarios with lower-than-expected user response.
- **Techniques** — Analysts must apply at least deterministic one-at-a-time tests (e.g., varying key parameters individually) and are encouraged to use combined scenario analysis (optimistic, pessimistic, or delayed-opening cases). Probabilistic methods (e.g., Monte Carlo) are optional for complex projects but not mandatory.
- **Reporting** — Compare the base case with sensitivity results, using NPV and BCR where costs are adequately estimated and BCR is defined. Analysts should assess the economic robustness of a policy across plausible changes in assumptions and not infer from one metric alone.

Through these conventions, Oregon's framework ensures that BCAs not only capture expected efficiency but also demonstrate resilience to plausible variations in assumptions and future conditions.

1 Overview

1.1 Introduction

Benefit–Cost Analysis (BCA) evaluates whether the incremental social benefits of a transportation intervention exceed its incremental social costs. It compares the proposed scenario with a credible base case representing expected conditions without the intervention. Future benefits and costs are converted to present values to support the comparison.

- Compares outcomes with and without intervention
- Uses present-value dollars to make future effects comparable
- Helps determine whether a scenario creates net positive value

This framework provides Oregon with a consistent way to carry out BCAs across a wide range of transportation decisions or other changes with transportation outcomes. It can be applied to physical infrastructure (like roads and rail), operational improvements (like signal coordination or ITS), and policy or program interventions (like emissions rules or safety campaigns). It generally aligns with federal guidance, but reflects Oregon's specific needs and goals. Regardless of the type, the same core methods, assumptions, and reporting formats are used.

Because different policies affect people and systems in different ways, the framework includes multiple methods to value impacts. Some projects have clear and direct benefits, such as reducing travel time or vehicle costs. Others—especially policies and long-term programs—affect things like emissions, health outcomes, or land use over time, which are harder to measure or monetize. The framework allows for both types:

- Provides methods to quantify time, cost, safety, and reliability benefits
- Includes approaches for valuing emissions, health, environmental impacts, and other indirect effects
- Allows for qualitative descriptions when monetary valuation is not possible or reliable

BCA emphasizes economic efficiency, but, in its standard form, it does not readily incorporate who gains and who bears burdens within the affected communities. This BCA framework integrates an equity analysis so that differential benefits and costs across population groups or regions can be accounted for, and evaluated alongside core BCA outputs such as NPV and BCR.

In short, this framework is designed to ensure that all transportation decisions in Oregon—whether big or small, urban or rural—are evaluated in a clear, consistent, and balanced way. It ensures that economic efficiency, environmental sustainability, and social equity are all taken into account, helping policymakers make informed and defensible choices.

1.2 Analysis Guide

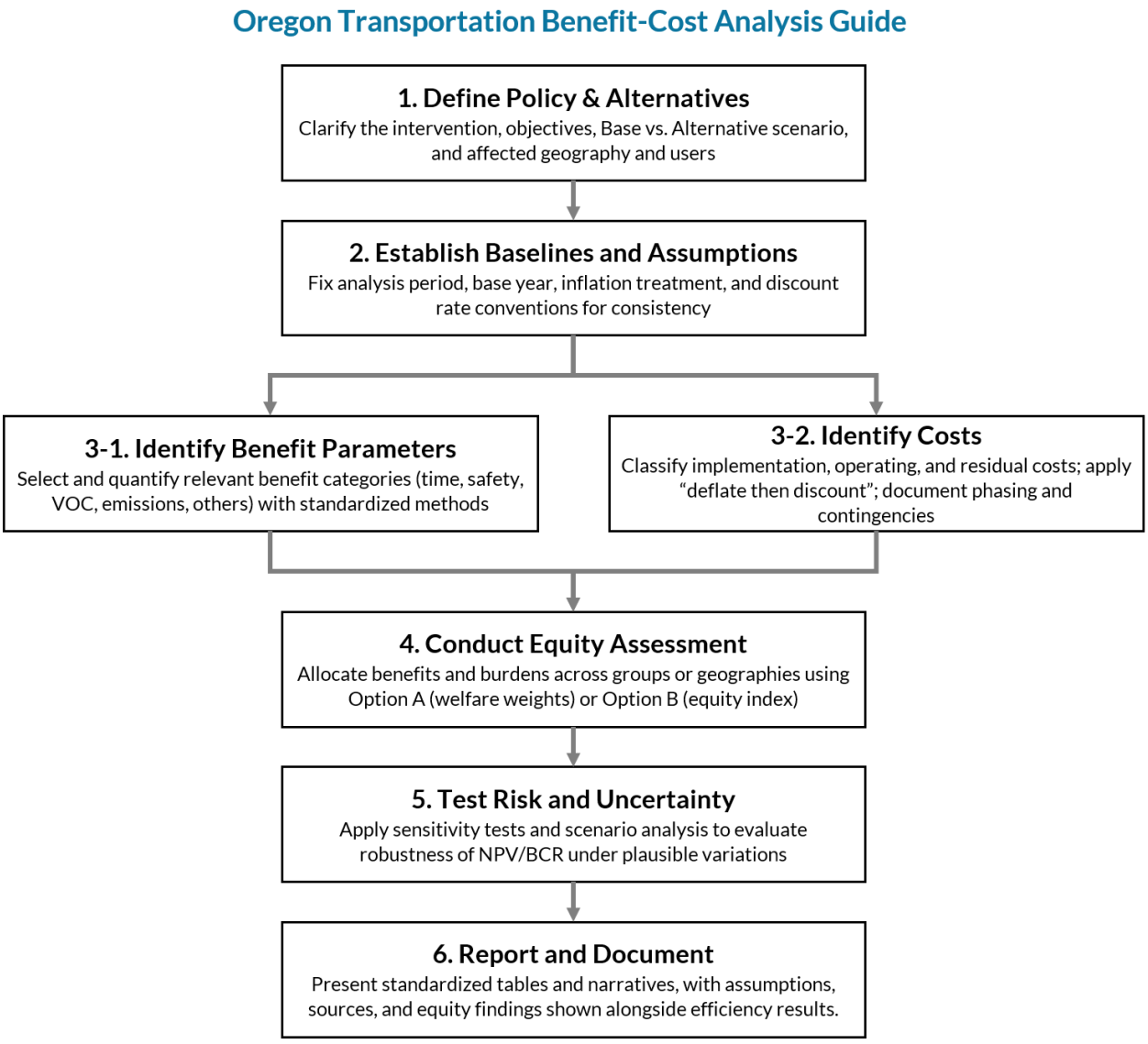


Figure 2 - Benefit-Cost Analysis Detailed Flowchart

The six-step sequence in Figure 2 above represents the Oregon framework's standard procedures for conducting benefit–cost analysis of transportation projects, programs, and policies. It provides a consistent structure for defining projects, establishing baselines, valuing benefits and costs, applying equity and sensitivity analyses, and reporting results in a transparent, comparable format. The following section provides guidance on how to carry out each of the steps in the BCA, with detailed instructions and methodologies in the corresponding sections.

Step 1. Define Project & Alternatives **→ See page 1 (Section 1)**

This step anchors the entire analysis by clarifying what intervention is under review, the counterfactual scenario, and the affected populations. Analysts will establish the Alternative option against a well-specified base case, describe the objectives, and identify the geographic and demographic scope of the appraisal.

- Classify the intervention. Specify whether the project is infrastructure, a program/policy, or an ITS/technology application. This classification determines which analytical pivots and risk considerations apply later in the process.
- State objectives. Describe the intended outcomes (e.g., congestion relief, safety improvements, emissions reduction). Objectives should be specific and clear, since they guide benefit category selection and sensitivity testing.
- Define Base vs. Alternative scenarios. The Alternative scenario captures the proposed intervention, while the Base case provides the counterfactual reference case.
- Identify affected users and geography. Map the study area (corridor, region, statewide) and the users impacted by the intervention. Analysts should note vulnerable or priority groups (e.g., low-income travelers, transit-dependent populations, etc.) for later equity modules if necessary.

Step 2. Establish Baselines and Assumptions **→ See page 8 (Section 2)**

Baselines provide the common economic ground on which all Oregon BCAs are built. Analysts can ensure that future benefits and costs are valued consistently across transportation interventions by setting the analysis period, discount rates, and base year with treatment of inflation. These conventions enable comparability with federal guidance while retaining flexibility for Oregon-specific policy needs.

- Define the analysis period. Standard practice is 20–30 years for most infrastructure and operational projects, aligning with asset life cycles. For programs with enduring or systemwide effects (e.g., environmental policies or resilience investments), longer horizons of up to 50 years may be used, but only when benefits clearly extend beyond normal ranges.
- Establish the base year. All costs and benefits must be expressed in constant-dollar terms referenced to a chosen base year. The base year should correspond to the latest year with available price indices from credible and reliable sources.
- Apply the “deflate then discount” principle. Monetary streams are first converted to constant-dollar terms using indices such as the GDP deflator. Only after deflation should analysts apply discounting using a real discount rate.
- Set up discounting assumptions. The framework specifies a flexible real discount rate range (3–7%) with a 7% federal benchmark and a 3% sensitivity rate to capture time

preference and intergenerational equity. Oregon permits lower rates (2–3%) in cases where projects generate long-lived public-good benefits (e.g., climate resilience). Sensitivity testing of discount rates is mandatory.

- Intergenerational and ethical considerations. For projects with horizons over 30–50 years (e.g., climate adaptation, major resilience measures), analysts may justify applying lower or declining discount rates. This reflects the ethical dimension of valuing future generations' welfare, subject to transparent documentation.

Step 3-1. Identify Benefit Parameters **→ See page 13 (Section 3)**

The credibility of a BCA rests on how clearly and consistently the analyst identifies and quantifies benefits. Oregon's framework sets out core categories—travel time, safety, vehicle operating costs, emissions, and others—that must be tested for inclusion. The guiding principle is to monetize benefits only when there is a clear causal mechanism, reliable data, and sufficient relevance to justify their role in decision-making.

- Benefit scope and inclusion. The framework treats benefits as a screened set of core categories—travel time, safety, vehicle operating costs, and emissions—tested for inclusion on the basis of clear causal pathways, reliable data, and significance; additional categories (e.g., journey quality, ecosystem services and wildlife impact, noise) are included.
- Computation and internal consistency. Detailed analyses may use traffic forecasts, changes in trips and travel times, VMT, speeds, and ridership. Where those outputs are unavailable, analysts may use annual changes in automobile vehicle-miles, transit passenger-miles, and walking or cycling person-miles with appropriate conversion parameters. The input basis must be documented.
- Parameters and documentation. Document the adopted sources, price year, geography, units, and conversion assumptions. Applicable sources may include recommended unit and values from USDOT guidance, Oregon Travel Study, crash and VMT records, VOC unit costs from AAA/ODOT/ATRI, EPA emission factors, NTD transit metrics, and the literature. Indicate whether a unit value is a direct estimate, an average-cost proxy, or an adopted value.

Step 3-2. Identify Costs **→ See page 47 (Section 4)**

A BCA is only as credible as its accounting of costs. Analysts shall systematically classify and phase all expenditures, ensuring they are stated in constant-dollar terms, aligned with realistic delivery schedules, and free of distortions from sunk or financial charges. Oregon's framework requires implementation costs, operating costs, and residual values so that the BCR and NPV

can truly represent the full economic resources consumed.

- Cost streams. Analysts should ensure that capital, operating & maintenance, and residual values are each accounted for, following the detailed procedures already laid out in the framework. Implementation costs must be phased to reflect realistic delivery schedules, operating costs handled as differentials before and after the intervention, and residuals credited for remaining service life where appropriate.
- Internal consistency. Always apply the "deflate then discount" rule: convert nominal costs to constant-dollar terms before applying the real discount factor. Never mix nominal flows with real rates. Analysts can also test capital cost uncertainty (±20% is common) in sensitivity analysis (see **Section 6** for more details) to reveal the robustness of results at early planning stages.
- Documentation and contingencies. Apply explicit contingencies (typically 10–30%) and document their rationale. Analysts ensure that allowances for design, minor items, or risk buffers are reasonable and updated as project development advances.

Step 4. Conduct Equity Assessment **→ See page 56 (Section 5)**

Equity analysis ensures that transportation projects in Oregon are judged not only by their overall efficiency but also by how benefits and costs are distributed across groups and places. The framework requires proportional, transparent, and comparable approaches, using one of several methodological pathways depending on data availability and project scale.

- Identify affected groups and geographies. Equity analysis must explicitly account for income groups, transit-dependent populations, people with disabilities, older adults, children, and residents near corridors or facilities. Analysts need to transparently define spatial boundaries such as census tracts, block groups, or other geographic overlays so that decision-makers can see who gains or bears burdens.
- Select appropriate method. Analysts will choose among the framework's two options, matching project size, data availability, and significance of equity concerns.
    - Option A (primary) – Standard Welfare Weights
      Benefits accruing to lower-income groups are weighed more heavily while those accruing to higher-income groups are weighed less within the impact areas, reflecting the diminishing marginal utility of income.
    - Option B (optional) – ODOT SEI Approach
      In this approach, we leverage ODOT's Social Equity Index (SEI) methodology to integrate income, age, disability, language, race, and vehicle access into a single composite measure of social vulnerability at the block-group level. Analysts overlay project impacts on these SEI scores to calculate how benefits and costs

vary across equity tiers, providing a quantified summary of how transportation outcomes align with socially vulnerable populations.

- Integrate findings into BCA reporting. Equity results are supplementary, not substitutes for base-case NPV/BCR. Analysts will report both unweighted and equity-weighted outcomes, highlighting whether projects are progressive, regressive, or neutral. Decision-makers can then weigh these results alongside efficiency metrics.

Step 5. Test Risk and Uncertainty **→ See page 67 (Section 6)**

Sensitivity analysis tests how fragile or robust your results are to plausible changes in assumptions. In addition to the required discount rate sensitivity tests, the Oregon BCA framework uses a hybrid approach: (i) deterministic, one-at-a-time tests on core drivers of uncertainty, and (ii) combined scenarios that bundle multiple uncertainties; probabilistic analysis is optional for complex cases. Results are summarized in standardized tables and interpreted with an explicit robustness judgment.

- Select the right set of sensitivities (3–5 high-leverage drivers). Identify parameters that materially move NPV/BCR or embody key uncertainties for the policy (e.g., discount rate, capital costs, aggregate benefits, a project-specific demand or safety driver). Use conservative, defensible ranges. Document the rationale for every bound.
- Stage 1 — Deterministic (one-at-a-time) tests. Vary each chosen driver individually to isolate its marginal influence on NPV/BCR and to rank risks. Discount-rate testing is mandatory; other parameters are at the analyst's discretion. Keep all other baselines fixed when you vary a rate or parameter, and record results in a compact table.
- Stage 2 — Combined scenario analysis. Build coherent scenarios by combining variations across parameters when interactions matter (e.g., demand + costs + horizon). This should typically include an Optimistic (or upper-bound), Pessimistic (or lower-bound), and, where relevant, a Delayed-Opening case (schedule slip).
- Reporting, interpretation, and robustness threshold. Present a standardized summary table with base-case, all individual tests, and each combined scenario, then provide a short narrative that identifies the dominant risks.

Step 6. Report and Document **→ See page 73 (Section 7)**

The reporting stage ensures that all prior analytical work is communicated in a clear, standardized format. Oregon's framework stresses comparability, transparency, and integration: results must be concise yet complete, with both tabular and narrative elements.

- Accompany tables with narrative interpretation. Analysts provide a short narrative that

explains the results, identifies the most critical risks, and discusses whether the project is robust under pessimistic scenarios.

- Integrate equity and sensitivity interpretations. Sensitivity and robustness results focus on efficiency; equity results should be presented alongside them as a separate but parallel layer. For example, analysts discuss whether pessimistic scenarios disproportionately burden low-income users or vulnerable groups.
- Document assumptions and provenance. All tables and narratives should cite parameter sources, modeling assumptions, and version dates.
- The appendix contains recommendations for updating the Oregon Transportation BCA framework based on data source update frequencies.

2 Analytical Foundations

2.1 Conceptual Basis

The analytical foundation of this framework is anchored in welfare economics, with a primary emphasis on quantifying changes in consumer surplus. This measures the difference between what transportation users would be willing to pay for a service and what they actually pay, serving as a key indicator of societal benefit. By translating project outcomes into monetized values, the BCA framework enables a consistent and transparent comparison against investment costs.

To evaluate the economic desirability of an investment, this framework utilizes two primary metrics: Net Present Value (NPV) and the Benefit-Cost Ratio (BCR).

- Net Present Value (NPV): The sum of the discounted stream of all benefits and costs over the analysis period. A positive NPV signifies that total benefits exceed total costs, confirming the project's economic viability.
- Benefit-Cost Ratio (BCR): The ratio of total discounted benefits to total discounted costs, providing a relative measure of efficiency. A BCR greater than one indicates that benefits surpass costs, suggesting a favorable investment.

A fundamental requirement for a rigorous evaluation is the use of incremental analysis. This approach maintains analytical integrity by explicitly comparing the outcomes of a project (“Alternative” scenario) against a clearly defined baseline (“Base” scenario), ensuring that benefits and costs are attributed only to the investment being studied. The baseline scenario must be an accurate and realistic forecast of future conditions without the proposed investment.

2.2 Baseline Parameters and Assumptions

BCA necessitates consistent application of clearly articulated baseline parameters and assumptions, forming the foundational structure upon which transportation investment evaluations are built. These baseline parameters directly influence how future costs and benefits are valued, projected, and compared across time and across various project types. While extensive review of existing federal, state, and international BCA practices provides critical insights, the precise values applicable to Oregon transportation policies must reflect specific local conditions, economic realities, policy priorities, and infrastructure characteristics. This document, therefore, guides practitioners and analysts to utilize a set of baseline parameters in assessing transportation investments by providing standard values.

Analysis period

The analysis period is the timeframe over which all project benefits and costs are projected and

discounted. Its selection is critical for determining a project's economic viability and ensuring comparability across different initiatives.

Common practice in the United States generally aligns with the useful life of typical infrastructure assets. Federal and state agencies often integrate the construction and initial ramp-up phases to ensure a full lifecycle evaluation.

- Standard Timeframe: 20 to 30 years.
- USDOT Recommendation (Major Projects): 30 years.
- Shorter-Term Projects (e.g., operational, technology): ~20 years or less.

In contrast, several international bodies use longer horizons to capture enduring societal impacts, though this can introduce greater forecasting uncertainty.

- United Kingdom: 60-year evaluation period.
- Australia: 50-year horizon.
- New Zealand: 40-year horizon.

The recommended analysis period for this framework is informed by a review of practices within Oregon state agencies, which vary based on the type of asset or program/policies being evaluated.

- Transportation (ODOT I-5/I-205 projects): 20 years for highway improvements.
- Buildings & Energy (Oregon Department of Energy (ODOE), Seismic Rehabilitation Grant Program (SRGP)): 30–50 years for systems and resilience.
- Environmental & Resource Management (Department of Environmental Quality (DEQ), Oregon Department of Forestry (ODF)): 50 years for long-term plans.
- Mosaic: 20 years as default sets but changeable from 20 to 50 years.

Based on this review, this framework recommends a flexible approach tailored to the nature of the investment.

- Standard Infrastructure & Operations: 20–30 years.
- Long-Duration Impact Programs: Up to 50 years.

Discounting and constant-dollar assumptions

This section defines the economic assumptions and analytical procedures required to convert future monetary values into present terms within the Oregon BCA framework. Specifically, it addresses the interrelated concepts of discounting and inflation treatment together, emphasizing their analytical inseparability.

The fundamental rationale underpinning the framework’s requirement to “deflate then discount” is rooted in welfare economics principles and established best practices. To ensure internal consistency and comparability of policy evaluations, all analyses will follow a clearly

prescribed sequence:

1. **Constant-dollar conversion**: First, convert all monetary streams (costs and benefits) to constant-dollar terms by removing the effects of inflation.
    - Select a recent, transparent base year (usually the study's current year).
    - Convert all nominal dollar amounts, benefit and cost streams, into base-year dollars using the GDP Implicit Price Deflator as the default; the CPI is acceptable when source data are CPI-based.
    - If some cost components are expected to outpace or lag general inflation (e.g., software licenses, specialized labor), apply a documented real escalation factor after deflation.
2. **Discounting:** Then, apply a real discount rate to translate these constant-dollar values into present values.
    - Apply a discount rate expressed in real terms (i.e., net of expected inflation) to the constant-dollar series.
    - Be cautious that mis-pairing nominal flows with a real rate—or vice-versa—can bias NPV/BCR results by double-counting or omitting inflation.

The analytical approach adopted in this framework is consistent with widely accepted national and international benefit-cost analysis practices:

- 2024 USDOT guide (OMB A-94): Recommends a standard 7% real discount rate.
- Sensitivity / Alternative Assumptions: Lower rates (e.g., 3%) used to reflect societal time preference or intergenerational equity.
- State Agencies: Usually adopt the rate between 3% and 7%
- International Practices: Vary widely, from the UK's declining rate schedule (starting at 3.5%) to fixed rates of 6-7% in Canada and Australia.

This framework's recommendation is informed by a review of practices across Oregon state agencies, which shows that rates are often calibrated to the nature of the investment.

- ODOT Infrastructure (INFRA Grants): 7% for primary analysis; 3% for carbon emissions.
- Environmental & Regulatory (DEQ, ODF): 3% for long-term societal impacts.
- Energy Efficiency (ODOE): 3%, consistent with federal energy program standards.
- Life-Safety (Seismic Retrofits): 2%, consistent with FEMA guidance emphasizing intergenerational equity.
- ODOT MOSAIC Tool: Allows a flexible range of 3–7% (4% as recommended by consultants).

Discount rate practice from the federal government agency: OMB Circular A-94

In addition to state DOTs and international practices, specifically, OMB Circular A-94 establishes the federal government's standard procedures for benefit-cost analysis of public investments. It provides a widely used benchmark that informs many transportation infrastructure BCAs, particularly those involving federal funding.

- Constant-dollar valuation: All benefits and costs must be expressed in real (constant-dollar) terms. Mixing nominal values with real discount rates—or vice versa—is explicitly prohibited.
- Real discount rate: For public investment BCAs, analysts must apply the base-case real discount rate published in Appendix D. As of the most recent update (2023), the required base-case real discount rate is 7 percent. This reflects the estimated average pre-tax rate of return on private capital in the U.S. economy.
- Sensitivity testing: OMB Circular A-94 encourages agencies to test alternative discount rates (e.g., 3%) to illustrate the sensitivity of conclusions to the assumed rate of time preference.
- Long-term flexibility: For projects with very long horizons (e.g., over 30–50 years), OMB Circular A-94 acknowledges that "special ethical and economic considerations" may justify the use of lower or declining real rates, subject to consultation with OMB.

This framework recommends a lower discount rate for certain intervention types based on the following analytical principles. This approach ensures the chosen rate aligns with the economic nature of the benefits being measured.

- Intergenerational equity: To ensure fairness to future generations by appropriately valuing legacy benefits (e.g., durable infrastructure, permanent safety improvements) and the avoidance of long-term societal costs.
- Valuation of public goods: To accurately assess projects delivering non-market benefits—such as enhanced public safety, system resilience, or foundational equity—which are not captured by private-sector return benchmarks.
- Prudent risk management: To act as a societal risk mitigation tool by placing a higher present value on avoiding uncertain but potentially severe future harms (e.g., from climate change, changes in travel behaviors, or systemic access barriers).

Accordingly, this framework adopts a flexible approach, recommending a rate calibrated to the type of project being evaluated.

- **Constant-dollar mandate**: All dollar amounts should be converted to a clearly stated base year using the GDP deflator unless compelling data reasons dictate utilizing specific CPI indicators.
- **Real discount-rate range:** The primary real discount rate should be between 3 % to 7 %. Policies delivering durable, public-good or intergenerational benefits (e.g., emissions abatement, ecosystem restoration, seismic resilience) may use lower rates (2-3 %).
- **Sensitivity analysis:** Analysts shall test at least one plausible alternative real discount rate, commonly 3% against the 7% benchmark; include additional lower or higher tests when relevant to project-specific uncertainty or required by a program.

3 Benefits

Standard benefit parameters in transportation BCAs encompass travel time savings, safety outcomes, vehicle operating costs, emission reductions, and broader quality-of-life impacts such as health and environmental benefits. These parameters form the analytical foundation of the Oregon BCA framework, ensuring that both direct user benefits and wider societal effects are systematically captured. While the framework emphasizes methodological consistency and Oregon-specific parameters, it also recognizes that transportation systems are inherently multimodal. For this reason, the framework aims to include as many travel modes as possible—automobile, transit, walking, and cycling—acknowledging the ways in which the externalities of one mode affect others. By structuring benefits across these categories, the framework provides a comprehensive basis for comparing diverse project types and assessing how investments improve safety, efficiency, and overall well-being across communities.

Table 1 summarizes the recommended monetized values for the core benefit categories. The "OR Custom" column indicates the extent to which Oregon-specific data are used. Additional benefits, including ecosystem services and wildlife impacts, and journey quality, require project-specific conditions and are addressed separately. The monetized values in the table generally represent statewide values unless they are geography specific. Detailed calculation methods and data sources are provided in the corresponding sections.

The framework accounts for geographic differences by providing parameters at several levels, including statewide, ODOT region, urban or rural area, and more localized areas where data are available. The relevant value depends on the geographic scope and characteristics of the affected transportation activity. Statewide values represent general defaults, while regional or local values provide greater specificity. Some parameters also vary by facility type, travel mode, trip purpose, or other analytical conditions.

Table 1 Recommended Monetized Values for Core Benefit Categories

Benefit Category	Parameter	Recommended value	Unit	OR Custom[1)]
Travel Time Savings	Local travel, personal	$20.49	Person-hour	O+
	Local travel, business	$37.22	Person-hour	O-
	Local travel, all purposes	$21.32	Person-hour	O+
	Intercity travel, personal	$28.68	Person-hour	O+
	Intercity travel, business	$37.22	Person-hour	O-
	Intercity travel, all purposes	$29.49	Person-hour	O+
Safety Benefits	PDO crash, all facilities	$27,670 (urban/rural)	Per crash	O+
	Moderate or minor injury crash, Interstate	$181,189 (urban) $205,784 (rural)	Per crash	O+
	Moderate or minor injury crash, Other state highway	$186,928 (urban) $213,163 (rural)	Per crash	O+

	Moderate or minor injury crash, off-system road	$189,285 (urban) $216,033 (rural)	Per crash	O+
	Fatal or serious-injury crash, Interstate	$4,065,265 (urban) $4,879,384 (rural)	Per crash	O+
	Fatal or serious-injury crash, Other state highway	$3,783,234 (urban) $5,236,944 (rural)	Per crash	O+
	Fatal or serious-injury crash, off-system road	$2,842,652 (urban) $4,460,641 (rural)	Per crash	O+
Vehicle Operating Cost (VOC) Savings	Fuel cost (gasoline)	$3.187	Per gallon	O-
	Fuel cost (diesel)	$3.287	Per gallon	O-
	Fuel cost (EV)	$0.473	Per mile	AD
	Non-fuel cost (gasoline)	$0.413	Per mile	AD
	Non-fuel cost (diesel)	$1.779	Per mile	AD
	Non-fuel cost (EV)	$0.847	Per mile	AD
	Transit operating cost	$2.792	Per passenger mile	O+
Emission Reductions	NOx	$0.0305	Per mile	O-
	PM 2.5	$0.0648	Per mile	O-
	SOx	$0.00046	Per mile	O-
	CO	$0.00418	Per mile	O-
	VOCs	$0.002	Per mile	O-
	CO2e (2024), 2.0%	$0.0764	Per mile	AD
	CO2e (2025), 2.0%	$0.0776	Per mile	AD
	CO2e (2030), 2.0%	$0.0844	Per mile	AD
	CO2e (2040), 2.0%	$0.0979	Per mile	AD
	CO2e (2050), 2.0%	$0.113	Per mile	AD
Health Benefits	Mortality reduction, waking trip (ages 20-74)	$7.34	Per person mile walked	O-
	Mortality reduction, cycling trip (ages 20-64)	$1.51	Per person mile cycled	O-
	Absenteeism reduction, walking	$0.004	Per person mile walked	O-
	Absenteeism reduction, cycling	$0.0037	Per person mile cycled	O-
Noise	Marginal external cost (automobile)	$0.001323	Per mile	AD
	Marginal external cost (Pickups and vans)	$0.001205	Per mile	AD

[1)] O+: Fully Oregon-derived values; O-: Partially adjusted values using Oregon-specific data; AD: Adopted values from other sources

3.1 Travel Time Savings

Travel time savings are a key benefit in transportation projects and programs that improve traffic flow, reduce congestion, enhance transit service, or provide more direct travel connections. These savings are calculated as the difference in total travel time for all users between the Base and Alternative scenarios. Travel time reductions may result from multimodal improvements—such as increased roadway capacity, expanded transit service, or reduced headways—and can affect both in-vehicle time and out-of-vehicle time (e.g., walking, waiting, or transferring).

The Value of Travel Time (VOTT) is a fundamental component in estimating the monetary benefits of reduced travel time. This value is based on the premise that saved travel time can be used for productive work, recreation, or other valuable activities. The same general VTTS calculation applies across travel modes, but the applicable activity measure, travel-time component, occupancy assumption, and VOTT may differ by mode and trip purpose. Where sufficiently detailed data are available, analysts should calculate travel-time changes separately for the affected modes and apply the corresponding values provided in this section. However, due to limitations in available data, practical applications rely on standardized assumptions, such as wage, income, and age, based on the trip purpose and travel mode.

Trip Purpose

Trip purposes are typically divided into two categories: business travel and personal travel.

Business Travel

This includes commercial drivers (whose travel time is part of their work) and business travelers who are unable to perform work while in transit. For these cases, the value of travel time is assumed to be 100% of the gross hourly compensation.

- Gross hourly compensation: Median wages for all occupations are obtained from the BLS National Occupational Employment and Wage Estimates (OEWS) multiplied with the ratio of average total compensation to wages and salaries.[1] Oregon-specific wage data can be obtained from Oregon's Quarterly Census of Employment and Wages (QCEW), which provides average wages by industry group each quarter.
- For specific vehicle operators (e.g., truck drivers, bus drivers, transit rail operators,

[1] The ratio of average total compensation to wages and salaries is calculated by dividing total compensation by average wage and salaries. This ratio can be obtained from the BLS report (https://www.bls.gov/news.release/pdf/ecec.pdf), which provides average values for total compensation, and wages and salaries by industry group.

locomotive engineers, airline pilots), the occupation-specific median wage is applied. To estimate total hourly compensation, multiply each median wage by the average total compensation ratio for transportation and material moving occupations. However, for truck drivers specifically, a weighted average of the median hourly wages for heavy truck drivers and light truck drivers is used, based on employment counts for each occupation.

Personal Travel

For personal travel, VOTT is typically estimated to be lower than VOTT of business travel, because personal travel time is not directly compensated by a wage, and individuals often have limited ability to convert saved time into additional income. These values may differ based on travel distance:

- Local travel: VOTT is typically estimated at 50% of the hourly median household income. The hourly income is calculated by dividing the annual household income by 2,080 hours per year (assuming a standard full-time work year).
- Intercity travel: Because intercity personal travel generally involves longer distances and higher time costs, VOTT is estimated at 70% of the hourly median household income.

Mode of Travel

Different transportation modes influence how VOTT is calculated.

- Walking, Cycling, Waiting, Standing, and Transfer Time: VOTT is valued at 100% of the traveler's hourly income, reflecting the higher perceived disutility of these out-of-vehicle time components.
- Air and High-Speed Rail Travel: these are high-cost modes typically used for fast, long-distance trips, so a distinct VOTT approach is applied:
  - Business Travel: VOTT is calculated as gross hourly compensation multiplied by a ratio, where the ratio is: (Median household income of business air travelers) / (U.S. Census Bureau median household income)
  - Personal Travel: VOTT is estimated as 70% of hourly median household income, adjusted by the same type of ratio: (Median household income of personal air travelers) / (U.S. Census Bureau median household income)

Since the VOTTs derived through the above process are calculated on a per-person basis, they are typically converted to vehicle hours by multiplying them by the average vehicle occupancy rate to estimate travel time benefits in a BCA. Vehicle occupancy rates can be localized using data specific to a region or corridor, or national-level data may be used if local data are

unavailable. In Oregon, the Oregon Travel Survey (OTS) is used to determine average occupancy rates.

For modes other than passenger cars, the USDOT recommends using localized occupancy factors where available. Additionally, occupancy rates should reflect time-of-day variations if the project specifically targets improvements in traffic flow or transit service during certain periods (e.g., peak hours).

Table 2 Vehicle Occupancy Rate by Vehicle Type

Vehicle Group	Vehicle Occupancy		Source
	Urban	Rural	
Passenger vehicles	1.4	1.4	2024 OTS
Passenger vehicles (weekday peak)*	1.42	1.43	2024 OTS
Passenger vehicles (weekday off-peak)*	1.37	1.38	2024 OTS
Passenger vehicles (weekend)**	1.81		2024 USDOT

* The weekday peak period value calculates trips starting between 6:00 AM – 8:59 AM and 4:00 PM – 6:59 PM, following the USDOT guide.
** The Oregon Travel Survey does not provide weighted estimates for weekend trips. The vehicle occupancy rate for weekend passenger vehicles is derived from the USDOT (2024) guide.

The recommended values provided are the current best estimates of VOTT, but they include inherent uncertainty. Therefore, users are encouraged to conduct sensitivity analysis using the plausible ranges available for each category. Using Oregon data, VOTT can be calculated as follows:

Personal Travel: Oregon's median household income reached $85,220 in 2024. Dividing this by 2,080 hours yields an hourly income of $40.97.

Business Travel: As of May 2024, the updated median hourly wage for all occupations is $25.67. To estimate total compensation, we apply the ratio of average total compensation to average wages from the Employer Costs for Employee Compensation (March 2024), which is 1.45. This results in a value of travel time estimate of $37.22 per hour for business travel.

- Truck Drivers: The 2024 BLS OEWS data report separate median hourly wages for Heavy and Tractor-Trailer Truck Drivers and Light Truck Drivers. The framework combines these values using employment counts for each occupation, resulting in an employment-weighted median wage of $26.97. Applying the compensation-to-wage ratio for the

transportation and material moving occupation group from the 2024 Employer Cost for Employee Compensation (1.45) we get a total median compensation of $39.11 per hour.
- Other Vehicle Operators: Median hourly wages are taken from 2024 BLS OEWS, and total compensation is estimated by applying the same 2024 compensation-to-wage ratio (1.45) for the transportation and material moving occupation group.
- In the Oregon QCEW, wage data for Subway and Streetcar Operators and Airline Pilots and Flight Engineers are not reported. These values are instead estimated using the wage ratio from national wage data.

Table 3 Recommended Hourly Values of Travel Time (2024$ per person-hour)

Category	Value of Time	Source
Local Travel		
Personal	$ 20.49	1
Business	$ 37.22	2
All Purposes*	$ 21.32	
Intercity Travel		
Personal	$ 28.68	1
Business	$ 37.22	2
All Purposes*	$ 29.49	

* Weighted averages were calculated using the distribution of travel by trip purpose: for local surface travel, 95.0% personal and 5.0% business; for intercity surface travel, 90.5% personal and 9.5% business (2024 OTS data).
Note: For air and high-speed rail travel, the values of travel time are not addressed. However, when a policy materially affects longer distance trips based on such modes, analysts can apply the values. Based on the 2024 USDOT guide, analysts can calculate those intercity-travel values for business travel by multiplying by 2.5. For personal travel, the value is calculated by multiplying by 1.9.
Sources: 1) Census ACS 1-year estimate (2024), 2) BLS OEWS (2024)

Table 3 provides statewide reference values. Where available, household income, wages and travel-purpose shares may be differentiated for urban and rural areas.

- Truck Drivers: $ 39.11
- Bus Drivers: $ 43.85
- Subway and Streetcar Operators: $59.13
- Locomotive Engineers: $53.82
- Airline Pilots and Engineers: $111.75
- Walking, Cycling, Waiting, Standing, and Transfer Time: $40.97

Calculation Methods

Step 1. Estimate the Change in Travel Demand and/or Travel Time

Users estimate the change in travel demand and travel time resulting from the transportation project or program. The specific inputs required to calculate the VTTS vary by travel mode, as outlined below:

a. Passenger Vehicle Travelers
    i. Change in vehicle trips
    ii. Travel time savings per trip
b. Transit Travelers
    i. Change in passenger trips
    ii. Travel Time savings for: 1) In-vehicle time (typically, the VOTT for all purposes is applied), 2) Out-of-vehicle (e.g., walking, waiting, transferring)
c. Bicycle and Pedestrian Travelers
    i. Change in biking/walking trips
    ii. Travel time savings per trip
d. All other changes

When a policy does not provide direct travel-time changes, annual differences in distance traveled may be converted to representative person-hours using mode-specific average trip lengths and durations. Automobile vehicle-miles are converted to person travel using an appropriate occupancy rate. An alternative approach based on the estimated travel-time change from a traffic or transit model is preferable when it is available.

Step 2. Calculate the Monetary Value of Travel Time Savings

Multiply the change in demand and/or change in travel time and the corresponding monetary value of time:

Notes:

- If detailed data are available, such as trip purpose, mode, travel distance, apply disaggregated VOTTs that reflect those characteristics. If such information is unavailable, the average VOTT for all purposes (Table 3) should be used.
    - Trip purpose: Business trip vs. personal trip
    - Mode: Auto, transit, walk, bike, micromobility
    - Distance: Local vs. intercity
- For transit user time savings, travel time savings benefits are calculated based on the consumer surplus theory. According to the “Rule of Half”, when a transportation improvement (such as reduced travel time) attracts new users, the average benefits to these new users is assumed to be half the pre-trip benefit experienced by existing users. This reflects that new users are only marginally induced by the improvement and value the benefit at a range between zero and the full benefit—so their average benefit lies at the midpoint.

Example 1 of Travel Time Savings: Improving Transit Service

- Project: Implementing traffic signal priority system
- Expected Impact/Changes:
  - Travel time savings: The project reduces average in-vehicle travel time by 10 minutes between a defined origin and destination
  - Change in ridership: The project increases annual ridership between two stations by 200,000 trips, from the current level of 2,000,000 trips per year.
- Calculation
  - Full time savings to existing riders
  - Half of the time savings to new riders

Table 4 Example 1 of Travel Time Savings

Input	First-Year Benefit Value	Units	Source
Ridership			
a. Current (Base)	2,000,000	Person-trips/year	User Input
b. Alternative	2,200,000	Person-trips/year	User Input
Average Travel Time			
c. Time reduction	10	Minutes/trip	User Input
Travel Time Benefits			
d. Existing Users	a x (c / 60) x $21.32*	2024$/year	Table 3
e. New Users	(b - a) x (c / 60) x 50% x $21.32*	2024$/year	Table 3
VTTS	$7,462,831	2024$/year	

* Although this example applies a uniform VOTT for all trip purposes, if data on trip distribution by purpose are available, users can calculate travel time benefits separately by trip purpose.

Example 2 of Travel Time Savings: Reducing Congestion

- Project: Adding a lane to reduce recurring congestion
- Expected Impact/Changes:
  - Travel time savings: The project reduces average travel time by 5 minutes per trip on the corridor
  - Affected daily vehicle trips: 50,000 vehicles, with an average vehicle occupancy of 1.4 persons/vehicle
- Calculation
  - Full time savings to existing riders (in this case, we assume that the project does not induce new demand)

Table 5 Example 2 of Travel Time Savings

Input	First-Year Benefit Value	Units	Source
Ridership			
a. Affected Person-Trips	50,000 x 1.4 = 70,000	Person-trips/year	User Input
Average Travel Time			
b. Time reduction	5	Minutes/trip	User Input
Travel Time Benefits			
c. Avoided Travel Time Benefits	a x AF x (b / 60) x $21.32	2024$/year	Table 3
Total Benefit	$45,398.886	2024$/year	

*AF: Annualization Factor; in this case, 365 days per year are assumed.

Special Issues for Travel Time Savings for Active Transportation (AT)

In practice, travel time savings benefits are not calculated uniformly for the VOTT in active transportation (AT) compared to other modes. The USDOT assigns personal time spent walking and bicycling a value equal to 100 percent of hourly median income, whereas Cal-B/C applies 50 percent of the average wage. USDOT's higher value reflects the additional disutility associated with time spent walking or cycling, including physical effort and exposure to potentially uncomfortable conditions. Cal-B/C applies its general personal-travel value to active transportation, treating the opportunity cost of time consistently across local personal trips while addressing facility comfort and other qualitative conditions separately through journey-quality benefits.

These approaches reflect different modeling assumptions, so analysts may select an appropriate VOTT based on policy conditions and supporting evidence.

3.2 Safety Benefits

Safety benefits are calculated by measuring the change in the number and severity of crashes between the Base and Alternative scenarios. This evaluation requires historical crash rates by crash type (fatalities, injuries, and property damage only) and the cost associated with each type of crash. Policies involving transit, walking, cycling, or mode shifts may apply those inputs when their safety effects are represented through changes in roadway VMT or an applicable roadway Crash Modification Factor (CMF) or Crash Reduction Factor (CRF). Safety effects that cannot be represented through these methods should be quantified only when supported by project-specific data and appropriate external inputs.

Historical Crash Rate by Crash Type

- Crash Types: Fatality, Injury, Property Damage Only (PDO) or KABCO level
- Unit: Crashes/Persons per Million Vehicle Miles (MVM) or Crashes per Year
- Geographic Area: Urban and Rural
- Time Period: Single year or multi-year average (e.g., 5-year average)

Oregon statewide crash rates are calculated using data from the Oregon Traffic Crash database. The crash rate is determined by dividing the number of crashes by Oregon's statewide VMT in 2024. The framework employs 22,100.39 and 15,298.5 million vehicle-miles in urban and rural areas from FHWA's highway statistics. The following values also can be calculated by selecting the appropriate geographic area that matches a particular project scope and calculating crash rates at a geographic scale smaller than the statewide level, such as city, county, and corridor. The monetized values for different crash types follow ODOT All Roads Transportation Safety (ARTS) Program.

Table 6 Vehicle-Injury Crashes and Crash Rates by Crash Type and Geography

Crash Type	Urban		Rural	
	Number of Crashes	Crash rate per Million VMT	Number of Crashes	Crash rate per Million VMT
Fatal Crash	221	0.01	268	0.018
Injury Crash	19,400	0.878	5897	0.385
PDO Crash	17,045	0.771	5583	0.365

Crash types can be categorized into three broad types, as shown above, or classified in more detail using the KABCO scale. The 2024 crash rates by KABCO classification for the state of Oregon are presented below. Most practical reports use the three broad categories shown in Table 6, while the KABCO classification (Table 7) is typically used when a more detailed classification is required. It is important to note that the three-type classification counts the number of crashes, whereas the KABCO classification counts the number of individuals involved.

Table 7 Vehicle-Injury Crashes and Crash Rates by the KABCO Severity Scale and Geography

Crash Severity	Urban		Rural	
	Number of Persons	Crash rate per Million VMT	Number of Persons	Crash rate per Million VMT
K—All Fatalities	237	0.011	299	0.02
A—Suspected Serious Injury	2,290	0.104	1,374	0.09
B—Suspected Minor Injury	14,166	0.641	4,884	0.319

C—Possible Injury	13,779	0.623	3,010	0.197
O—No Injury	46,980	2.126	9,951	0.65

ODOT provides the monetized value per crash by crash type and severity combined, highway type, and geography. Analysts select the value that matches the affected facility type, severity category, and urban or rural setting when assigning monetary values to expected crash reductions.

Table 8 Comprehensive Economic Value per Crash (2024)

Road Type*	Urban	Rural
PDO		
All facilities	$27,670	$27,670
Moderate (Injury B) and Minor (Injury C) Injury		
Interstate	$181,189	$205,784
Other State Highway	$186,928	$213,163
Off System	$189,285	$216,033
Fatal (K) and Serious (Injury A) Injury		
Interstate	$4,065,265	$4,879,384
Other State Highway	$3,783,234	$5,236,944
Off System	$2,842,652	$4,460,641

* Road type refers to the roadway facility group for applying ODOT crash-cost values. Interstate refers to state highways classified as Interstate Highways. Other State Highway refers to ODOT-jurisdiction state highways other than Interstates. Off System refers to local roads outside the state highway system, including roads generally under cities, counties, or other local agencies.

Calculation Methods

Safety benefits can be estimated using two primary methods: VMT-based Method and Crash Modification Factor Method. Method selection depends on how the intervention changes crash exposure rather than on the transportation mode alone. The VMT-based method applies when the intervention changes roadway VMT, including reductions in automobile travel resulting from shifts to other modes. The CMF method applies when an appropriate CMF or CRF is available for a specific roadway treatment, including supported pedestrian and bicycle infrastructure improvements.

VMT-based Method (Vehicle Miles Traveled)

This method estimates the change in roadway crash costs associated with a change in motor-vehicle VMT. Reduced VMT may result from lower travel demand, shorter vehicle trips, or shifts

from automobile travel to transit, walking, cycling, or another mode. The method captures the safety effect associated with reduced motor-vehicle exposure but does not, by itself, estimate changes in crash risk experienced by users of the receiving mode.

Step 1. Calculate the Reduced VMT

- Daily vehicle volume (estimated directly from travel demand model) x trip distance
- Number of travelers shifting from automobile travel ÷ applicable vehicle occupancy rate × average avoided vehicle-trip distance.

Step 2. Estimate Avoided Crashes

- Multiply the reduced VMT by the historical crash rate for each crash type

Step 3. Calculate Monetary Value of Avoided Crashes

- Multiply the estimated number of avoided crashes by the corresponding crash costs for each type

Example of VMT-based Safety Benefit Calculation

- Project: An employer commute trip reduction mandate
- Changes/Expected Impact: This project is expected to reduce daily traffic volumes along the interstate in the urban area. Assume an estimated reduction of 1,000 vehicles per day as a result of the project. To estimate the annual VMT reduction, multiply the reduced daily volume by an annualization factor (AF) and the length of the roadway segment.
- Calculation Method:
  - Multiply the annual VMT reduction by crash rates by crash type to estimate the number of crashes avoided per year, categorized by crash type.
  - Multiply the number of avoided crashes per type by the corresponding monetary value to calculate the annual safety benefit.

Table 9 VMT-Based Safety Benefits

Input	First-Year Benefit Value	Units	Source
Avoided Vehicle Miles			
a. Reduced Daily Volume	1,000	Trips/day	User Input
b. Trip Distance	6	Miles/Trip	User Input
c. Reduced Vehicle Miles	a x AF x b	Vehicle-Miles/Year	
Avoided Crashes			
d. Fatal Crash	(c x 0.01)/1,000,000	per year	Table 6, 1

e. Injury Crash	(c x 0.878)/1,000,000	per year	Table 6, 1
f. PDO Crash	(c x 0.771)/1,000,000	per year	Table 6, 1
Monetization			
g. Fatal Crash	d x $4,065,265	2024$/year	Table 8, 2
h. Injury Crash	e x $181,189	2024$/year	Table 8, 2
i. PDO Crash	f x $27,670	2024$/year	Table 8, 2
Value of Safety Benefits	g + h + i = $484,083	2024$/year	

*AF: Annualization Factor; in this case, 365 days per year are assumed
Sources: 1) Oregon Traffic Crash database (2024), 2) ODOT ARTS Program

Crash Modification Factor (CMF) Method

This method uses Crash Modification Factor (CMFs) to quantify the impact of specific safety improvements, particularly for roadway treatments, bike/pedestrian infrastructure, or intersection modifications. A CMF is a multiplier used to estimate the change in crash frequency resulting from the implementation of a specific roadway safety measure. It is closely related to the Crash Reduction Factor (CRF), which is calculated as CRF = 1 - CMF. For example, a countermeasure with a CMF of 0.65 indicates an expected 35% reduction in crashes, corresponding to a CRF of 0.35.

Step 1. Identify the appropriate CMF and the most recent crash data for the existing facility

- Identify the CMF that accurately corresponds to the specific safety improvement, facility type, facility context (urban/rural) crash type, and crash severity from ODOT's Crash Reduction Factor Manual or FHWA's CMF Clearinghouse[2].
- Obtain the most recent annual crash frequency by crash type and severity for the existing facility, or estimate the expected annual crashes under the base scenario

Step 2. Estimate monetary value of avoided crashes

- Calculate the Base annual crash cost: Baseline annual crash frequency x crash cost (by type and severity)
- Apply the selected CRF to estimate the reduction in crash costs under the Implementation scenarios:
  ODOT CRF x Base crash cost = Annual safety benefit
- If an external CMF is used because no applicable ODOT CRF is available, convert the CMF to a CRF before calculating benefits:
  (1 - CMF) x Eligible base crash cost = Annual safety benefit

[2] The online CMF Clearinghouse (https://cmfclearinghouse.fhwa.dot.gov/) provides CMF estimates for a wide range of roadway improvements and safety strategies based on published research.

Example of Safety Benefit Calculation using CRF

- Project: A system-wide retrofit program to improve right turn lane on single major road approach at high-risk unsignalized intersections in an urban interstate.
- Changes/Expected Impact: According to ODOT manual, the CRF for installing a right-turn lane on single major road approach at a 3- or 4-leg unsignalized intersection is 14% for all crash types and all severities.
- Calculation Method:
  - Identify right-turn-related crashes per year at the treatment intersection: For example, 2 fatal crashes, 5 nonfatal injury crashes, and 0 PDO crashes annually.
  - Monetized value of avoided crashes: Baseline annual crashes by type and severity x CRF x monetized value per crash

Table 10 Safety Benefits using CRF

Input	First-Year Benefit Value	Units	Source
Recent Crash Data for the Existing Facility			
a. Base Annual Fatal Crashes	2	per year	User Input
b. Base Annual Injury Crashes	5	per year	User Input
c. Base Annual PDO Crashes	0	per year	User Input
CMF			
d. CRF for H2 countermeasure	0.14	Reduction factor	1
Avoided Crashes			
e. Fatal Crash	a x d	per year	
f. Injury Crash	b x d	per year	
g. PDO Crash	c x d	per year	
Monetization			
h. Fatal Crash	e x $4,065,265	2024$/year	Table 8, 2
i. Injury Crash	f x $181,189	2024$/year	Table 8, 2
j. PDO Crash	g x $27,670	2024$/year	Table 8, 2
Value of Safety Benefits	h + i + j= $1,265,106	2024$/year	

Sources: 1) ODOT CRF Manual, 2) ODOT ARTS Program

Special Issues for Safety Benefits for Other Modes

Although usage of micromobility has increased and the severity of crashes involving these modes is high, we do not have sufficient data for addressing safety issues related to micromobility. Incorporating safety benefits for micromobility into the BCA framework presents several challenges. Crash and injury data remain inadequate and inconsistent; reporting systems often lack standardized code for e-scooters and e-bikes, leading to misclassification and

underreporting. Injury surveillance coding has been deficient, making it difficult to capture severity and crash context accurately. Micromobility safety effects may be quantified when project-specific or external evidence supports the expected change in crashes by severity and is compatible with the valuation approach used in this section. Otherwise, analysts describe the expected safety effect qualitatively and document its exclusion from the monetized results.

3.3 Vehicle Operating Cost (VOC) Savings

Vehicle Operating Cost (VOC) savings result from improvements in transportation infrastructure and systems that reduce travel distance, improve operating efficiency, or encourage shifts to more cost-effective modes of travel. VOC is commonly divided into fuel and non-fuel categories. Dividing VOC into fuel and non-fuel categories allows analysts to easily adjust for volatile fuel prices without re-estimating all VOC components.

Fuel Costs

Fuel costs refer to the out-of-pocket expenses incurred by consumers for gasoline, diesel, or other energy sources. The fuel cost value ($/gal) excludes federal, state, and local taxes (such as excise and sales taxes), since these are considered transfer payments and user fees used to fund transportation improvements. To exclude fuel taxes from the average fuel cost, tax data from ODOT were used.

Non-Fuel Costs

Non-fuel costs encompass all other mileage-dependent costs such as vehicle maintenance and repair, tire wear, and depreciation. Costs such as financing, insurance, licensing, registration, and taxes are excluded because they are either fixed (not dependent on vehicle mileage), represent transfer payments, or are accounted for under other benefit categories.

Fuel costs and non-fuel costs for Oregon are provided in Table 11. Analysts are advised to select a fuel cost appropriate for the project period because fuel prices can fluctuate significantly over the course of a year. For non-fuel costs, a fixed per-mile cost based on the U.S. average is applied, since variation across states and regions is considerably smaller than for fuel costs. The table provides recommended values for gasoline-powered automobiles, diesel-powered trucks, and electric vehicles. When another vehicle type materially affects the results, analysts may use a documented external value that is consistent with the vehicle class, energy source, analysis year, and cost components used in this section.

Table 11 Fuel and Non-Fuel Costs

Cost Category	Applicable Type	Recommended Value	Unit	Source

Fuel Cost	Gasoline	$3.19	2024$/gal	1,2
	Diesel	$3.29	2024$/gal	1,2
	Electric Vehicle	$0.473	2024$/mile	3
Non-Fuel Cost	Automobile	$0.413	2024$/mile	3
	Truck	$1.779	2024$/mile	4
	Electric Vehicle	$0.847	2024$/mile	3

Source: 1) AAA Fuel Prices (2025), 2) ODOT, Fuel Taxes (2025), 3) AAA Your Driving Costs (2025), 4) American Transportation Research Institute (2025)

Table 12 Fuel economy by vehicle and fuel type

Vehicle type	Gasoline	Diesel
Passenger vehicle	23.23	24.23
Motorcycle	28.75	32.16
Truck	19.10	18.48

Source: Oregon DMV (2024)

Table 12 provides Oregon-specific fleet fuel economy values derived from DMV vehicle registration data. The values reflect differences in fuel economy by vehicle and fuel type and may be used as default assumptions when project-specific or speed-based fuel consumption rates are unavailable. For gasoline- and diesel-powered vehicles, MPG is converted to gallons per mile and applied to VMT to estimate fuel consumption. Because the recommended electric-vehicle energy cost in Table 11 is expressed directly per mile, its fuel economy is not required for the standard VOC calculation.

VOC analysis covers mileage-dependent costs for light-duty vehicles and commercial vehicles, and it may also account for changes in transit operating resource costs. Walking and cycling do not have motor-vehicle operating costs within the scope of this section. Transit operating costs require separate treatment because transit passenger-miles measure user travel, whereas agency operating expenses depend on the level and composition of service provided.

For the transit operating costs, operating expenses per passenger-mile can be estimated using the 2024 FTA National Transit Database metrics for Bus, Bus Rapid Transit, Light Rail, Streetcar Rail, and Hybrid Rail. Several modes, such as Demand Response, Vanpool, and Aerial Tramway, are excluded from this surface-mode aggregation. The combined value equals the sum of operating expenses for the selected modes divided by their combined passenger-miles. The value is approximately $2.792 per passenger-mile (Table 1). This is an average-cost proxy and is not used as the marginal cost of accommodating an additional passenger-mile.

Calculation Methods

VOC benefits are divided into fuel costs and non-fuel costs. Non-fuel costs equal the change in VMT multiplied by the applicable non-fuel cost per mile. Fuel costs are calculated using the change in VMT, fuel consumption rate, and fuel price for the applicable vehicle type and operating condition. For public transit, the estimated VOC change is calculated as the change in passenger-miles multiplied by the average operating cost per passenger-mile.

Step 1. Calculate Reduced VMT

- Daily vehicle volume (estimated directly from travel demand model) x trip distance
- The number of travelers shifting from auto to other modes (e.g., avoided vehicle trips replaced by transit) x trip distance / average vehicle occupancy rate

Step 2. Calculate the Monetary Value of Fuel Costs

- Determine an appropriate vehicle speed for the project area by vehicle type, or alternatively it can be derived from traffic counts data that report average speeds by roadway.
- Obtain the fuel consumption rate (gallons per mile) as a function of speed and vehicle type from the U.S. Department of Energy. When scenario-specific or speed-based rates are unavailable, use the Oregon fleet fuel economy values in Table 12. Select the value corresponding to the applicable vehicle and fuel type and convert MPG to gallons per mile.
- Multiply the fuel consumption rate and VMT by the fuel price for each vehicle type.

Step 3. Calculate the Monetary Value of Non-Fuel Costs

- Multiply VMT for each vehicle type by the corresponding non-fuel cost per mile.

<u>Example 1 of Vehicle Operating Costs Savings</u>

- Project: Improve peak-hour transit frequency to shift commuter trips from private internal combustion engine (ICE) vehicles to public transit.
- Changes/Expected Impact: The project is expected to shift approximately 2,000 commuters from driving to transit.
- Calculation Method:
  - Estimate the reduction in VMT based on the number of new transit trips and trip distance.
  - Calculate the monetary value of avoided fuel costs: Avoided VMT (miles) x Fuel consumption rate (gal/mile) of passenger vehicles (gasoline) x Fuel cost ($/gal)
  - Calculate the monetary value of avoided non-fuel costs: Avoided VMT (miles) x Non-fuel cost ($/mile)

Table 13 Vehicle Operating Costs Savings

Input	First-Year Benefit Value	Units	Source
Avoided Vehicle Miles			
a. Increased Transit Trips	2,000	person-trips/day	User Input
b. Trip Distance	20	miles/trip	User Input
c. Reduced Vehicle Miles	a x AF x b/occupancy rate	vehicle-miles/year	
Monetization of Fuel Cost			
d. Fuel Cost	c x (1/19.1) x $3.58	2024$/year	1,2,3
Monetization of Non- Fuel Cost			
e. Non-Fuel Cost	c x $0.413	2024$/year	4
Value of VOC Savings	d + e = $5,014,744	2024$/year	

*AF: Assumes 292 weekdays per year.
*Occupancy rate: An average occupancy rate of 1.4 for passenger vehicles, based on the 2010 OHAS.
Sources: 1) AAA Fuel Prices (2025), 2) ODOT, Fuel Taxes (2025), 3) ODOT, Passenger Vehicle Fuel Economy, 4) AAA Your Driving Costs (2025)

3.4 Emission Reductions

Emission reduction benefits are primarily calculated using emission rates and the corresponding cost per pollutant. Evaluations cover a standard set of pollutants—carbon dioxide (CO2), nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), and sulfur dioxide (SOx). It is also important to distinguish between criteria air pollutants, which affect local air quality with immediate health impacts, and greenhouse gases, whose damages are global and long-term. Users apply the discount rates to criteria-pollutant emission benefits and apply a lower long-term real discount rate (e.g., 2-3%), to greenhouse gas emission benefits because their damages are global, cumulative, and intergenerational.

Emissions Rates

Emission rates represent the amount of each pollutant generated by transportation activity. Rates usually vary by vehicle type, fuel type, operating conditions, location, and year. Emission rate factors can be developed using models such as EPA's MOVES or CARB's EMFAC2021. Analysts can use locally applicable emission rates when reliable information is available. When such information is unavailable, the framework provides standardized rates to support consistent estimation of emission changes using EPA data.

Criteria-pollutant emission rates are based on EPA Tier 1 emissions estimates for Oregon and corresponding Oregon VMTs. Greenhouse-gas rates are expressed as carbon dioxide equivalent (CO2e) to account for the combined effects. Following EPA transportation emission factors, the emission rates are calculated using the applicable global warming potentials. The framework adopts US national emission factors. The applicable rate depends on the transportation activity being evaluated, and analysts should use the corresponding unit and mode shown in Table 14 and Table 15.

Table 14 Criteria-pollutant emission rates

Emission Type	Emission Rates		Unit[2]
	Urban	Rural	
NOx	2.4234	3.5008	g/vehicle-mile
PM2.5	0.1071	0.1548	g/vehicle-mile
SOx[1]	0.0136	0.0196	g/vehicle-mile
CO	16.7570	24.2074	g/vehicle-mile
VOCs	1.4179	2.0484	g/vehicle-mile

Sources: EPA Air Pollutant Emissions Trends (2024)
1) Sulfur dioxide (SO2) estimates are used for SOx emission rate.
2) The unit (g/vehicle-mile) is converted by dividing the short ton values by 1.1023 to express them in metric tons.

Table 15 Greenhouse gas emission rates (CO2e-based)

Vehicle Type[1]	Emission Rates	Unit[2]
Passenger Car	307.98	g CO2e/vehicle-mile
Light-Duty Truck	408.37	g CO2e/vehicle-mile

Sources: EPA GHG Emission Factors Hub (2025)
1) Passenger cars are personal-use automobiles, while light-duty trucks include SUVs, minivans, and other light passenger or cargo vehicles generally weighing 8,500 pounds or less (EPA, 2025).
2) CO2 equivalent value is calculated using 100-year global warming potentials of 28 and 265 for CH4 and N2O, respectively.

Emissions Costs

Emission costs are the monetary values assigned to pollutants to capture their broader social and environmental impacts. Criteria air pollutants are monetized using per-ton estimates that account for health effects such as respiratory illness and premature mortality, environmental damages such as acid rain and smog formation, and regional differences in exposure and impact.

For criteria air pollutants, the framework applies fixed damage-cost values per metric ton as a

practical approximation. Their damages depend strongly on local exposure, population, baseline health conditions, atmospheric formation, and project geography. Greenhouse gases are treated separately because their damages are cumulative, global, long-term, and sensitive to the year in which emissions occur. The framework therefore provides fixed values for criteria air pollutants and annual social cost of carbon dioxide values for greenhouse-gas changes expressed as carbon dioxide equivalent (CO2e).[3]

Table 16 Emissions Costs (2024$ per metric ton)

Emission Type	Recommended Monetized Values	Source
NOx	$21,316	1
PM2.5	$1,023,080	1
SOx	$57,185	1
CO	$422	2
VOCs	$2,392	2

Sources: 1) USDOT guide (2024), 2) ODOT Mosaic User Guide (2014)

Greenhouse gas emissions are monetized using EPA's social cost of carbon dioxide estimates. The SC-CO2 represents the net global damages associated with emitting one additional metric ton of CO2 in a given year. Each value includes the future stream of climate damages attributable to that emission, discounted back to the year in which the emission occurs. Because the marginal damages vary by emission year, analysts should apply the annual SC-CO2e value corresponding to the year of the estimated emissions change.

The framework adopts EPA's approach for applying annual values. Analysts use the 2.0 percent reference case for the primary analysis and the 2.5 percent and 1.5 percent cases for sensitivity analysis. For each analysis year, multiply the change in CO2 emissions by the SC-CO2 value for that emission year, then discount the resulting annual value to the BCA base year using the percentage associated with the selected series.

Table 17 Social Cost of Carbon, Carbon Dioxide (2024$ per metric ton of CO2e)

Emission year	2.5% sensitivity case	Reference case (2.0%)	1.5% sensitivity case
2024	$152	$248	$424
2025	$155	$252	$429

[3] Carbon dioxide equivalent (CO2e) expresses carbon dioxide and other greenhouse gases on a common basis using global warming potential factors. EPA's Greenhouse Gas Equivalencies Calculator combines multiple greenhouse gases as CO2e and directs users to treat emissions already reported as CO2e as a single equivalent quantity. The EPA social cost values adopted in this framework are formally estimated per metric ton of CO2. Applying those values to metric tons of CO2e is a simplifying convention when emissions estimates are reported in CO2e. Analysts should use the converted CO2e output produced by the applicable emissions model.

2030	$171	$274	$457
2040	$206	$318	$513
2050	$244	$367	$574

Source: EPA (2023)

Calculation Methods

Step 1. Calculate Reduced VMT

- Daily vehicle volume (estimated directly from travel demand model) x trip distance
- The number of travelers shifting from auto to other modes (e.g., avoided vehicle trips replaced by transit) x trip distance / average vehicle occupancy rate

Step 2. Calculate the Monetary Value of Emission Reductions

- Quantify the reduced emissions for each pollutant and vehicle type: Avoided VMT (miles) x Emission Rate (tons/mile)
- Multiply reduced pollutant emissions (tons) x Value per pollutant ($/tons); for CO2e, use the annual SCC value for the corresponding emission year
- Sum across pollutants and vehicle types.

Example of Emission Reductions

- Project: Increase public parking prices in a downtown area to reduce automobile commuting.
- Changes/Expected Impact: The policy reduces passenger-car travel by 1,500 vehicle trips per weekday, with an average affected trip distance of 8 miles. It estimates reductions in NOx and CO2e.
- Calculation Method:
  - Calculate the annual reduction in passenger-car VMT.
  - Multiply reduced VMT by the applicable emission rate for each pollutant.
  - Convert avoided emissions from grams to metric tons.
  - Monetize each avoided pollutant using the corresponding value.

Table 18 Emission Reductions Benefits

Input	First-Year Benefit Value	Units	Source
Reduced Vehicle Travel			
a. Reduced Vehicle Trips	1,500	vehicle-trips/day	User Input
b. Average Trip Distance	8	miles/trip	User Input
c. Annual Reduced Miles	a x b x AF	vehicle-miles/year	
Reduced Emissions			
d. NOx	c x 1.4322/1,000,000	metric tons/year	Table 14
e. CO2e	c x 307.98/1,000,000	metric tons/year	Table 15
Monetized Benefits			

f. NOx Reduction	d x $21,316	2024$/year	Table 16
g. CO2e Reduction*	e x $252	2024$/year	Table 17
Value of Emission Reduction Benefits	f + g = $338,694	2024$/year	

*AF represents 261 weekdays per year.
*The CO2e reduction benefits assume 2025 is the first year of policy benefits.

When an intervention affects emissions from more than one mode, analysts calculate and report the benefit for each mode separately when supporting data are available. The benefits are calculated based on the net change in emissions across the affected modes. For shifts to walking or cycling, they report the avoided emissions under the mode whose travel decreases. Additional transit passengers produce no emission change unless transit service or vehicle activity changes. The total emission reduction benefit equals the sum of the mode-specific benefits. Analysts should report effects that cannot be separated by mode as multimodal or unallocated and document the limitation.

3.5 Health Benefits

Health Benefits refer to the positive health outcomes associated with projects that improve walking and biking. These benefits primarily include reduced mortality risks and reduced absenteeism.

Mortality Reduction Benefits

The mortality reduction benefits from additional active transportation trips (walking and cycling) resulting from mode shift require four inputs: 1) baseline annual mortality risk (for specific age groups), 2) Annual risk reduction per daily mile walked or cycled, 3) Average walking/cycling trip distance, and 4) Value of a Statistical Life (VSL). Table 19 presents the estimated mortality reduction benefit values. The USDOT guide (2024) adopts these values based on findings from several existing studies.

Table 19 Mortality Reduction Benefits Values

Mode	Applicable Age Range	Recommended Value per Induced Trip (2024$)
Walking	Ages 20-74	$8.24
Cycling	Ages 20-64	$7.34

Calculation Method:

Step 1. Calculate additional trips meeting criteria

From the additional walking or cycling trips generated by the project, identify the number that fall within the applicable age range and originate from non-active transportation non-AT modes.

- New trips (walking) = Number of new walking trips × % in age range (20–74) × % from non-AT modes
- New trips (cycling) = Number of new cycling trips × % in age range (20–64) × % from non-AT modes

If analysts do not have information on the proportion of expected active transportation users, Oregon average percentage falling into the above age ranges may be applied: 70% for walking and 58.5% for cycling. If specific or local data are unavailable, analysts may assume that 89% of induced walking or cycling trips originate from non-active transportation modes, consistent with the USDOT guidance.

Step 2. Monetize mortality reduction benefits

- Multiply the recommended value per additional trip by the number of additional trips meeting the criteria.

Absenteeism Reduction Benefits

Increased active transportation may reduce employee absenteeism through additional physical activity. This effect can be estimated from existing studies. Based on WHO (2003), at least 30 minutes of physical activity per day reduces annual sick days by about 6%. Because absenteeism is an employee-level outcome, the calculation should be based on the number of employed travelers receiving additional active travels.

Calculation Method:

Step 1. Calculate additional walking/cycling commuting trips

- Number of additional walking/cycling trips generated by the policy x % of commuting trips.

Step 2. Estimate reduced sick days

- Average employee absence x percentage attributable to short-term sick leave x 6% reduction from being active at least 30 minutes per day.

Step 3. Monetize absenteeism reduction benefits

- New walking/cycling business trips x reduced sick days x median daily wage (calculated as $25.67 x 8 hours)

<u>Example 1 of Health benefits</u>

- Project: Construction of designated cycling lanes to encourage mode shift to cycling
- Expected Impact: The project is expected to affect 240 daily trips in the project area. Because it expects an increase in daily trips without mode specification, the calculation requires applying mode shares.
- Calculation Method:

- Mortality Reduction Benefits
  - Calculate eligible new trips: 240 x 58.5% (in age range 20-64) x 89% (from non-AT modes) x bike mode share (1.6%)
  - Monetize mortality reduction benefits by multiplying the number of eligible trips by the recommended value per trip.
- Absenteeism Reduction Benefits
  - Estimate cycling trips: 240 x 1.7%
  - Estimate reduced sick days per employee: 3.5 (average annual absences) x 0.66 (% of short-term leave) x 0.06 (% reduction from activity)
  - Monetize absenteeism reduction benefits by multiplying the number of additional personal trips by the estimated reduced sick days and the median daily wage.

Table 20 Health Benefits

Input	First-Year Benefit Value	Units	Source
Affected Trips			
a. Affected daily trips	240	Trips/day	User Input
Induced Cycling Trips			
b. Cycling trips for mortality reduction benefit	a x 58.5% x 89% x 1.6%	Trips/day	1
c. Commuting cycling trips for absenteeism benefit	a x 1.7%	Trips/day	1
Monetization			
d. Mortality Reduction Benefit	b x AF1 x $7.34	2024$/year	Table 19, 1
e. Absenteeism Benefits	c x AF2 x reduced sick days (0.1386/year) x $25.67 x 8	2024$/year	1,2,3
Value of Health Benefits	d + e = $35,666	2024$/year	

*AF: Annualization Factor; in this case, AF1 represents 365 days per year, and AF2 represents 261 weekdays per year, since absenteeism benefits apply only to commuters.
Sources: 1) OTS (2024), 2) Maestas et al. (2018), 3) WHO (2003)

3.6 Additional Benefits

3.6.1 Ecosystem Services and Wildlife Impacts

Ecosystem services and wildlife impacts refer to the direct and indirect benefits that transportation policies may create or preserve through changes in land cover, ecological function, wildlife movement, and the interaction between transportation infrastructure and natural systems. These benefits may include ecosystem services such as clean air, water quality, flood protection, climate stability, and habitat functions, as well as wildlife preservation benefits

associated with reducing crashes between vehicles and sorts of animals.

These benefits are applied when a policy affects natural land cover, restores ecological function, reduces conflicts between vehicles and wildlife, or changes habitat access and movement patterns. Analysts use different methods for the two analyses. Land-cover changes are evaluated using ecosystem service values where applicable. Wildlife impact benefits are evaluated separately based on the expected value of avoided animal mortality. Benefits related to human injuries, fatalities, or property damage should not be included in this category because they are addressed under the safety benefits.

Ecosystem Services Calculation Methods

Step 1. Identify the land cover category (or categories) affected by the project, measured in acres.

Step 2. Estimate the value of the lost ecosystem services by multiplying the area of each land cover type by the pre-calculated annual benefit value (in USD/acre/year) associated with that category. These values are available for a range of land cover types, including forest, urban green open space, rural green open space, riparian areas, coastal wetlands, inland wetlands, coral reefs, shellfish reefs, beaches, and dunes. When using FEMA's BCA values (see Table 21), users should confirm that the land aligns with FEMA's definitions for each land cover type.

Step 3. Calculate the total disbenefit by multiplying the annual value of lost ecosystem services by the number of years in the project's analysis period. This reflects the ongoing opportunity cost of the ecosystem services no longer provided due to the project.

Table 21 Summary of Ecosystem Service Values by Land Cover Category

Land Cover Category	Value (2024$/acre/year)
Forest	$14,330
Urban Green Open Space	$17,691
Rural Green Open Space	$12,103
Riparian	$42,345
Coastal Wetland	$10,194
Inland Wetland	$9,301
Coral Reefs	$8,105
Shellfish Reefs	$3,138
Beaches and Dunes	$342,238

Sources: FEMA, *Ecosystem Service Value Updates* (June 2022)

* The 2021 values reported in the FEMA document were adjusted to

2024 dollars using the GDP deflator.

Wildlife Impacts Calculation Methods

Step 1. Identify the wildlife species or species group affected by the policy and estimate the baseline annual animal mortality associated with the existing facility.

Step 2. Estimate the reduction in animal mortality under the implementation. This may be based on specific monitoring data, agency estimates, or an applicable reduction factor for the wildlife treatment, such as ODOT records of animals killed, or project-specific studies. It is expressed as avoided animal deaths per year. Where unavailable, analysts may use a screening value of 65 animals struck and killed per year over a 22-mile corridor, according to the Northeast Oregon Highway 82 Wildlife Crossing Project.

Step 3. Calculate the total wildlife benefit by multiplying the expected number of avoided animal deaths by the preservation value per animal for the affected species over the analysis period. If no Oregon-specific valuation is available, analysts may use passive values for selected animals from the Nevada DOT report. In an application, analysts should identify which animals are affected and how the policy context is reasonably comparable. The benefits represent the preservation value of wildlife no longer lost due to animal-related crash treatments.

Table 22 Passive Values for Selected Animals

Species	Value (2024$/animal)
White-tailed deer	6,041
Elk	33,031
Wolf	48,018
Grizzly bear	5,041,747

Sources: NDOT, *Cost–benefit analyses of mitigation measures along highways for large animal species* (September 2022)
* The 2020 values reported in the NDOT document were adjusted to 2024 dollars using the GDP deflator.

Example of Ecosystem services Calculation

- Project: Conversion of a roadway in a city center into a one-acre park
- Changes/ Expected Impact:
  - Land use shifts from paved roadway (no existing ecosystem service) to Urban Green Space (ecosystem service land)
  - Net gain of 1 acre of Urban Green Open Space

- Calculation:
  - Estimate changes in land acreage which generates ecosystem benefit
  - Identify the ecosystem service value for the land cover category—Urban Green Space: $17,691 per acre per year (2024$)
  - Multiply the change in acreage by the per-acre ecosystem value

Table 23 Ecosystem Services Benefits

Input	First-Year Benefit Value	Units	Source
Land Cover Change			
a. Roadway	- 1.0	acres	User Input
b. Urban Green Open Space	1.0	acres	User Input
Ecosystem benefits			
c. Annual Benefit	$17,691 x b	2024$/year	Table 21, 1
Value of Ecosystem Benefits	$17,691	2024$/year	

Sources: 1) FEMA, *Ecosystem Service Value Updates* (June 2022)

Example of Wildlife Impacts Calculation

- Project: A wildlife crossing and fencing project is implemented along a rural highway segment.
- Changes/ Expected Impact:
  - This project is expected to reduce elk mortality by 80 percent.
  - The baseline condition includes an average of 2 documented elk deaths per year at the facility.
- Calculation:
  - Estimate avoided elk mortality by multiplying baseline mortality by the expected reduction factor
  - Identify the preservation value per elk—Elk: $33,031 per animal per year (2024$)
  - Multiply avoided elk mortality by the preservation value per elk

Table 24 Wildlife Impacts Benefits

Input	First-Year Benefit Value	Units	Source
Baseline Animal Mortality			
a. Elk mortality	2.0	Animal/year	User Input

Expected Mortality Reduction			
b. Mortality reduction factor	0.8	Reduction factor	User Input
c. Avoided mortality	a x b	Animal/year	Calculated
Wildlife Preservation Value			
d. Preservation value per elk	$33,031	2024$/animal	Table 22, 1
Value of Wildlife Preservation Benefits			
e. Annual wildlife impact benefits	c x d	2024$/year	Calculated
Value of Wildlife Impacts Benefits	$52,850	2024$/year	

Sources: 1) NDOT, *Cost–benefit analyses of mitigation measures along highways for large animal species* (September 2022)

3.6.2 Journey Quality Benefits

Journey quality benefits capture the improvements in comfort, safety, and overall experience of travelers resulting from enhancements to pedestrian, bicycling, and transit facilities. These benefits are distinct from travel time savings, as they reflect user preferences for better amenities, safer conditions, and improved reliability. Although difficult to measure directly, recent studies using revealed and stated preference methods have developed monetization values that allow such qualitative improvements to be incorporated into BCA.

Pedestrian Journey Quality

Pedestrian journey quality benefits are typically measured in cents per mile of walking, depending on the amenities provided along a corridor. These amenities include street lighting, curb-level sidewalks, and pavement evenness.

Bike Journey Quality

For cyclists, journey quality is closely tied to both perceived safety and route amenities. These benefits are calculated as a function of distance traveled by trail class or based on specific elements such as segregated cycle tracks and lanes, wider lanes, and end-of-trip facilities. The underlying principle is that cyclists are willing to spend more time or travel farther if the route offers a higher level of comfort or safety, which can be monetized through their value of time.

Transit Journey Quality

Journey quality for transit users is linked to improvements in facilities, vehicles, and system reliability. Based on various states and revealed preference studies, components can be grouped as follows:

- Facility and Vehicle Amenities — Projects that improve station design, cleanliness, or vehicle quality can apply established monetization values for each attribute.
- Reduced Crowding — Standing during transit trips imposes disutility compared to seated travel. This can be quantified by applying the net difference between the value of personal travel time and standing travel time.
- Reduced Passenger Transfers — Transfers impose an additional penalty beyond actual wait or travel time, often termed the "transfer penalty." Projects that eliminate or reduce transfers may count these avoided penalties as benefits.

The monetized values provide standardized estimates for journey quality effects—changes in comfort, convenience, perceived safety, and overall user experience. The appropriate value is not unique because journey quality depends on what exactly changes and where and to whom the change applies. Accordingly, the values present multiple case-specific values that vary by mode, context, and attribute definition, and they implicitly reflect different incidence and attribute types. The USDOT guidance (2024) recommends a set of monetized values by modes, attributes, and facility type referencing the literature. In the estimation, analysts may use the consolidated ranges below: identify the policy's relevant journey quality change(s), match each change to the corresponding incidence basis (person-miles, uses, user trips, boardings, passenger-hours), and then choose the case-specific value(s) that best align with the target facility classification and service context. For case-specific monetized values, analysts can utilize their monetized values in Appendix D – Monetized Values for Journey Quality Benefits. When multiple plausible cases apply, analysts should document the selected case assumptions and reflect uncertainty by reporting a reasonable range anchored in the corresponding case-specific entries in Table 25.

Table 25 Monetized journey quality values by mode/attribute/facility

Group	Unit	Range (2024$)
Pedestrian—corridor comfort	$/person-mile walked	$0.0011–$1.23
Pedestrian—crossing quality	$/use	$0.22–$0.56
Bicycle—facility comfort/safety	$/cycling mile	$0.33–$2.18
Transit—stop/station amenities (Bus stop)	$/user trip	$0.04–$0.72
Transit—stop/station amenities (LRT/Streetcar stop)	$/user trip	$0.03–$0.72
Transit—stop/station amenities (Rail station)	$/user trip	$0.04–$0.99
Transit—vehicle amenities (Bus)	$/user trip	$0.05–$0.44
Transit—vehicle amenities (LRT/Streetcar)	$/user trip	$0.05–$0.44
Transit—vehicle amenities (Rail)	$/user trip	$0.03–$0.72
Transit—mode boarding quality	$/boarding	$0.36–$5.77
Transit—mode ride quality	$/passenger-hour	$0.43–$4.32

Example 1 of Journey Quality Benefits: Sidewalk Improvement

- Project: A project to limit traffic speed to improve pedestrian safety and journey quality
- Changes/Expected Impact: This project is expected to reduce operating speed by 5 mph along two blocks, each approximately 0.1 miles in length
- Calculation:
  - Identify the journey quality values of reducing traffic speed by 1mph: $0.1 per person-mile walked (2024$)
  - Multiply the value by the total annual pedestrian miles: (Speed Reduction) x (Annualization Factor) x (Daily Average Pedestrian Trips) x (Block Length)

Table 26 Example 1 of Journey Quality Benefits

Input	First-Year Benefit Value	Units	Source
Improvement Type			
a. Reduced Traffic Speed	5	mph	User Input
Annual Mile Walked			
b. Block A	AF x 600 x 0.1	mile/year	User Input
c. Block B	AF x 800 x 0.1	mile/year	User Input
Monetization			
d. Block A	a x b x $0.1	2024$/year	1
e. Block B	a x c x $0.1	2024$/year	1
Value of Journey Quality Benefits	d + e = $26,184.2	2024$/year	

*AF: Annualization Factor; in this case, 365 days per year are assumed
Sources: 1) USDOT (2024).

Example 2 of Journey Quality Benefits: Sidewalk Improvement

- Project: A project to install bike sharrows along 1.2 miles and upgrade 10 bus stops with PA systems and weather protection.
- Changes/Expected Impact: This project is expected to induce 50 new cycling trips per day. The upgraded bus stops will serve a total of 1,200 user trips per day across all 10 stops.
- Calculation:
  - Cycling facility benefit:
    - Existing user benefits = Number of existing cyclists (200) x Value per mile ($0.33) x Distance (1.2 miles)
    - New user benefits = ½ x Number of new cyclists (50) x Value per mile ($0.33) x

Distance (1.2 miles)

- Transit amenity benefit:
  - Amenity value per user trip = PA system ($0.36) + Weather protection ($0.29) = $0.65
  - Transit benefit = $0.65 x Daily transit trips (1,200) x AF (365 days/year)

Table 27 Example 2 of Journey Quality Benefits

Input	First-Year Benefit Value	Units	Source
Improvement Type			
a. Bike Sharrows	1.2	miles	User Input
Increased Trips			
b. New Cycling Trips	50	trips/day	User Input
c. New Bus Trips	1200	trips/day	User Input
Monetization			
d. Existing Users	200 (existing cyclists) x $0.33 x a x AF	2024$/year	1
e. New Users	½ x a x b x $0.33 x AF	2024$/year	1
f. Transit amenity benefit	$0.65 x c x AF	2024$/year	1
Value of Journey Quality Benefits	d + e + f= $315,108.3	2024$/year	

*AF: Annualization Factor; in this case, 365 days per year are assumed
Sources: 1) USDOT (2024).

Special Issues for Journey Quality Benefits for Other modes

While the monetized values of journey quality benefits for walking, biking, and transit have been examined in numerous studies, evidence on journey quality for micromobility modes such as electric scooters is still limited within the BCA framework. Factors such as equipment reliability, smooth ride quality, and intuitive design can enhance the quality of service and user experience in micromobility. Future studies that monetize these factors, alongside traditional journey quality benefits, will provide a more comprehensive assessment of the benefits of transportation environments where micromobility plays an important role.

3.6.3 Noise Pollution

Noise pollution refers to the adverse effects of noise generated by transportation activities on both humans and animals. Despite its significant impacts, few BCA frameworks provide clear methods for measuring noise pollution. Two approaches are commonly used: (1) the exposure-

based method and (2) the VMT-based method.

Exposure-based method

The exposure-based method estimates annual noise damages by combining modeled roadway noise levels, the number of affected housing units, and the estimated effect of noise on housing values. The approach is adapted from FHWA's roadway-noise cost methodology and consists of three primary components: estimating noise levels above a threshold, identifying affected housing units, and monetizing the corresponding property-value effect.

Step 1. Estimate noise levels by facilities. Noise estimates account for traffic volume, average speed, vehicle composition, distance from the roadway, and other relevant site conditions.

Step 2. Identify housing units exposed to noise above 55 dBA. Housing units are assigned to the applicable modeled noise level or noise band. Where several roadway segments affect the same area, noise exposure should be combined before damages are monetized to avoid double counting.

Step 3. Annual noise damage may be calculated as:

$$ND = \sum_{r} \max(0, L_r - 55dBA) \times H_r \times HV_r \times AH \times AF \times VC$$

Where,

- ND: Annual noise damage
- L_r: Modeled noise level for area r
- H_r: Affected housing units
- HV_r: Median housing value
- AH: Adjustment for housing located near facilities (0.95)
- AF: Annualization factor (0.065)
- VC: Estimated housing-value change per additional dBA (0.85%)

This hedonic approach developed by Dodson and Dunleavy (2024) guides analysts to use current affected area housing values and test the valuation parameters where they materially affect the results.

VMT-based method

The VMT-based method provides a simplified estimate when specific exposure modeling is not feasible. This approach measures noise impacts using per-VMT external costs of noise. Because external noise costs differ by vehicle type and facility type, impacts are calculated by analyzing changes in traffic volume by vehicle and facility type between the Base and Alternative scenarios. Table 28 presents the marginal highway noise costs for different vehicle types. These values represent the additional noise cost caused by one more vehicle on major highways and

do not account for surface streets, where noise impact costs are generally expected to be higher. The values are provided across a range from low to high, with the figures shown here representing the middle value of that range.

Table 28 Marginal External Noise Costs (2024 cents per mile)

	Location Type	
Vehicle Type	**Rural Highways**	**Urban Highways**
Automobiles	0.02	0.21
Pickups and Vans	0.02	0.19
Buses	0.25	3.27
Single Unit Trucks	0.19	2.26
Combination Trucks	0.49	7.09

Source: US Federal Highway Administration (1997)

Example of Noise Pollution Benefits

- Project: Install a noise barrier along an urban highway adjacent to a residential area.
- Changes/Expected Impact: Noise modeling identifies two affected residential areas. In Area A, the project reduces the modeled noise level from 67 dBA to 61 dBA for 50 housing units. In Area B, it reduces the modeled noise level from 61 dBA to 58 dBA for 80 housing units. The median housing value in the affected area is $400,000.
- Calculation:
  - Calculate the noise level exceeding the 55 dBA threshold in each area under the Base and Alternative scenarios.

Table 29 Example of Noise Pollution Benefits

Input	First-Year Benefit Value	Units	Source
Area A			
a. Base noise level	67	dBA	User Input
b. Changed noise level	61	dBA	User Input
c. Affected housing units	50	housing units	User Input
Area B			
d. Base noise level	61	dBA	User Input
e. Changed noise level	58	dBA	User Input

f. Affected housing units	80	housing units	User Input
Median housing value			
g. Median housing value	$400,000	2024$/house	User Input
Base noise damage			
h. Base damage in area A	Max(0, a-55) x c x g x 0.95 x 0.065 x 0.85%	2024$/year	Calculated
i. Base damage in area B	Max(0, d-55) x f x g x 0.95 x 0.065 x 0.85%	2024$/year	Calculated
j. Total base noise damage	h + i = $226,746	2024$/year	Calculated
Alternative noise damage			
k. Alternative damage in area A	Max(0, b-55) x c x g x 0.95 x 0.065 x 0.85%	2024$/year	Calculated
l. Alternative damage in area B	Max(0, e-55) x f x g x 0.95 x 0.065 x 0.85%	2024$/year	Calculated
m. Total base noise damage	k + l = $113,373	2024$/year	Calculated
Value of Noise Pollution Benefits	j - m = $113,373	2024$/year	Calculated

*Sources: Dodson and Dunleavy (2024)

4 Costs

Cost estimation captures the real economic resources required to deliver, operate, maintain, and eventually dispose of or replace a transportation investment. These costs form the indicator calculations (NPV, BCR) alongside benefits; precision in their timing, valuation (constant-dollar terms), and categorization is therefore essential for analytical integrity.

Unlike benefits—often modeled with project-specific behavioral, environmental, and safety parameters—costs tend to follow standardized engineering and accounting conventions, supported by established unit-cost libraries and routine phasing rules.

The definition and treatment of costs vary with the type of intervention. Physical infrastructure projects rely on the familiar triad of capital costs, operations and maintenance (O&M) costs, and residual values, whereas policies and programs (e.g., congestion charging, electrification incentives) introduce implementation, enforcement, indirect fiscal, and participant-borne costs that extend beyond the traditional structure.

This framework restructures costs across all intervention types into the three broad categories of implementation costs, operating costs and residual values. All monetary amounts are converted to constant (real) dollars, then discounted to ensure comparability and avoid inflation-driven distortions. Following the baseline assumptions, the framework requires analysts to maintain internal consistency across cost and benefit streams.

4.1 Implementation Costs

Implementation costs represent the upfront economic resources required to establish and launch a transportation investment or program. In BCA, they are a foundational input used to calculate the metrics (NPV and BCR), typically forming the denominator of the latter. These costs are measured in constant-dollar terms and must be phased across time to reflect their actual disbursement profile. Their accurate treatment is essential to align with real-world delivery schedules and to ensure that future benefits are fairly compared against present-day expenditures.

Across transportation interventions, the structure and composition of implementation costs differ substantially. Infrastructure projects involve physical asset development, while policy and programmatic interventions center on institutional, technological, and administrative setup. For multimodal interventions, analysts identify costs by mode or modal component when they are directly attributable, while retaining shared and program-wide costs at the project level. Modal attribution accounts for consistency between benefits and costs and should not change the total incremental implementation cost included in the BCA.

Components of implementation costs

Common implementation cost elements for infrastructure projects include:

- Engineering and Design: Feasibility studies, environmental permitting, and final design specifications.
- Right-of-Way (ROW) Acquisition: Purchase or legal acquisition of land parcels and easements.
- Utility Relocations: Adjustments to existing water, power, telecom, or sewer lines.
- Construction: Costs for roadways, bridges, stations, tracks, and structures.
- Vehicles and Equipment: Procurement of buses, railcars, signaling systems, or intelligent transportation systems.
- Contingencies and Incidentals: Typically 10–30% of direct construction costs to account for risk, minor items, or quantity variations.
- Construction Management and Oversight: On-site supervision, inspection services, and administrative costs during delivery.

Non-infrastructure interventions, such as transportation policies and programs, have capital-like expenditures tied to initial deployment. These costs commonly include:

- Technical Systems and Equipment: Installation of automated license-plate recognition systems, camera networks, software, payment infrastructure, and digital enforcement tools.
- Administrative and Institutional Setup: Legal drafting, regulatory compliance, institutional coordination, and administrative infrastructure.
- Public Communication and Outreach: Extensive public information campaigns, consultation, and stakeholder engagement activities.
- Staff Training and Evaluation Procedures: Costs associated with preparing staff to operate and manage newly implemented systems or policies.

Practice reviews

U.S. and international practices exhibit varying methodological nuances when handling implementation costs. Although common U.S. state practices generally take capital costs of the infrastructure projects into account, they frequently treat implementation expenditures consistently, emphasizing timing and phasing for accurate NPV computation:

- Connecticut: Clearly separates capital items (design, ROW, utilities, construction) with explicit contingencies (15–40%), phased annually across the construction schedule. O&M differentials and residual values are placed on the benefit side.
- Missouri and Oklahoma: Denominator limited strictly to capital costs, carefully phased; avoided O&M and residual values appear as benefits.
- Massachusetts: Capital outlays phased over a multi-year schedule, clearly delineating construction, ROW, and equipment expenses, ensuring proper time-value-of-money treatment.
- Utah: Discounting at 7% (with carbon-related components at 3%) for capital phased across the 2024–2025 window; no residual values credited due to matching asset lifecycle with analysis horizon.

International and policy-based examples highlight additional complexity due to broader capital definitions and upfront investment packages:

- Transport for London (Congestion Charging): Includes IT, infrastructure, administrative, and public outreach expenditures as indivisible capitalized startup costs.
- Stockholm Congestion Charging: Comprehensive startup capitalization covering technical equipment, reliability testing, public communication, and legal infrastructure.
- Federal Transit Administration (FTA): Explicit inclusion of capital-related expenditures—such as rolling stock, property acquisition, engineering, and contingency allowances—as eligible project capital costs; excludes pre-project development expenditures.

In practical terms, implementation costs must be carefully phased to accurately reflect their timing, ensuring reliable NPV and BCR outcomes.

Example of Capital Cost Calculations

- Project: Automated speed safety camera program (program launch and system deployment)
- Inputs/Assumptions:
  - Total capital budget: $45 million in real 2024 dollars.
  - Phasing: $25m in Year 0 (2024), $15m in Year 1 (2025), $5m in Year 3 (2026)
  - Real discount rate: 7%
- Calculation Method:
  - Phase expenditures (real terms)
    - Year 0 (2024): Statutory/regulatory setup, program design, and procurement of camera systems = $25.00m.
    - Year 1 (2025): Installation and commissioning (site preparation and equipment deployment) = $15.00m.
    - Year 2 (2026): Expansion deployment (additional sites and hardware, integration refinements for full operating capability) = $5.00m.
  - Discounting to base year (2024)
    - Year 0 PV : $PV_0\ (million) = 25/(1+0.07)^0 = 25$
    - Year 1 PV : $PV_1\ (million) = 15/(1+0.07)^1 = 14.02$
    - Year 2 PV : $PV_2\ (million) = 5/(1+0.07)^2 = 4.37$
  - Total capital costs
    - Sum of present values = $25.00 million + $14.02 million + $4.37 million = $43.39 million (real 2024 PV)

Table 30 Example of Implementation Costs Calculation

Input	Value	Units	Source
Discounting parameters			
a. Real discount rate	0.07	real	Given

Base year for valuation	2024	year	Given
Costs phasing (real 2024 $)			
b. Year 0 (2024): Program Design and Setting	$25,000,000	$2024 (real)	User input
c. Year 1 (2025): Installation/commissioning	$15,000,000	$2024 (real)	User input
d. Year 2 (2026): Expansion deployment	$5,000,000	$2024 (real)	User input
Discount factors			
e. DF (Year 0)	1/(1+a)^0		
f. DF (Year 1)	1/(1+a)^1		
g. DF (Year 2)	1/(1+a)^2		
Present values (PV)			
h. PV Year 0	b x e	$2024 PV	
i. PV Year 1	c x f	$2024 PV	
j. PV Year 2	d x g	$2024 PV	
Total PVs	h + i + j = $43,385,885	$2024 PV	

Treatment of Sunk Costs

Sunk costs are prior expenditures that have already been incurred, cannot be recovered, and do not create remaining economic value for the selected intervention. True sunk costs should be excluded because they do not affect the incremental cost stream.

The exclusion should be applied narrowly. A cost should not be excluded only because it was incurred before the BCA was prepared. Analysts should determine whether the prior expenditure still supports the policy or contributes to the benefits counted in the analysis.

In the BCA, analysts can include prior expenditures when they still provide value, such as:

- Land or right-of-way already acquired
- Reusable planning, design, or engineering work
- Valid permits or environmental documentation
- Utility relocation completed for the project
- Purchased materials or equipment that will be used
- Partially completed construction that remains useful
- Legal, regulatory, or administrative setup needed for implementation
- Program delivery (outreach, training, or monitoring) and compliance capacity

It is noted that analysts should screen costs incurred before the BCA for remaining economic value rather than automatically excluded, while costs incurred after the decision to proceed should generally be included when they are necessary to implement the policy.

Analysts should document any excluded sunk costs, including the amount, year incurred, reason for exclusion, and whether the expenditure created any remaining asset or usable deliverable.

Considerations

In addition to treatment of sunk costs, the following recommendations set the minimum technical conventions that analysts must follow when estimating implementation costs under the framework. Adhering to them ensures methodological consistency and comparability across Oregon transportation projects, programs, and policies.

- Deflate then discount: Express all capital streams in constant dollars and discount at the framework's real rate; never mix nominal flows with real rates.
- Phase capital realistically: Match disbursements to the construction/implementation schedule (e.g., quarterly or annually) to capture timing effects on NPV.
- Include all indispensable implementation elements for non-infrastructure programs (IT systems, legal setup, outreach) as capital if required at launch.
- Apply explicit contingencies (10–30%) and document the logic or source of these allowances; update them as project design advances.
- Omit financing charges unless they represent real resource use that materially alters delivery timing or efficiency.
- Keep the denominator confined to real resource use (discounted Implementation capital); treat net O&M differences and residuals as benefits unless an Oregon program directive specifies otherwise.
- Test implementation cost uncertainty (e.g., ±20%) in sensitivity analysis per Section 6, especially for early-stage estimates.

4.2 Operating Costs

Operating costs are the annual, recurring expenditures required to operate, administer, and sustain a transportation investment after initial implementation. They include a variety of ongoing economic resources from routine maintenance and daily operating expenses to continuous administrative operations and enforcement and compliance activity.

In most BCA practice, operating costs are modeled for both Base and Alternative cases; the incremental difference (savings or increases) is typically recorded on the benefit side rather than counted as a cost. For policy and program interventions, recurring costs may include billing systems, enforcement activities, data management, software upgrades and other ongoing costs associated with policy or program implementation, all of which must be captured over the full analysis period. For multimodal interventions, analysts identify operating costs by mode or asset component when they are directly attributable. Shared operating costs and program-wide administrative costs should remain at the project level unless a documented allocation basis is

available.

As with implementation costs, all operating streams must be converted to constant (real) dollars and discounted at the framework's real discount rate to maintain internal consistency.

Components of Operating costs

Common operating cost elements for infrastructure projects include:

- Routine Maintenance: Pavement patching, bridge inspection, vegetation management, minor asset repairs, and preventive maintenance.
- Operational Expenses: Energy consumption, staff salaries, security and surveillance, system monitoring, and daily management costs.
- Periodic Minor Rehabilitation: Replacement or repair of short-lived equipment, minor structural repairs, resurfacing, and preventive asset preservation.

For non-infrastructure interventions—such as transportation demand management programs, congestion charging schemes, or electrification initiatives—operating costs typically involve:

- System Operation Costs: Continuous operational expenses, including technical support for digital systems, customer support centers, and routine system updates.
- Enforcement and Compliance: Staffing costs related to enforcement actions, penalty administration, compliance monitoring, and regulatory oversight.
- Administrative and Institutional Management: Ongoing administrative tasks, inter-agency coordination, stakeholder consultations, and reporting activities.
- Periodic Technology Updates: Replacement cycles for software, hardware, and digital infrastructure components due to rapid technological obsolescence.

Practice reviews

U.S. and international practices consistently highlight methodological distinctions and standard practices for treating Operation and Maintenance (O&M) costs. Common U.S. state practices generally emphasize incremental treatment of O&M costs, often highlighting differential costs relative to Base conditions:

- Connecticut: O&M expenses modeled explicitly for both Base and Alternative scenarios, capturing avoided periodic rehabilitation expenditures on the benefit side rather than in the cost denominator.
- Massachusetts: Incremental O&M differences against the baseline appear as benefits, isolating capital expenditures in the cost denominator.
- Louisiana: O&M costs explicitly excluded from project costs if they are contractually assigned to private operators; differential O&M appears on the benefit ledger.
- Oklahoma and Missouri: Base-Alternative O&M differentials treated as benefit-side cost savings rather than included within project costs.

Non-infrastructure and policy-based interventions internationally and domestically reflect

broader and more diverse operating cost treatments:

- Transport for London (Congestion Charging): Clearly delineates continuous administrative operations, enforcement activities, payment collection, customer support, and periodic hardware/software refresh cycles as O&M expenditures.
- Stockholm Congestion Charging: Systematic annual operational expenses including technical infrastructure management, billing, public communications, enforcement operations, and periodic equipment replacements.
- Federal Transit Administration (FTA): Separately accounts for O&M expenses outside of capital cost calculations, reflecting their significance for financial planning but distinguishing clearly from capital investment appraisal.

Example of calculations

- Project: Transportation Demand Management (TDM) program; routine O&M begins in Year 1 (2025) after opening and continues for 30 years.
- Input/Assumptions:
  - O&M stream: $5,000,000 per year.
  - Real discount rate: r = 7%
- Calculation Method:
  - Formula:
    - $PV_{O\&M} = \sum_{n=1}^{30} \frac{Budget_n}{(1+r)^n}$
  - O&M costs: We assume an annual $5,000,000 O&M budget in this example (program staffing and administration, contracted support for outreach and employer technical assistance, monitoring and evaluation, and routine updates).
    - $PV_{O\&M} = \sum_{n=1}^{30} \frac{\$5{,}000{,}000}{(1+0.07)^n} = \$62.05\ million$

Considerations

The below recommendations establish the minimum conventions analysts must follow when modeling operating costs within the Oregon BCA framework. Following them ensures transparent, comparable, and policy-relevant evaluations for both infrastructure and non-infrastructure investments.

- Model recurring costs in both Base and Alternative cases and treat the net difference as a benefit, unless agency policy instructs inclusion in costs.
- Capture all recurring program costs for policies (billing, enforcement, IT refreshes) as annual costs, not as new implementation outlays.
- Document unit-cost sources (agency histories, federal benchmarks) and clearly state assumptions for maintenance cycles and labor/material rates.
- Avoid double counting: Do not include the same operating cost savings in both costs

and benefits ledgers.
- Test operating-cost uncertainty: vary major cost drivers within sensitivity analysis following Section 6.
- Acknowledge indirect fiscal impacts (e.g., lost fuel tax) when relevant to the economic resource base, and treat them consistently across scenarios.

4.3 Residual Values

Residual values represent the end-of-horizon adjustment needed to avoid misstating the lifetime resource requirements of an intervention. In BCA, the values are typically handled as a terminal adjustment in the final year of analysis that may take the form of a credit for remaining service life or an explicit closeout burden when an intervention requires decommissioning, transition, or retirement activities. Residuals are typically calculated with straightforward methods—most commonly straight-line depreciation or a remaining-life fraction of the original implementation cost.

Standard asset lives often guide these calculations (e.g., bridges 50–75 years, pavements 20–40 years, rail infrastructure 30–50 years), but analysts must document the basis for each asset class. For infrastructure projects, residual values are widely credited in practice; many state BCAs insert the credit in year 20–40 and discount it back to present value. For non-infrastructure interventions—especially IT-heavy, rapidly depreciating systems—residual value is frequently zero due to technological obsolescence and rolling reinvestment cycles.

Practice reviews

U.S. state practices usually book residuals as benefits and exclude them from the capital denominator:

- Connecticut: Credits residual asset value at year 30; capital denominator reflects only discounted Build outlays.
- Oklahoma: Uses straight-line depreciation for bridges with 75-year lives; residual credited at the end of a 20-year analysis.
- Missouri and NCTCOG: Residual bridge/pavement value is shifted to the benefit ledger, consistent with USDOT conventions.

International and policy-based examples underscore context-specific approaches:

- Transport for London (Congestion Charging): No residual credit—monitoring tech is obsolete by period end, requiring continuous replacement.
- NZTA (New Zealand): Recognizes avoided or deferred costs as “saved” resources; sunk costs excluded. Residuals apply when assets retain market value.

The following recommendations represent the minimum required conventions that analysts must follow when estimating residual values under the Oregon BCA framework. Adhering to

them ensures accuracy and consistency across diverse Oregon transportation investments.

- Credit residual values explicitly for infrastructure assets with significant remaining service life at the end of the analysis horizon; place them on the benefit side of the ledger.
- Apply straight-line depreciation or proportional remaining-life fractions consistently; clearly document depreciation assumptions (asset lifespan, salvage methodology).
- Assign zero residual value with analysis periods matching their remaining life, or when technological obsolescence is likely (e.g., digital enforcement, software systems).
- Use constant-dollar valuation for residual estimates and discount at the Oregon framework's specified real rate.
- Exclude residual value from implementation cost denominator; it is a cost offset (negative cost) captured in the benefit ledger to avoid double-counting.
- Clearly document all assumptions (service life, salvage approach, discount factor) to ensure reproducibility and transparency.

5 Equity Analysis

Equity analysis in the Oregon BCA framework ensures that policy evaluations explicitly document how benefits and burdens are distributed across population groups and places. Traditional BCA aggregates outcomes into system-wide measures, but such aggregation can conceal disparities in how specific groups experience mobility, safety, affordability, and environmental impacts. Transportation investments may have uneven consequences for populations such as low-income households, communities of color, rural residents, individuals with disabilities, older adults, and households without vehicles. Incorporating equity analysis makes these differences visible and enables decision-makers to assess whether interventions reduce or reinforce disparities in access and well-being.

This framework, therefore, establishes equity analysis as a structured component that parallels the main benefit–cost evaluation. The process is organized into three steps: identifying the relevant populations and geographies of concern, assigning project benefits and costs to these groups, and reporting the results in a standardized format alongside the main BCA outputs. This approach ensures that while the core analysis results remain intact, distributional impacts are also documented, allowing them to inform choices and prioritizations in a transparent manner.

5.1 General Approach

Equity analysis follows a structured and proportionate approach. The aim is to provide a transparent account of how the benefits and burdens of transportation projects are distributed among different population groups and geographies. This framework draws on international practice—particularly the U.K. Department for Transport's distributional impact methodology and Australia's ATAP guidance—while adapting methods to Oregon's planning and policy context.

General principles

The following general principles guide the equity component of the analysis:

- Parallel to core analysis: Equity assessment is carried out as a companion exercise rather than integrated into the calculation of primary BCA indicators. The main benefit–cost outputs remain unchanged, while distributional findings are reported in a separate but standardized format.
- Stepwise proportionality: The process proceeds through a three-step sequence—screening, localized assessment, and full appraisal. Only indicators showing significant or spatially concentrated effects advance to detailed appraisal.
- Indicator-specific focus: Equity analysis applies only to defined categories where distributional impacts are expected, such as user benefits, safety, emissions, noise, accessibility, affordability, severance, and security. This maintains analytical discipline and avoids diffuse or speculative claims.

- Transparency and reproducibility: Group definitions, thresholds, geographies, and data sources must be declared before modeling begins. All assumptions, crosswalks, and screening decisions are documented in reproducible appendices.
- Standardized reporting: Results are presented in an independent report format (e.g., Distributional Impact Matrix) with a clear, plain-language narrative of "who benefits and who bears." These outputs are designed to inform decision-making directly, while remaining analytically distinct from the original findings.

Identification of affected groups and geographies

This section identifies which population groups and geographies are considered in the equity assessment. The framework defines these ex-ante, with clear thresholds and transparent data sources, to avoid post-hoc adjustments and ensure comparability across projects. Groups are generally drawn from established equity and environmental justice categories, with thresholds based on statewide percentiles. ODOT's Social Equity Index (SEI) will serve as the primary indicator set for identifying socially vulnerable populations of concern, including seven indicators: population aged 64 or older, youth population (18 or younger), people living in poverty, individuals with limited English proficiency, people with disabilities, persons of color (non-white or Hispanic), and households without access to a vehicle[4]. Different or additional sets of social vulnerability indicators may be utilized to create a custom SEI depending on project or program relevance as well.

Equity analysis also requires a standardized geographic framework so that modeled transportation impacts can be linked directly to the demographic characteristics of affected communities. To ensure reproducibility and comparability across projects, the framework prescribes a general approach using Geographic Information Systems (GIS).

- The baseline unit of analysis is the census tract (or block group where finer resolution is needed). These geographies are cross-walked to the Transportation Analysis Zone (TAZ) structure used in regional travel models.
- Impact areas are defined using spatial overlays created in GIS. For network-based projects, the affected geographies are all census tracts that intersect a fixed buffer around the project corridor—for example, 1-mile buffers for highways, or ½-mile buffers for transit investments.
- For exposure-based indicators (air quality, noise, construction disamenities), analysts will use corridor buffers (e.g., half mile for near-road emissions) or receptor grids produced by environmental models. These zones are then intersected with census boundaries to determine the affected population.

[4] The SEI relies on demographic and social variables at the census block group level. Data are drawn from the U.S. Census Bureau's American Community Survey (ACS) 5-year sample, and each variable is calculated at the block group scale.

- For non-infrastructure projects, the affected geographies are defined by the jurisdiction or coverage area of the intervention, not by a physical buffer. Examples include statewide geographies for fuel-tax policies, jurisdictional boundaries (e.g., MPO/county/city) for regional pricing schemes, or school district boundaries for student transportation programs. Analysts shall clearly state the spatial scope of the policy and link it to population data within those boundaries.

The GIS output should clearly identify which tracts (or block groups) fall inside the project's area of influence and document the buffer distances or receptor thresholds applied.

Assessment and Reporting

Equity assessment does not apply to all possible impacts of a transportation policy, instead it focuses on benefit and cost categories (or net benefits) where distributional differences are both plausible and significant. Results should be presented alongside the main BCA outputs, highlighting whether the project improves outcomes for high vulnerability communities or disproportionately harms those same communities.

Analysts should identify the affected geographic areas and population groups when assessing equity impacts. For a standardized analysis, they can use broader geographic classifications (statewide, urban, or rural) and income-group allocations (e.g., income quintiles). In cases where policies have significant localized benefits or burdens, analysts may conduct a more detailed assessment of the affected populations and locations.

5.2 Equity Impact Assessment Methods

This section operationalizes the equity analysis established in section 5.1. The purpose is to provide a systematic way to link the affected groups and geographies with the actual benefits and costs generated by transportation interventions. While the preceding subsection defines who and where is of concern, this section defines how the assessment is carried out.

Equity impact analysis in this framework is designed to meet three objectives:

- Proportionate effort. The level of detail in equity analysis should reflect the size, complexity, and likely distributional effects of the project or policy. Small projects with broadly diffuse impacts can rely on a rapid assessment, while larger or more consequential interventions require more rigorous methods.
- Transparent allocation. The analysis must show clearly how benefits and burdens are assigned to population groups, whether through geographic overlays, household incidence, or welfare weights. This ensures that results can be replicated and compared across projects.
- Standardized handoffs. Regardless of the method chosen, the analysis must produce

outputs in a consistent format—tables and summaries. This guarantees comparability across projects and ensures that the interpretation and reporting of results is based on a common evidence base.

Analysts will select one of the available methods described in the next subsection. The choice is based on the availability of data, the nature of the project, and the importance of its potential impacts.

Overview

This subsection sets out the methodological options available for carrying out the equity impact analysis. The purpose is not to prescribe a single uniform technique but to provide a structured menu of approaches that can be applied proportionately to the scale, scope, and distributional salience of each project or program. By offering a set of options, the framework ensures that equity analysis is feasible for small projects with limited data, while also rigorous enough to handle large or complex interventions.

All options build on the foundations established in this section. The same equity groups, the same geographies, and the same equity analysis targets apply regardless of method. What differs across the options is the analytical depth, the type of allocation used, and the form of outputs generated.

The framework specifies two methods:

- **Option A – Welfare-Weighting Standard Approach (Primary)**
  provides a generally applicable method, suitable for a variety of projects, including policy/program interventions. It allows analysts to apply welfare weights to highlight distributional sensitivity and influenced areas.
- **Option B – ODOT SEI Approach (Optional)**
  This is a hybrid approach that is based on ODOT's Social Equity Index (SEI), developed separately from this framework. The index combines multiple affected-group indicators at the census-tract level to provide a single summary of equity outcomes. Analysts using Option B must follow the dedicated methodological documentation for the index and present outputs in the standardized format required for reporting. For detailed information, please see Appendix B – ODOT SEI Approach for Equity Analysis.

Option A – Welfare-Weighting Standard Approach

Option A provides a structured standard method for evaluating the distributional sensitivity of a transportation project's outcomes using welfare weights. This approach is rooted in economic theory and offers a powerful way to understand how the valuation of a project might change if the benefits accruing to disadvantaged groups were given greater weight in the analysis. It is the

most broadly applicable method in this framework, suitable for a variety of transportation investments, and is particularly valuable in contexts where detailed, geographically disaggregated modeling of impacts is not feasible or proportionate to the project's scale.

The primary objectives of the welfare weighting method are to:

- Assess distributional progressivity or regressivity: Determine whether a project's benefits are skewed toward lower-income groups (progressive), higher-income groups (regressive), or are distributed neutrally.
- Provide a sensitivity analysis: Test how the overall BCA result changes under different assumptions about the social value of benefits to different income groups.
- Enable comparison across diverse project types: Offer a standardized quantitative method that can be applied consistently to infrastructure investments, pricing policies, subsidy programs, and regulatory changes, facilitating a more uniform approach to equity assessment.
- Fulfill proportionality: Serve as a robust yet data-efficient tool for projects where the cost and complexity of granular spatial analysis would be prohibitive.

This method is primarily applied to monetized impacts, such as travel time savings, vehicle operating cost reductions, fare or toll impacts, and safety benefits. While it is most commonly used to analyze distribution by income, the underlying principles can be extended to other groups where a clear rationale for differential weighting exists, though this framework defaults to an income-based application for consistency.

Theoretical foundation of welfare weights

The theoretical basis for welfare weights is the principle of the diminishing marginal utility of income. In simple terms, this economic concept posits that an additional dollar provides more value (or "utility") to a person with a low income than it does to a person with a high income. For example, a $50 benefit from reduced travel costs represents a more significant improvement in well-being for a household earning $30,000 per year than for a household earning $200,000 per year.

Standard BCA does not account for this difference. It implicitly assumes that the marginal utility of income is constant for everyone—a dollar of benefit is valued equally, regardless of who receives it. This "dollar-is-a-dollar" assumption prioritizes economic efficiency but is silent on equity.

Welfare weights explicitly correct for this by adjusting the monetary value of benefits and costs based on the income level of the recipient group. This is accomplished by applying a weight greater than one to benefits for lower-income groups and a weight less than one to benefits for higher-income groups.

The key parameter in this calculation is the elasticity of the marginal utility of income (e). This parameter quantifies how much the marginal utility of income decreases as income increases. Its value reflects a societal preference for equity:

- e = 0: This represents the standard BCA assumption where no weights are applied. A dollar is a dollar to everyone.
- e > 0: This indicates a preference for equity. Benefits to lower-income groups are valued more highly than benefits to higher-income groups.
- e > 1.0: This represents a stronger preference for equity and results in larger weights for lower-income groups.

Empirical reviews and guidance generally support values above 1.0, with the UK Green Book using 1.3 (HM Treasury, 2022), the OMB A-4 guidance recommending 1.4, and a meta-analysis recommending ≈1.6 (sensitivity 1.2–2.0) (Acland & Greenberg, 2023).

The choice of e is a normative policy judgment, not an empirical fact. Therefore, transparency about the selected value and conducting sensitivity analysis with a range of values is critical.

Analysis Process

The application of welfare weights follows a systematic process. Analysts need to document the data sources and assumptions made at each stage.

First, classify the intervention and define the influenced area. For corridor or area projects, the influenced area should be constructed from corridor buffers or modeled catchments (tracts or block groups, cross-walked to TAZs where available). For jurisdiction-wide policies or programs (e.g., fare changes, statewide rebates), the jurisdiction itself serves as the influenced area. This selection step determines how impacts are allocated in the subsequent analysis.

Next, define the population segments for the analysis. For example, as established in Section 5.1, the analysts can use three income categories. After describing specific data sources (e.g., American Community Survey, HUD income data), they determine the average (or median) household income for each of these groups. Depending on policies, an overall average household income for the entire population in the influence area may be required.

The analysts, then, select and declare the value of e that will be used for the primary analysis. As a recommendation, the default value for this framework is e = 1.4. A sensitivity analysis using at least one lower and one higher value (e.g., 1.0 and 1.8) should also be conducted to show how the results vary with different equity preferences.

The welfare weight for each income group is calculated using the following formula:

$$W = (\frac{\bar{I}}{I_{ig}})^e$$

where:
Overall Average Income ($\bar{I}$) is the average household income for the entire area population.
Group Average Income (I_{ig}) is the average household income for the income group i in the influence area g (if applicable).
e is the selected elasticity parameter.

The total monetized benefit (or cost) for a specific impact category (e.g., travel time savings) is accordingly distributed among the defined income groups. The equity-weighted benefit is calculated by multiplying each group's share of the benefit by its corresponding welfare weight and summing the results.

If the project specifies the affected areas, apply the weights to group-level impacts and compute equity-weighted totals:

$$B_k{}^{(\omega)} = \sum_g W_{ig} B_{kg}$$

It allocates project benefits and costs to the defined groups across the influenced area. For each impact category, analysts use modeled outputs or documented proxy shares to distribute the total impact (B_{ka}) for area a across groups g. This produces group-level impacts (B_{kg}), which form the unweighted Distributional Impact Matrix (DIM).

Analysts should allocate benefits and costs across groups using policy evidence or clearly stated

assumptions, then apply welfare weights. Weighted and unweighted results should be compared to assess how benefits and costs are distributed. A higher weighted total does not necessarily indicate greater equity or progressivity. It should consider the affected groups, the distribution of benefits and costs, and the assumptions underlying the allocation.

Example of Welfare-Weighted Standard Approach

Using the income data, the welfare weights are calculated for each group. The framework recommends conducting a distributional impact analysis by calculating weights for a range of elasticity parameters. Table 31 illustrates this calculation for three different elasticity values: 0.0 (no equity preference), 1.0 (low equity preference), 1.4 (default), and 1.8 (high equity preference). The Low-Income group, with an average income below the overall average, receive a weight greater than one, while the High-Income (HI) group receives a weight less than one. The table also demonstrates the impact of the elasticity parameter: a higher value results in a greater divergence in weights, reflecting a stronger societal preference for directing benefits to lower-income households.

Table 31 Example of Welfare Weight Calculations

Income Group	Group Avg. Income ($)	Welfare Weight (e = 0)	Welfare Weight (e = 1.0)	Welfare Weight (e = 1.4)	Welfare Weight (e = 1.8)
LI	30,000	1	2.50	3.61	5.20
MI	80,000	1	0.94	0.91	0.89
HI	150,000	1	0.50	0.38	0.29

Note: In calculating the weights, average income for the entire area population is assumed $75,000.

Table 32 presents the final output of the welfare weighting analysis, quantifying the distributional impact of a project's benefits. If the total benefits are monetized and distributed according to income groups, analysts apply the calculated welfare weights to these unweighted benefits. Assuming the elasticity parameter as 1.4, the weighted benefits are calculated by multiplying them to arrive at the final equity-weighted benefits for each group. The totals present the core analysis results: the project's unweighted benefit is $10,000,000, but its equity-weighted benefit is over $21.7 million. The increase illustrates the effect of assigning greater welfare value to benefits received by lower-income groups under the specified income distribution and elasticity.

Table 32 Example of Distributional Impact by Income

Income Group	Unweighted Benefit ($)	Welfare Weight (e = 1.4)	Weighted Benefit ($)
LI	5,000,000	3.61	18,033,749

MI	3,500,000	0.91	3,197,627
HI	1,500,000	0.38	568,394
Total	10,000,000		21,799,770

Example of Welfare-Weighting Standard Approach within Impacted Geographical Areas

Equity analysis often requires combining geographic allocation with welfare weighting. In this example, the influenced area consists of three tracts (A, B, C) along a proposed transit corridor. Each tract has a different mix of income groups, and project benefits are first allocated across these tracts based on modeled ridership. Analysts then apply welfare weights (using 1.4 elasticity) to reflect equity preferences.

This approach illustrates how spatial definition of the influenced area interacts with group allocation, providing clear outputs in the DIM format.

Table 33 Example of Unweighted Allocation of Project Benefits by Tracts and Income Groups

Tract	Tract Benefit ($)	LI Share	MI Share	HI Share	LI Benefit ($)	MI Benefit ($)	HI Benefit ($)
A	5,000,000	50%	35%	15%	2,500,000	1,750,000	750,000
B	4,000,000	20%	40%	40%	800,000	1,600,000	1,600,000
C	3,000,000	10%	30%	60%	300,000	900,000	1,800,000
Total	12,000,000				3,600,000	4,250,000	4,150,000

Table 34 Example of Welfare-Weighted Benefits by Tracts and Income Groups (e = 1.4)

Tract	LI Benefit × Weight (3.61)	MI Benefit × Weight (0.91)	HI Benefit × Weight (0.38)	Weighted Total ($)
A	9,016,874	1,598,814	284,197	10,899,885
B	2,885,400	1,461,772	606,287	4,953,459
C	1,082,025	822,247	682,072	2,586,344
Total	12,984,299	3,882,833	1,572,556	18,439,688

The results in Table 33 show the unweighted allocation of corridor benefits across tracts and income groups. The distribution appears roughly balanced, with $3.6 million to low-income households, $4.25 million to middle-income households, and $4.15 million to high-income households, totaling $12.0 million.

After applying welfare weights, Table 34 demonstrates how the valuation of benefits changes.

The low-income group's benefits rise sharply from $3.6 million to $12.9 million, while high-income benefits fall from $4.25 million to $1.57 million. The overall equity-weighted total increases to $18.4 million, compared with the unweighted $12.0 million.

The comparison between Table 33 and Table 34 highlights two important insights:

- Progressivity: Because weighted totals are larger than unweighted totals, the project is considered progressive—its benefits accrue disproportionately to groups whose welfare gains are valued more highly.
- Geographic sensitivity: The concentration of low-income households in Tract A (see Table 33) magnifies the effect of weighting. This confirms that defining and analyzing the influenced area is critical: the same total benefits allocated differently across tracts would yield different progressivity outcomes.

Example of Welfare-Weighting Application

- Project: Increase bus service frequency on specific routes for low-income communities
- Expected impact/changes:
  - Waiting time savings: The policy reduces average waiting time by 4 minutes per trip
  - Ridership: The policy increases annual ridership by 5% from 5 million trips to 5.25 million trips per year
- Assumptions
  - The affected geographies' ridership is composed of LI 60%, MI 30%, HI 10%.
  - The waiting-time reduction applies uniformly to existing and induced riders.
  - The composition of riders (LI/MI/HI) is the same for existing riders and new riders.
- Benefits Calculation
  - Following VTTS values from the Benefits section, apply the rule of half for induced demand

Table 35 Example of benefits calculation by the policy

Input	First-Year Benefit Value	Units	Source
Ridership			
a. Base	5,000,000	Person-trips/year	User Input
b. Alternative	5,250,000	Person-trips/year	User Input
c. Average waiting time	4	Minutes/trip	User Input
Travel Time Benefits			
d. Existing Users	a x (c / 60) x $40.97	2024$/year	Table 3, Calculated
Existing Users (LI)	d x 0.6	2024$/year	Calculated
Existing Users (MI)	d x 0.3	2024$/year	Calculated

Existing Users (HI)	d x 0.1	2024$/year	Calculated
e. New Users	(b – a) x (c / 60) x $40.97 x 50%	2024$/year	Table 3, Calculated
New Users (LI)	e x 0.6	2024$/year	Calculated
New Users (MI)	e x 0.3	2024$/year	Calculated
New Users (HI)	e x 0.1	2024$/year	Calculated
Total Benefits	d + e = $13,998,083	2024$/year	Calculated

- Distributional Impacts
  - Allocate the total VTTS values by these shares to calculate both the unweighted and weighted benefits, then apply welfare weights with the elasticity (1.4): LI 3.61, MI 0.91, HI 0.38

Table 36 Example of equity impacts by the policy (elasticity 1.4)

Income Group	Unweighted Benefit ($)	Welfare Weight (e = 1.4)	Weighted Benefit ($)
LI	Existing and New User Benefits = 8,398,850	3.61	30,292,550
MI	Existing and New User Benefits = 4,199,425	0.91	3,836,627
HI	Existing and New User Benefits = 1,399,808	0.38	530,428
Total	13,998,083		34,659,606

The analysis results shall be documented in a section of the BCA report. The following elements are essential for reporting:

- Parameter declaration: The elasticity parameter used in the primary analysis and the range used for sensitivity testing are clearly stated and justified.
- Allocation methodology: A clear description of the methods or assumptions used to distribute the unweighted benefits and costs across the income groups.

It is crucial to reiterate that the equity-weighted result is a supplementary metric and does not replace the primary BCA result. Instead, it provides decision-makers with an explicit, quantitative measure of the project's performance against equity objectives.

6 Risk and Uncertainty Analysis

Sensitivity analysis is a crucial methodological step, explicitly designed to assess the robustness and reliability of economic conclusions under conditions of uncertainty. Given that key analytical parameters such as discount rates, future demand forecasts, capital costs, crash reduction factors, and valuation metrics inherently involve normative judgments and predictive uncertainties, even modest variations can substantially impact the assessment outcomes. Drawing on best practices across federal agencies such as FHWA, FRA, and international counterparts in Australia, Canada, and New Zealand, sensitivity analysis should systematically vary these parameters within plausible bounds to demonstrate how results shift under alternative assumptions. While the core purpose is not predictive, this approach provides critical insights into which parameters significantly drive project viability within the BCA framework.

6.1 Analytical Approaches

Sensitivity analysis typically utilizes two primary techniques—deterministic and scenario analysis—with methods and values informed by a review of agency practices. Probabilistic simulation (i.e., Monte Carlo simulation) may be used in highly complex cases. This BCA framework focuses on the two primary types of sensitivity analysis.

The most common approach is deterministic sensitivity analysis, which isolates the influence of individual parameters on the final outcome. This method transparently identifies which assumptions are most critical to the project's economic viability.

- Method: Varies one parameter at a time, a technique used by agencies like FHWA and FRA (e.g., ±20%).
- Purpose: Isolate the specific influence of key variables.

For example, the Oklahoma Department of Transportation evaluated the reconstruction of the US-75/W. 81st Street interchange into a Diverging Diamond Interchange (DDI). In this project-level BCA, Oklahoma DOT tested individual parameters—such as capital cost, vehicle delay, demand growth, and crash modification factors—using a ±20% range. Ranking the resulting changes in NPV and BCR revealed that the capital cost assumptions were the most influential driver, while crash factors had minimal impact.

Scenario analysis evaluates robustness by changing multiple parameters simultaneously to model different potential futures. This technique is useful for conveying a comprehensive range of potential economic outcomes under combined uncertainties.

- Method: Varies multiple parameters at once to create optimistic (upper bound), pessimistic (lower bound), or alternative scenarios.

- Purpose: Create and test comprehensive future scenarios.

For example, Washington State DOT conducted scenario analysis, evaluating a portfolio of light rail, commuter rail, and bus rapid transit corridor investments. The analysis combined ±15% variations in benefits and costs, alternative evaluation periods, and different real wage growth assumptions to illustrate how overall program outcomes change under optimistic and pessimistic economic conditions.

Sensitivity analysis within the Oregon BCA framework adheres to clear methodological rules that guide the identification, implementation, and interpretation of analytical uncertainties as follows:

- Parameter identification: Select parameters that have substantial impacts on the analysis outcomes or reflect significant uncertainty in estimation.
- Parameter variation: Define and document logical, defensible parameter variation ranges based on plausible uncertainty.
- Scope of testing: Conduct sensitivity tests systematically, using both individual parameter variations and combined scenarios. Clearly differentiate and document single-variable tests versus multi-variable scenarios.
- Reporting standards: Present sensitivity results concisely in structured tables or summaries, clearly displaying tested parameters, their variations, and impacts on key metrics (NPV, BCR).
- Infrastructure vs. Non-Infrastructure projects: Recognize that non-infrastructure projects may involve different or less predictable forms of uncertainty (e.g., behavioral response, policy compliance). Analysts must explicitly document sources of uncertainty, provide evidence-based justifications for sensitivity ranges, and consider wider variation when behavioral assumptions significantly influence outcomes.

6.2 Implementation of Sensitivity Analysis

This section operationalizes the analytical rules established in the previous section. It provides a structured yet flexible methodology for implementing sensitivity analysis, ensuring all evaluations are robust and transparent. A hybrid approach that combines foundational testing of core uncertainties with analyst-defined scenarios tailored to project-specific risks is recommended.

Table 37 provides recommended parameters for sensitivity analysis, and corresponding ranges for variation. The variation ranges suggested below are conservative guidelines drawn from the literature and practice. The analyst is responsible for defining and documenting a logical, defensible range for each sensitivity based on the specific context and available evidence for the project.

We recommend basic sensitivity analyses to test a 7% real discount rate against 3%, a 30-year

evaluation period against 20 years, and total monetized benefits at 100% against 80%. These are simple and standardized settings for an initial one-at-a-time assessment, not mandatory values for every policy. Analysts can select alternative assumptions when the asset life, funding program, or empirical uncertainty warrants different bounds.

Table 37 Recommended Sensitivity Analysis Identification and Variation

Categories	Rationale for testing	Range for variation
Baseline parameters	These foundational parameters ensure consistency with federal guidance and account for broad economic uncertainty that affects all projects. ▪ Analysis period ▪ Discount rates	Vary based on asset life and benefit timing (e.g., 20–50 years). Test a range (e.g., 3%–7%) reflecting project type and societal valuation.
Costs	Project costs capture risk of cost overruns, a common and well-documented uncertainty. ▪ Implementation costs ▪ Operating costs ▪ Total project costs	Test within a reasonable range (e.g., ±10–20%) based on project stage and historical estimation uncertainty. Optionally assess total project cost impacts if component interactions or scope changes are significant.
Benefits	Total benefits may be tested for uncertainty as one block, reflecting correlated errors in demand forecasts, behavioral response, and valuation.	Use a documented range such as ±10–25% (early-stage projects toward the higher end; late-stage designs toward the lower end). For policy/programs with higher behavioral volatility, justify a wider low case (e.g., up to −30%).
Project-specific drivers	Stress-tests the parameter(s) that most dictates project outcomes, thereby capturing uncertainty unique to the specific investment. ▪ Traffic growth ▪ CRFs ▪ Travel speed ▪ Behavioral response	Apply evidence-based bounds drawn from the parameter's own data set and document the source for each bound.

	rate

Systematic process for testing

To fulfill the requirement for systematic testing, analysts can conduct either individual variations or combined scenarios using the following two-stage process.

Stage 1: Individual Parameter Variation (Deterministic Testing)

The analyst may test each sensitivity category separately to gauge its marginal influence on NPV/BCR and to identify which uncertainties exert the greatest leverage on results; use this when a quick diagnostic or parameter isolation is appropriate. This isolates the influence of each major area of uncertainty and identifies which factors pose the greatest risk to the project's economic viability.

- Core sensitivity — Discount rate (required)
  Every analysis must include at least one test of the real discount rate. The real discount rates apply to all constant-dollar streams. The analysts use the framework's defined low/high rates as holding other baseline parameters fixed when isolating the rates.
- Optional sensitivities — Analyst's choice
  Beyond the discount rate, analysts may select other sensitivities when they are significant to the project. These may include variations in project horizon, capital formation, aggregate benefits, or a project-specific driver, but the choice is discretionary.

Stage 2: Combined Scenario Analysis

Analysts may construct and test coherent scenarios that combine variations across multiple sensitivity categories. This approach is appropriate when interactions between uncertainties are policy-relevant or when single-factor tests do not adequately represent plausible futures. This moves beyond single-variable testing to assess how the project performs under different potential futures.

- Requirement: The rationale for the construction of each scenario must be clearly documented. The scenarios must be relevant to the project's specific risks.
- Example Common Scenarios (Illustrative, not prescriptive):
  - Pessimistic (lower bound) scenario: Combines High Total Costs (+20%) with Low Total Benefits (-20%).
  - Optimistic (upper bound) scenario: Combines Low Total Costs (−20%) with High Total Benefits (+20%).
  - Delayed implementation scenario: Models a delay in project opening, which defers the benefit stream and can significantly impact project measures.

Non-Infrastructure Projects

As noted previously, non-infrastructure projects may involve different forms of uncertainty. The analysis must therefore include broader consideration of these risks.

- For many non-infrastructure interventions, behavioral assumptions such as participation, compliance, or mode shift are important project-specific drivers. The analyst should choose ranges consistent with available evidence and test a low-response case when these assumptions materially influence benefits.
- At least one of the analyst-defined scenarios must explicitly test the impact of a lower-than-expected behavioral response.

Reporting and Robustness Assessment

Consistent with the framework's reporting standards, the results must be presented concisely and interpreted clearly.

- Reporting format: Present a structured summary of the central case and each individual test, with tested assumptions, present-value benefits and costs, NPV, and BCR where defined. Report any combined scenarios separately so their interpretation is not confused with one-at-a-time effects.
- Narrative interpretation: The report must include a narrative that discusses the results, identifies the mos8t critical risks, and provides a clear robustness assessment.
- Robustness assessment: The assessment must explicitly address the project's performance in scenarios that yield negative outcomes. A project is considered economically robust if it maintains BCR of 1.0 or greater under a plausible and well-defined pessimistic scenario. This assessment is a critical input for project screening and prioritization.

6.3 Use of Results

The outputs of the sensitivity analysis are essential for moving beyond a single deterministic result to a more complete understanding of project risk. These findings must be used to inform decision-making, be presented in a clear format, and be considered alongside other policy goals.

- Informing decision-making: The primary use of sensitivity analysis is to provide a clear-eyed view of a project's risk profile. The results must be used to:
  - Assess robustness: Determine if a project remains economically viable (BCR > 1.0) under plausible pessimistic scenarios. This serves as a key secondary criterion for project selection and prioritization.
  - Identify critical risks: Isolate which factors (e.g., cost overruns, benefit shortfalls) pose the greatest threat to project success.
  - Understand momentums: Reveal the conditions under which a project would fail,

providing decision-makers with a clear understanding of the project's margin of safety.

- Formats: To ensure clarity and comparability, results must be presented in a standardized format. The analysis shall include a summary table that clearly displays the NPV and BCR for the Base Case alongside the results for each individual sensitivity test and combined scenario. This table must be accompanied by a brief narrative that interprets the findings and provides a clear robustness assessment.
- Integration with equity analysis: The results of the sensitivity analysis focus on aggregate economic efficiency. The distributional or equity impacts of different scenarios should be considered as a separate, parallel analysis. For example, a pessimistic scenario might not only lower the overall BCR but could also disproportionately harm low-income users. These equity interpretations should be discussed separately to inform the final policy decision.

7 Reporting and Documentation

The core BCA results should be presented in a standardized format. The documentation begins with a concise policy description that specifies the intervention under review and the corresponding Base and Implementation alternatives. The analysis period is clearly indicated, including both the start and end years, so that the time horizon for benefits and costs is transparent. Monetary results are expressed in constant dollars, with the base year of prices explicitly labeled, and the deflate-then-discount sequence shall be applied to all streams to ensure consistency across studies. The reporting identifies the real discount rate or rates used, making clear whether the primary federal benchmark, alternative sensitivity rates, or a range of values were applied. Results need to include undiscounted totals for benefits and costs, as well as monetized parameters and the headline metrics of NPV and/or BCR. To accompany these numerical outputs, a short interpretive statement can be provided that specifies whether the project demonstrates economic desirability under the framework's assumptions and how the results are positioned for policy comparison.

Following the BCA setup and baseline parameters, analysts should also clearly describe the analytical methods, data, and parameters used:

- Methods summary: A concise account of the benefit and cost mechanisms applied (e.g., travel time, safety, vehicle operating costs, emissions, residual value) and the functional forms or models used (e.g., rule-of-half, crash modification factors, emissions factors, straight-line service life). This section should also indicate how demand responses and network effects are treated.
- Data catalog: A complete listing of all datasets and parameters, including the source, vintage (release or publication date), version (or URL/date stamp), geographic unit, temporal coverage, and units. The catalog must also identify the price index used for deflation and the base year of prices.
- Departures from defaults: Any parameter that differs from the framework's defaults (e.g., social cost of carbon, vehicle operating cost factors, value of time by user class) must be flagged, justified briefly, and referenced to sensitivity tests where relevant.
- Model outputs: For model-dependent inputs (e.g., traffic volumes, speeds, ridership, VMT, emissions inventories), the documentation must provide relevant descriptions, including the model name, scenario label, run date, and key scenario settings.
- Assumptions list: Key assumptions that materially affect results (e.g., opening year, ramp-up profile, work zone timing, maintenance cycles) must be enumerated in a concise list.

The reporting of distributional outcomes and risk and uncertainty analysis should accompany the core BCA results. For equity analysis,

- Equity pathway and scope: The reporting identifies the equity pathway applied—welfare weighting of monetized benefits and costs or ODOT SEI distributional analysis of affected groups—and states the rationale for the selected pathway in relation to

data availability and project context. The scope defines the affected group categories considered and the geographic unit of analysis, with clear notation of the reference year and any alignment procedures used to match model zones to statistical geographies.

- Computation and inputs for equity: The documentation specifies the unweighted benefit allocations established from evidence or explicit proxies, the income quintiles or other groups, the elasticity, and the resulting weights. Allocate project costs to groups only when a defensible incidence basis exists. For SEI-based analysis, report the index construction, spatial overlay, and whether the results represent allocated benefits, costs, or a combined measure.
- Equity results and interpretation: Results indicate unweighted distributional results alongside weighted benefits or, when justified, weighted net results. The presentation includes a statement on distributional pattern—progressive, regressive, or approximately neutral—with a short explanation linking the observed pattern to the underlying mechanisms (e.g., demand uptake, service coverage, travel-time changes, or exposure reductions)..

For risk and uncertainty analysis,

- Deterministic sensitivities (one-at-a-time): The reporting summarizes required one-at-a-time tests, listing the parameters varied, the variation ranges applied, and the corresponding shifts in the core analysis results. A basic comparison setting may include a 7% to 3% discount-rate test, a 30- to 20-year analysis-period test, and an aggregate-benefit change from 100% to 80%.
- Combined scenarios (multi-factor): Analysts may conduct combined scenario analysis when interactions among uncertain parameters are significant or individual sensitivity tests do not adequately represent plausible outcomes. These scenarios may include optimistic (upper-bound), pessimistic (lower-bound), or delayed-opening cases, depending on project-specific risks. When combined scenarios are applied, the documentation must identify the parameters and assumptions included in each scenario (e.g., demand, costs, opening year, external prices) and explain their rationale. Results should be reported separately from individual sensitivity tests, comparing present-value benefits and costs, NPV, and BCR (where defined) against the baseline results.
- Integrated synthesis: A closing synthesis brings equity and robustness together, stating (i) how benefits and costs are distributed across groups under the base case, (ii) how that pattern changes under key sensitivities or scenarios, and (iii) whether the project's efficiency case remains intact under plausible variations. This integrated synthesis may require qualitative assessments to compare scenarios when utilizing the ODOT SEI distributional analysis approach (because this approach cannot be incorporated into the NPV/BCR calculations).

In addition to reporting total monetized benefits and costs, analysts shall separately present private and public components of results wherever feasible. To ensure comparability across

studies, the reporting package shall include a Private–Public Results Table that accompanies the core NPV/BCR summary. For each monetized benefit and cost category, the table reports: the present value total, the portion classified as private and public, and a short note describing the allocation rule and key assumptions. Where allocation is not feasible due to data limitations (e.g., the underlying unit values are bundled and cannot be decomposed), the category should be reported as mixed/unallocated with an explicit note stating why it cannot be separated and the likely direction of bias, if any. The methods summary and assumptions list should explicitly document how the private–public split was implemented and whether any categories were treated as mixed/unallocated.

Appendix A - Updating the BCA Framework

This section outlines the sources and update cycles for the data used to derive results for each parameter. While it is necessary to adjust values for inflation to align with the year in which impacts occur, it is even more critical to rely on the most recent data provided by the original source. This approach ensures consistency with source methodologies and accounts for changes that may not be captured by the GDP deflator, including shifts in measurement practices or broader societal trends.

The frequency of updates should follow the update cycle of each dataset, with values reviewed and refreshed before use. For parameters with annual updates, users should consult the original data sources each year to ensure accuracy. For parameters updated irregularly, it is recommended to review the latest research and adjust value either annually or, at a minimum, every five years. In addition, for benefit categories or modes not yet included in the current framework due to methodological limitations (e.g., economic impacts, reliability, accessibility) or data limitations (e.g., crash data for micromobility, autonomous vehicles, etc.), we recommend reviewing and updating the BCA framework and parameters every five to ten years to ensure its relevance.

Table 38 Framework update guidance

Framework area	Parameter	Primary source	Update schedule
Baselines	Deflators	• Bureau of Labor Statistics • Bureau of Economic Analysis	Review annually
	Discount rate	• OMB Circular A-94 and Appendix D	Review annually
Travel Time Savings	Vehicle occupancy rates	• Oregon Travel Survey	Update when a new survey estimate is released
	Value of time	• Census ACS • BLS OEWS and Oregon QCEW • BLS Employer Costs for Employee Compensation	Update annually
	Travel pattern	• Oregon Travel Survey	Update when a new survey estimate is released
Safety	Crash rates	• Oregon Traffic Crash database • ODOT Oregon statewide	Update annually

		VMT or FHWA highway statistics	
	Crash cost	• ODOT ARTS program – Comprehensive economic value per crash	Review annually
	CMF or CRF	• Applicable ODOT CRF manual or FHWA source	Review annually
VOC	Fuel cost	• AAA Fuel Prices • ODOT fuel-tax information	Update annually
	Non-fuel cost (automobile)	• AAA Your Driving Costs	Update annually
	Non-fuel cost (truck)	• American Transportation Research Institute	Review annually
	Transit operating costs per passenger-mile	• FTA National Transit Database	Review annually
	Fuel consumption	• Oregon DMV	Update annually
Emission reductions	Emission rates	• EPA MOVES or pollutant estimates • ODOT Oregon statewide VMT or FHWA highway statistics	Update when a new model version, fuel assumption, or analysis-year dataset becomes available
	Emission cost (criteria pollutant)	• USDOT guidance • EPA	Review annually
	Social cost of carbon	• EPA greenhouse gas information	Review annually
Health benefits	Mortality and absenteeism values	• USDOT guidance and the underlying health studies referenced by USDOT	Review annually
Ecosystem services and wildlife impacts	Ecosystem service values	• FEMA ecosystem service value	Review annually
	Baseline wildlife mortality	• Project monitoring, ODOT records, wildlife-agency data, and other sources	Update whenever new project, corridor, species, or regional monitoring data become available
	Wildlife preservation value	• Applicable wildlife valuation research	Update when a new study relevant to Oregon species and conditions is published
Journey	Journey quality	• USDOT guidance	Update annually

quality benefits	values			
Noise	Noise exposure assumptions	•	Noise estimate studies	Update when a new study relevant to noise exposure measure is published
	Marginal external noise costs	•	FHWA	Review annually
Equity analysis	Welfare-weight elasticity	•	Current distributional-analysis literature • OMB	Retain the framework default unless the literature provides sufficient evidence for revision
	Social Equity Index indicators	•	ODOT Social Equity Index	Update when ODOT releases a new SEI dataset, methodology, or geographic classification
Model inputs	Regional travel-demand and land-use model vintages	•	Applicable MPO, regional transportation plan, or ODOT model	Update when a new adopted model is released

Appendix B – ODOT SEI Approach for Equity Analysis

This approach operationalizes the BCA framework's equity analysis as a place-based distributional assessment using ODOT's Social Equity Index (SEI). It is intended for cases where analysts can reasonably allocate project impacts to communities (e.g., corridors, neighborhoods, service areas) and need a consistent way to report whether benefits and burdens are concentrated in socially vulnerable areas. In the framework, we propose SEI-based approach in BCA applications because it relies on an explicit spatial overlay and multi-indicator vulnerability measure rather than a single economic proxy; its value is in producing results that are transparent, comparable across projects, and interpretable for decision-making.

The SEI provides the standardized vulnerability lens for this option and should be treated as the source-of-record dataset for defining equity geographies and tiers. In its form, the SEI combines seven indicators—population aged 64 or older, youth population (18 or younger), people living in poverty, individuals with limited English proficiency, people with disabilities, persons of color (non-white or Hispanic), and households without access to a vehicle—summarized for small-area geographies (e.g., tract/block group as defined in SEI documentation). These indicators are designed to highlight areas where transportation decisions may have historically imposed disproportionate burdens or where access and outcomes are likely to be inequitable.

For SEI construction, age over 64, youth population, and disabled population are grouped together as a single variable called vulnerable population. Each variable is divided into five quantile groups and assigned a score from 1 to 5 (lowest to highest). The SEI is the sum of these scores across all variables. The resulting values are then categorized into four groups (Low, Low/Medium, Medium/High, High) using quartiles. A higher SEI indicates a higher proportion of socially vulnerable populations, signifying areas that require particular attention in planning and investment decisions. Based on these definitions, we constructed an updated 2023 SEI map which reflects these groupings across Oregon (Figure 3).

The SEI can also be modified for specific applications. While the standard SEI incorporates seven variables, users may choose to construct a customized SEI by selecting a subset of these variables and applying the same methodology. For example, if users wish to focus only on Zero-Vehicle Households and Living in Poverty, they would divide each variable into five quantile groups, assign scores from 1 to 5, and sum the scores to create a new SEI. However, it is important to note that absolute comparisons are not valid in this case, since the value ranges differ between an SEI based on all seven variables and one based on a reduced set.

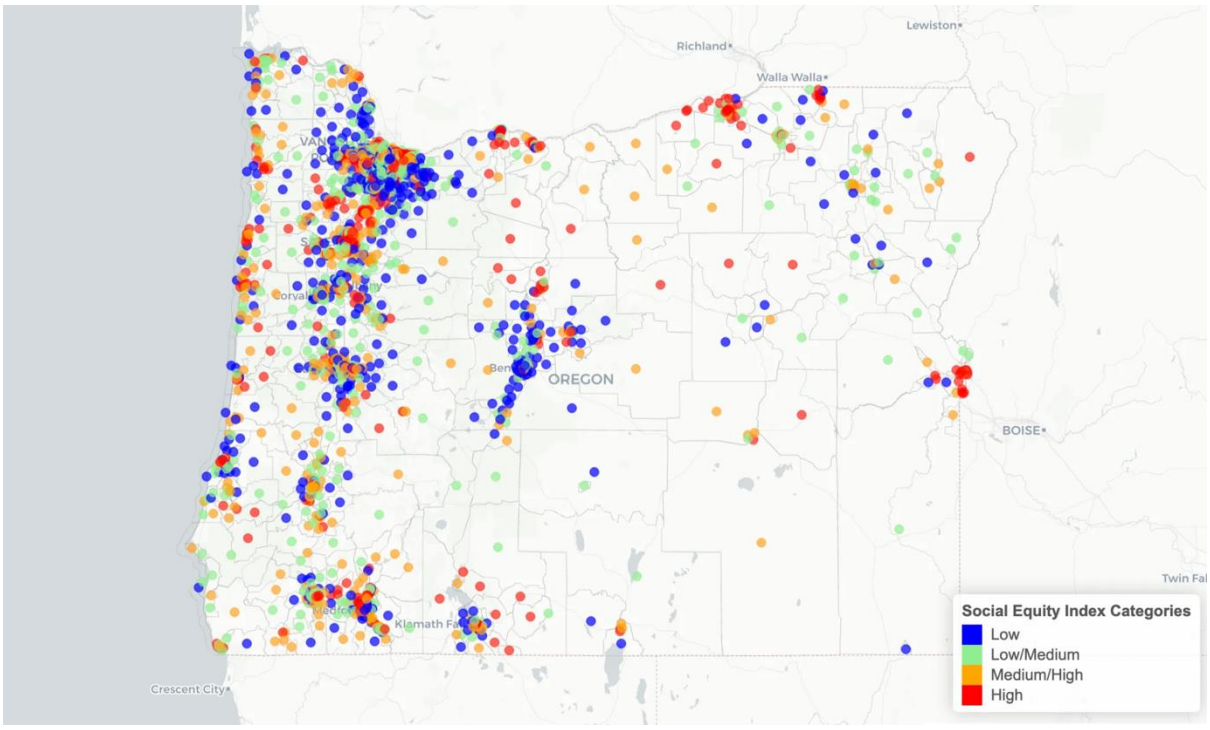


Figure 3 Social Equity Index (based on ACS 2019 – 2023 5-year data)

Analysis Approach

To incorporate SEI into a BCA equity analysis, we adapt the methodology used in EPA's EJSCREEN, which combines environmental indicators with demographic data to identify locations where vulnerable populations face disproportionate environmental burdens. EJSCREEN calculates an Environmental Justice (EJ) Index using the following formula:

EJ Index = (Environmental Indicator) x (Demographic Index for Block Group - Demographic Index for US) x (Population count for Block Group)

In this equation, environmental indicators represent environmental burdens (e.g., air pollution, hazardous waste exposure). The demographic index is the average of the percentage of minority and low-income residents. Subtracting the national average highlights whether a block group has more or fewer vulnerable individuals relative to the U.S. as a whole. Multiplying by population count scales the measure to reflect the number of people affected. In practice, EJ Index values are then converted into percentiles, allowing comparisons across geographies.

We utilize a similar adaptation for BCA equity analysis:

BCA Equity Index = (Net Benefit per capita) x (Z_{SEI}) x (Population count for Block Group)

Where Z_{SEI} represents the z-score of the SEI for each census block group (the number of standard deviations by which a block group's SEI value differs from the Oregon [or study area] mean SEI value).

In this formulation, the impacts requiring equity consideration (e.g., safety outcomes, travel time savings) are weighted by the relative social vulnerability of each block group compared to the state or study area average. The result is then scaled by population count. This BCA equity index enables analysts to measure and compare how benefits and costs are distributed across socially vulnerable populations, quantifying the distribution of net benefits weighted by social vulnerability.

To assess the relative equity status of each block group, the BCA Equity Index is then converted into percentile measures to allow for comparison across geographies (as long as the comparison group chosen is consistent), regardless of differences in absolute magnitude or population size. Percentiles show how a block group compares to others in the state or study area and is calculated as the number of residents in block groups with equal or lower BCA equity index values divided by the total population with valid data.

- High percentiles (≥ 75%) represent the top quartile of equity-weighted net benefit distribution, identifying the most significantly affected socially vulnerable block groups.
- Above average percentiles (≥ 50%) indicate block groups where residents experience above-average equity-weighted net benefits; in other words, these are areas with relatively higher social vulnerability and greater proportional access to project net benefits.
- A 50^{th} percentile value indicates block groups where social vulnerability and net benefit levels are near the study-area average.
- Low percentiles (≤ 25%) denote block groups with below average equity-weighted net benefits, typically less vulnerable or less directly affect populations.

The BCA Equity Index is designed to facilitate within-project equity analysis, allowing comparison of how net benefits are distributed among block groups in a study area. In order to support evaluation across projects or study areas, the BCA Equity Index will need to be standardized using the Oregon statewide mean and standard deviation; and then, the percentile results can then be utilized for comparisons.

<u>Example of BCA Equity Index calculation: Emission Reduction Benefit Parameter</u>

- Project: Conversion of a 4-lane roadway to a 3-lane road over a 3-mile segment.
- Emission Reduction Benefits: The project is expected to reduce daily traffic along the corridor by approximately 2,000 vehicles. Using the methodology described above, the estimated emission reduction benefits are calculated as XXXX, which benefit each affected individual in the area equally.
- Equity Analysis:

- Step 1. Define the geographic boundary of analysis.
  A buffer of 0.3 miles is applied, consistent with the literature where this distance is identified as the average area of impact for traffic-related air pollution (Figure 4).
- Step 2. Calculate the BCA Equity Index.
  The BCA Equity Index may be calculated relative to different comparison areas, usually the study area itself or the state. In this study area of 12 block groups, the average SEI is approximately 17.42; in Oregon, the average 2023 SEI is about 17.42. The following calculations utilize the study area as the comparison group.
- Step 3. Convert the BCA Equity Index into a percentile.
  The percentile is determined by summing the population of block groups with a BCA equity index value equal to or lower than the block group of interest and dividing by the total population.

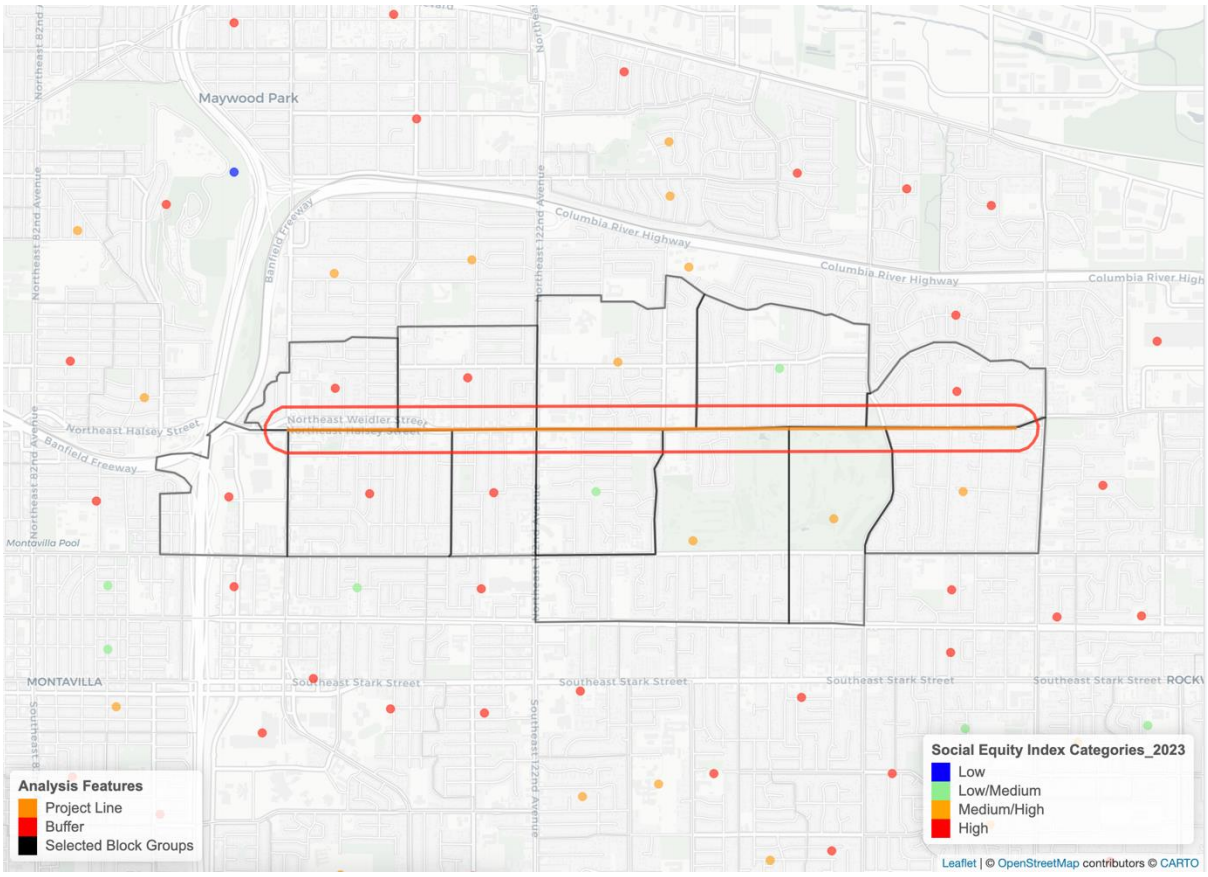


Figure 4 Example of BCA Equity Index Geographic Boundaries

- Results and Interpretation:
  Table 39 presents the results of the equity analysis. The BCA Equity Index is calculated using the study area as the comparison group, rather than the entire state of Oregon. In this example, because emission reduction benefits are identical across all block

groups, differences in the BCA Equity Index are determined by population size and SEI values. If differentiated impact values can be calculated for each block group, those values should be applied instead. Those block groups with positive BCA Equity Index values

The percentiles represent the relative share of equity-weighted net benefits for each block group within the study area. Higher percentiles identify block groups within the study area where net benefits disproportionately accrue to more socially vulnerable populations. For example, block group 410510081003 ranked at a percentile of 100%, indicating that this population received the largest total equity-weighted net benefit from the emissions reduction. Similarly, block group 410510080012 with a percentile of 86.9%, also indicating strong net benefits accruing to the highly vulnerable population in this block group. Block group 410510093021 is ranked at 7.03% percentile, denoting its low social vulnerability and the least amount of relative equity-weighted benefits.

Table 39 BCA Equity Index and Percentile Values Relative to the Study Area

GEOID	Population	SEI Value	SEI Categories	BCA Equity Index	Percentile
410510094005	1180	19	High	Benefit x 526	59.81%
410510081003	2482	22	High	Benefit x 3,201	100.00%
410510093022	2358	16	Medium/High	Benefit x -940	43.95%
410510093023	1149	15	Medium/High	Benefit x -781	50.02%
410510093011	2196	15	Medium/High	Benefit x -1,493	18.64%
410510093021	1330	13	Low/Medium	Benefit x -1,653	7.03%
410510094002	1531	15	Medium/High	Benefit x -1,041	31.49%
410510094003	901	12	Low/Medium	Benefit x -1,373	23.40%
410510080012	1190	23	High	Benefit x 1,870	86.88%
410510080022	1806	20	High	Benefit x 1,313	69.35%
410510081001	671	19	High	Benefit x 299	53.57%
410510081002	2127	20	High	Benefit x 1,546	80.59%

Appendix C – Social Cost of Carbon (annual unrounded values)

Emission year	2.5% sensitivity case	Reference case (2.0%)	1.5% sensitivity case
2024	$152	$248	$424
2025	$155	$252	$429
2026	$158	$256	$434
2027	$162	$261	$440
2028	$165	$265	$446
2029	$168	$269	$452
2030	$171	$274	$457
2031	$175	$279	$463
2032	$179	$282	$469
2033	$182	$287	$474
2034	$184	$292	$480
2035	$188	$295	$486
2036	$192	$300	$490
2037	$195	$305	$496
2038	$199	$308	$502
2039	$202	$313	$507
2040	$206	$318	$513
2041	$209	$323	$519
2042	$213	$327	$525
2043	$217	$332	$531
2044	$221	$337	$537
2045	$225	$342	$543
2046	$229	$346	$550
2047	$232	$352	$556
2048	$237	$357	$562
2049	$240	$362	$568
2050	$244	$367	$574

Source: EPA (2023)

Appendix D – Monetized Values for Journey Quality Benefits

Appendix D-1. Pedestrian Facility Improvements Revealed Preference Values

Parameter	Value (2024$/year)
Expanded Sidewalk (per foot of added Width)	0.11
Reducing Upslope by 1%	1.23
Reducing Traffic Speed by 1 mph (for speeds <= 45mph)	0.10
Reducing Traffic Volume by 1 Vehicle per Hour (for ADT<=55,000)	0.0011
Install Marked-Crosswalk on Roadway with Volumes >=10,000 Vehicles per Day	0.22
Install Signal for Pedestrian Crossing on Roadway with Volumes >= 13,000 Vehicles per Day	0.56

Parameter	Value (2024$/year)
Cycling Path with At-Grade Crossings	1.74
Cycling Path with no At-Grade Crossings	2.18
Dedicated Cycling Lane	2.07
Cycling Boulevard/"Sharrow"	0.33
Separated Cycle Track	2.07

Appendix D-2. Transit Facility Amenity Revealed and Stated Preference Values

Parameter	Value (2024$/year)		
	Bus Stop	Light Rail / Streetcar Stop	Rail Station
Clocks	0.04	0.04	0.07
Electronic Real-Time Information Displays	0.36	0.17	0.99
Information/Emergency Button	0.27	0.27	0.12
PA System	0.36	0.06	0.11
Platform/Stop Seating Availability	0.22	0.15	0.14
Platform/Stop Weather Protection	0.29	0.18	0.14
Restroom Availability	0.16	0.16	0.12
Retail/Food Outlet Availability	0.12	0.12	0.07
Staff Availability	0.08	0.03	0.20
Step-Free Access to Station/Stop	0.37	0.37	0.24
Step-Free Access to Vehicle	0.48	0.08	0.08
Surveillance Cameras	0.36	0.36	0.37
Temperature Controlled Environment	0.72	0.72	0.72
Ticket Machines	0.12	0.12	0.07
Timetables	0.27	0.11	0.54

Bike Facilities	-	-	0.11
Car Access Facilities	-	-	0.13
Elevator	-	-	0.08
Escalators	-	-	0.04
On-Site Ticket Office	-	-	0.11
Taxi Pickup/Dropoff	-	-	0.06
Waiting Room	-	-	0.24

Appendix D-3. Transit Vehicle Amenity Values

Parameter	Value (2024$/year)		
	Bus	Light Rail / Streetcar	Rail
Electronic Real-Time Information Displays	0.25	0.25	0.26
Handrails	0.14	0.14	0.36
Luggage Storage	0.10	0.10	0.10
PA System	0.44	0.44	0.45
Surveillance Cameras	0.26	0.26	0.72
Temperature Control	0.36	0.14	0.54
Wheelchair Space	0.05	0.05	0.05
Food Service Availability	-	-	0.03
Restroom Availability	-	-	0.22

Appendix D-4. Transit Mode Boarding and Ride Quality Revealed Preference Values

Parameter	Value (2024$/year)	
	Boarding Quality Benefit	Vehicle Ride Quality Benefit
Low-Intensive BRT	0.36	0.43
Medium-Intensive BRT	0.72	0.86
High-Intensive BRT	1.80	1.73
Streetcar or On-Street Light Rail Light	2.16	2.16
Off-Street Light Rail Transit	3.61	3.89
Heavy Rail	3.97	4.32
Commuter Rail	5.77	4.32
Ferry	3.97	4.32

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