# Appendix C: Benefit-Cost Analysis

The PSRC has reviewed the Sound Transit System Plan methodology for Benefit Cost Analysis and found that methodology to be appropriate.

## ST3 Regional High-Capacity Transit System Plan

# Benefit-Cost Analysis Methodology and Results

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# Contents

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# Acronyms and Abbreviations

| | |
|---|---|
| B/C | Benefit-cost |
| CT | Community Transit |
| ERP | Expert Review Panel |
| ESD | Washington State Employment Security Department |
| FTA | Federal Transit Administration |
| HCT | High capacity transit |
| HVAC | Heating, ventilation and air conditioning |
| KCM | King County Metro |
| O&M | Operations and maintenance |
| PSRC | Puget Sound Regional Council |
| PT | Pierce Transit |
| R&R | Rehabilitation and Replacement |
| ST | Sound Transit |
| ST2 | Sound Transit 2 system plan (approved by voters in November 2008) |
| ST3 | Sound Transit 3 system plan |
| TIGER | Transportation Investment Generating Economic Recovery |
| TMP | City of Seattle Transit Master Plan |
| VMT | Vehicle Miles Traveled |
| YOE | Year of Expenditure |

# 1 Introduction

In 2014 Sound Transit embarked on a wide-ranging study to develop a plan for the agency's third phase of major transit investments, referred to as ST3. This document provides a methodology for conducting a comprehensive benefit-cost (B/C) analysis of the eventual proposed program of high capacity transit (light rail) and related investments resulting from the ST3 planning effort. The B/C methodology, and ultimately its application to provide an evaluation of the ST3 program, is provided to ensure consistency with the PSRC's overall transportation plan and applicable evaluation measures.

As such, this report reviews the state-of-the-practice in performing B/C analysis for transit investments in the United States, including a review and refinement of the benefit and cost assumptions applied in the previous ST2 B/C analysis conducted in 2007-08. In addition, the review identifies the universe of benefits and costs potentially quantifiable for consideration in the ST3 B/C analysis, as well as procedures for estimating/quantifying them.

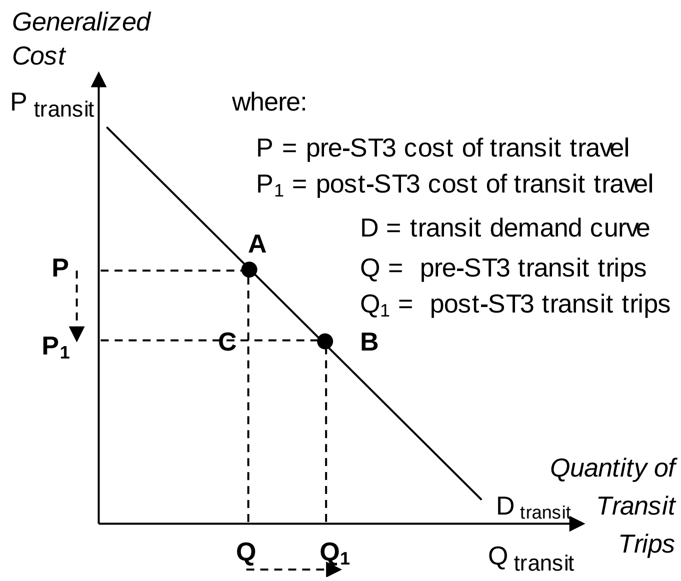
Based on the review of current practice and an assessment of available information from the existing Sound Transit and PSRC demand models, this document outlines the approach and methodology to be used for conducting a B/C analysis of the ST3 light rail investments. The approach identifies the benefits considered/quantified; procedures for doing so; data requirements from existing sources; capital, operating and maintenance cost data requirements; and key analysis assumptions including justifications for those assumptions.

As indicated in Appendix B - Benefit-Cost Analysis Results, this analysis shows that the anticipated, quantifiable benefits from the ST3 light rail transit investments exceed the anticipated costs of the investments net of their residual values. It is important to note this analysis does not include all of the potential benefits that light rail investments will contribute to region which are further outlined on pages 21-23. While the construction period for such a large investment program requires a significant period of time before full benefits can be realized, the value of providing additional transportation capacity in new right-of-way is ultimately substantial, benefitting tomorrow's transportation system users and supporting the continued economic growth expected for the region's future.

# 2 Background and Current Practice

The basic paradigm for estimating benefits, used almost universally in transportation B/C studies, is consumer surplus. People will travel to a destination using their selected mode when the overall cost of travel is less than or equal to the benefit of travel, where the benefit is essentially the maximum cost that they would be willing to incur for that travel. When the cost is less than this "willingness to pay", the difference between the two is referred to as the "consumer surplus". It represents the benefit of travel above and beyond the required cost. This concept as it relates to transit is illustrated in Exhibit 1.

Exhibit 1 - Change in Transit Consumer Surplus due to Reduced Cost of Transit Use

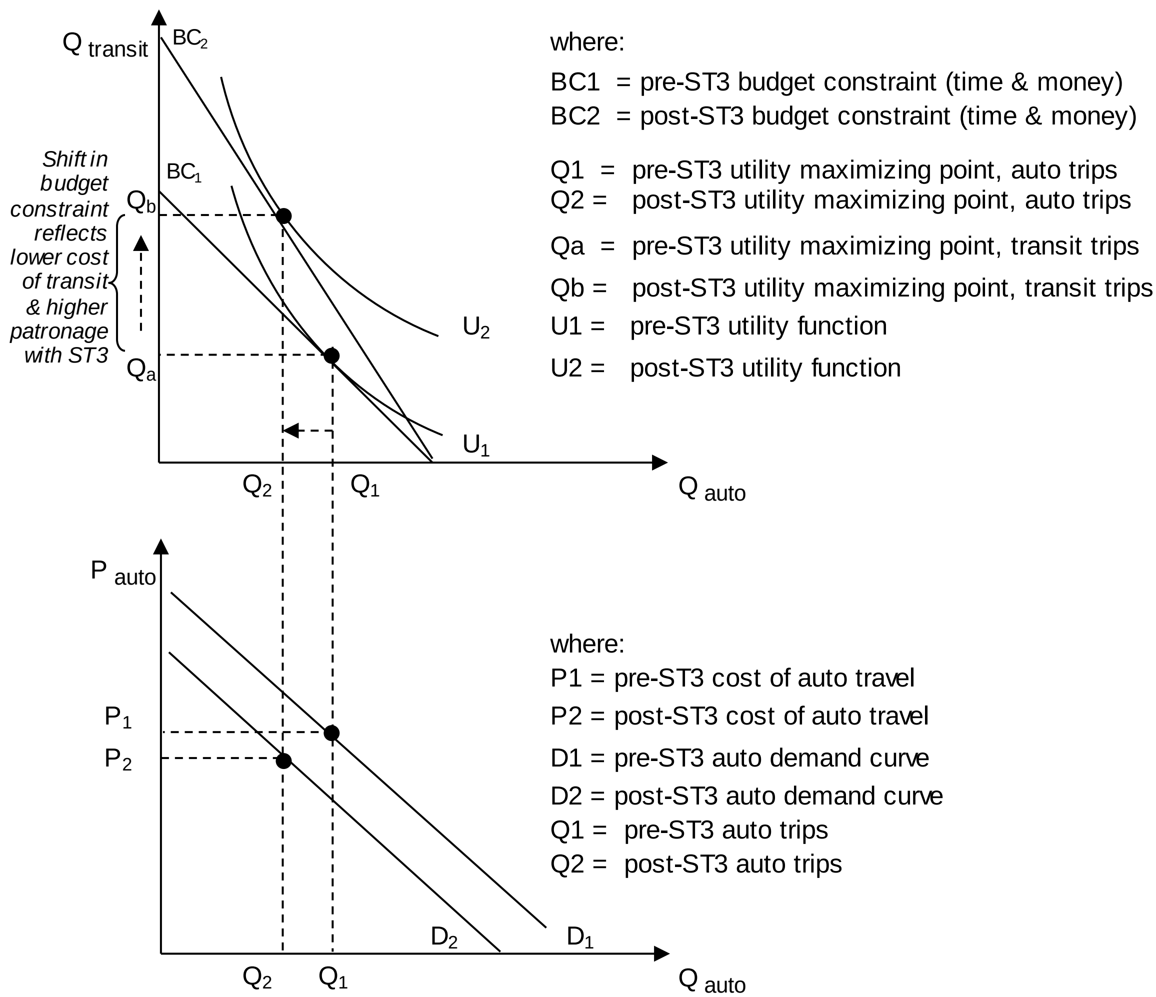



The downward sloping line D represents the travel demand curve or function for transit — at lower generalized travel costs, people travel more often and/or more people travel via transit. In this example, the existing transit infrastructure would accommodate Q trips at generalized travel cost P (travel time plus out-of-pocket costs) prior to the ST3 light rail investments. The area above P and below the demand curve D represents the collective costs that users are willing to incur above and beyond what they have to spend for travel level Q. This area represents the benefit or "consumer surplus" of transit travel at levels P and Q.

After the proposed ST3 investments, the marginal cost of transit travel falls from P to P1, reflecting reduced overall travel time, reduced out-of-pocket costs, or new transit service in areas which did not previously have transit. As the cost of using transit declines and more people use transit, there are more opportunities in which transit use is economically attractive and the number of transit trips generated increases from Q to Q1. Area PABP1 is the increase in consumer surplus, which includes gains to both existing riders/level of travel Q (the rectangular area bounded by PACP1) in the form of lower costs (e.g., time savings) and the benefits to new transit riders/additional travel Q1 minus Q (the triangular area bound by ABC).

For comparison, Exhibit 2 illustrates the pre- and post-transit investment impacts on auto travel demand and the corresponding changes in consumer surplus from the mode shift to transit.

Exhibit 2 – Change in Auto Consumer Surplus due to Reduced Cost of Transit Use




*Long term gain in consumer surplus (auto) = $(P_1 - P_2) \times Q_2$, resulting from reduction in cost of auto travel for existing auto users, due to reduced congestion from mode shift to transit.*

The top graph in Exhibit 2 shows a median traveler's utility function (U1) subject to a transportation time and monetary budget constraint (BC1), and how the modal split would change when the generalized cost of transit use decreases due to the ST3 investments. The resultant mode shift to transit with ST3 is reflected in BC2 (at a lower cost, utility is maximized with more transit trips and less auto trips). The change in transit trips from Qa to Qb matches that shown for the transit demand curve in Exhibit 1. The bottom graph in Exhibit 2 shows the impact on the demand for auto travel as the transit mode is substituted for some auto trips. This is represented by the inward shift in the auto demand curve, which reflects that at any given price or cost for auto travel, there would be a lower level of auto trips after the ST3 improvements. The mode shift from auto to transit combines with the decline in highway congestion to lower the overall cost of auto travel for those trips that remain. The net gain in consumer surplus or benefit to remaining auto travel is represented by the area calculated as (P1 – P2) × Q2.

To actualize the consumer surplus concept, B/C analysis is largely dependent on the outputs generated from travel demand models, which typically produce data in the form of matrices of trips, times, and costs on the network. In practice, this involves outputs for a 'no action' case, which then becomes a basis of comparison

from which to measure the changes in consumer surplus attributable to the alternative case with transit improvements. In measuring the direct benefits to transit users, the consumer surplus calculations are made for transit trips by origin-destination (O-D) pair. Other mobility benefits are primarily estimated as functions of the highway O-D matrices or trip tables, vehicle miles traveled (VMT) data, and model input assumptions.

Note that by assuming a linear demand curve over the range of change in travel costs (P to P1), gains in consumer surplus (CS) accruing to transit users from reduced transportation costs and increased ridership can be estimated as the area of rectangle, PACP1 (gains to existing riders) plus the area of triangle ABC (gains to new transit riders). The formula for this is:

$$\Delta\ CS = \underbrace{[\ (P - P1) \times Q\ ]}_{\text{Rectangle Portion}} + \underbrace{[\ \tfrac{1}{2} \times (P - P1) \times (Q - Q1)\ ]}_{\text{Triangle Portion}}$$

For the ST3 light rail investments, the Sound Transit and PSRC travel demand models are used to estimate transit and highway user benefits, respectively, relative to the case without the ST3 investments. Note that because current travel demand models are only capable of counting “new riders” as those who shift from other modes, they likely underestimate transit user benefits by not also accounting for “induced trips”. In reality, the ST3 investments are also likely to increase the overall level of travel within the region because they will increase accessibility and potentially generate some trips that would otherwise not be made.

There are also indirect mobility benefits to the rest of the system, primarily highway user benefits generated due to some highway travelers shifting modes to transit. The analysis assumes that benefits for travelers who continue to use the highway network include improved travel times/mobility, vehicle operating cost (VOC) savings, parking cost savings, and savings from a reduction in vehicle collisions (these benefits are discussed later in the paper).

Though not necessarily recognized by individual users in their own actions, societal benefits may also be accounted, and include savings in the societal/external cost of highway collisions and savings in environmental costs such as air pollution. Because these benefits are primarily associated with reduced automobile travel or less congestion, an implicit assumption is that new highway trips are not induced by the ST3 investments directly or indirectly through alleviating highway congestion via mode shift. This will be discussed in more detail in the following section. Exhibit 3 summarizes these three categories of benefits.

Exhibit 3 — Categories of Benefits

| | | |
|---|---|---|
| ***Direct Transit User Benefits*** The economic value of changes in consumer surplus (for both existing and new transit riders) | ***Indirect Highway System User Benefits*** The economic value of congestion reduction impacts within the highway network due to mode shift to transit | ***External/Societal Benefits*** The net economic value of reduced pollution, noise and energy use arising from changes in travel behavior |

# 3 Key Analytical Assumptions

Several analytical and procedural assumptions are required to apply B/C analysis methods to the available data and unique conditions regarding the proposed ST3 light rail investments. The following outlines these assumptions and their basis.

## 3.1 Real Discount Rate

A real discount rate measures the risk-free interest rate that the market places on the time value of resources after accounting for inflation. Put another way, the real discount rate is the premium that one would pay to have a resource or enjoy a benefit sooner rather than to have to defer it until later. For example, most people would prefer and thus, place a higher value on taking a vacation now instead of waiting ten years into the future, illustrating the preference for having a resource (vacation) or the choice to have it sooner rather than later. As such, the values of future resources must be discounted.

Benefits and costs are typically valued in constant (e.g., 2015) dollars to avoid having to forecast future inflation and escalate future values for benefits and costs accordingly. Even in cases where costs are expressed in future, year of expenditure values, they tend to be built upon estimates in constant dollars, and are easily deflated. The use of constant dollar values requires the use of a real discount rate for present value discounting (as opposed to a nominal discount rate).

For evaluation of ST3 investments in the B/C analysis, all benefits and costs are expressed in constant 2015 dollars. Cost estimates are provided in 2015 dollars while figures used to calculate the dollar values of benefits that are based in other (historical) years are converted to 2015 dollars using the Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) as estimated for the Seattle-Tacoma-Bremerton metropolitan statistical area (MSA).

For a given evaluation period, U.S. government securities of similar maturity provide an approximate estimate of the time value of resources reflected in a real discount rate, where the real rate is a "Treasury Inflation-Indexed" bond of the same maturity. Historically, this risk-free real interest rate has generally been within the range of 2.0 to 4.0 percent, with the average 30-year TIPS rate from 2000-2009 at 2.65%. However, the current TIPS rate of 0.67% reflects the presently low real interest rates, which averaged 0.9% from July 2011 to July 2016 (30-year rate) with no indication that rates will increase substantially, despite the economic recovery from the Great Recession.

Choosing an appropriate real discount rate is essential to appropriately assessing the costs and benefits of a project. The higher the real discount rate, the lower the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the real discount rate tends to reduce the net present value or economic feasibility of the investment. Use of the current, historically low current TIPS rates as a basis for a real discount rate in the ST3 B/C analysis runs the risk of optimistically over-estimating future benefits. As a result, a more conservative approach is proposed for the ST3 B/C analysis.

Federal guidance requires present value discounting using real interest rates published by the United States Office of Management and Budget's (OMB) Circular A-94. In the ST2 analysis a real discount rate of 3% was applied, consistent with OMB's 2008 guidance. OMB's 2015 guidance indicates a real interest rate of 1.5% for 2016; for this analysis, the real discount rate proposed for evaluating the ST3 investments remains at 3.0% for consistency with long-term historical averages. Given current interest rates for risk free investments in the present economy, the rate may be regarded as high, and thus conservative in terms of estimating the present

value of future benefits. In June 2016, the Federal Transit Administration (FTA) indicated that a real discount rate of 2.0% should be used to evaluate projects applying for New Starts, Small Starts, and Core Capacity grant funding, according to the FTA Standard Cost Categories (SCC) workbook.[1] Based on this latest information, as a sensitivity test Sound Transit will also calculate a benefit-cost range using a 2.0% real discount rate. Therefore, results will show a range, based on the use of the 2.0% real discount rate as a sensitivity test as well as the 3.0% real discount rate.

## 3.2 Evaluation Period

Benefits and costs are typically evaluated for a period that includes the construction period and an operations period ranging from 20-50 years after the initial project investments are completed. Given the permanence and relatively extended design life of light rail transit investments, longer operating periods, and thus, evaluation periods are often used. However, beyond 50 years, the ability to forecast meaningful future benefits and costs is increasingly difficult, and any such values contribute less to the results, given the high degree of present value discounting this far into the future.

For the ST3 B/C analysis, the evaluation period includes the relevant (post-design) construction period during which capital expenditures are undertaken, plus 40 years of operations beyond project completion within which to accrue benefits.

For the purposes of this study, it has been assumed that construction of the ST3 investments will begin in the year 2021 and will be close to completed and fully operational by the end of 2039. As a simplifying assumption, all benefits and costs are assumed to occur at the end of each year. Since some investments will come on-line in an incremental manner, generating partial benefits and operating costs prior to the first year of full system operations in 2040, a three-stage approach to the calculation of the annualized B/C was employed. Exhibit 4 below provides a description of each of the three stages.

Exhibit 4 — Evaluation Period Stages

| Stage | Measure | Values or Assumptions |
|---|---|---|
| **Stage 1:** | **Timeline** | From 2021 through 2024 |
| | **Benefits** | None Modeled |
| | **Costs** | Yearly capital construction costs. |
| **Stage 2:** | **Timeline** | From 2025 through 2039 |
| | **Benefits** | Partial system light rail benefits ramp up in proportion to capital expenditures through 2039, the assumed year prior to full system operating benefits (program construction closeout finishes in 2042) |
| | **Costs** | Yearly construction capital costs, escalating system LRT O&M costs, and periodic R&R expenditures. |
| **Stage 3:** | **Timeline** | From 2040 through 2072 |
| | **Benefits** | Full light rail benefits. |
| | **Costs** | LRT O&M costs; periodic R&R expenditures; and residual value (negative) costs at the end of the evaluation period. |

[1] *Final Interim Policy Guidance Federal Transit Administration Capital Investment Grant Program* https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FAST_Updated_Interim_Policy_Guidance_June%20_2016.pdf

## 3.3 Study Region Definition

The geographic coverage of the ST and PSRC travel demand models dictates the study region for the ST3 B/C analysis. While the ST service district represents the urbanized subset of King, Pierce and Snohomish Counties, for purposes of measuring mobility benefits, the entire region becomes the defined area for which the models outputs apply. Benefits from the ST3 investments accrue within the ST district since that is where the investments are made but extend to residents beyond the ST boundary in the region. As such, the ST3 B/C analysis considers the ST service area shown in Exhibit 5 as well as the trips from outside the service area that enter the district from which benefits and costs are measured.

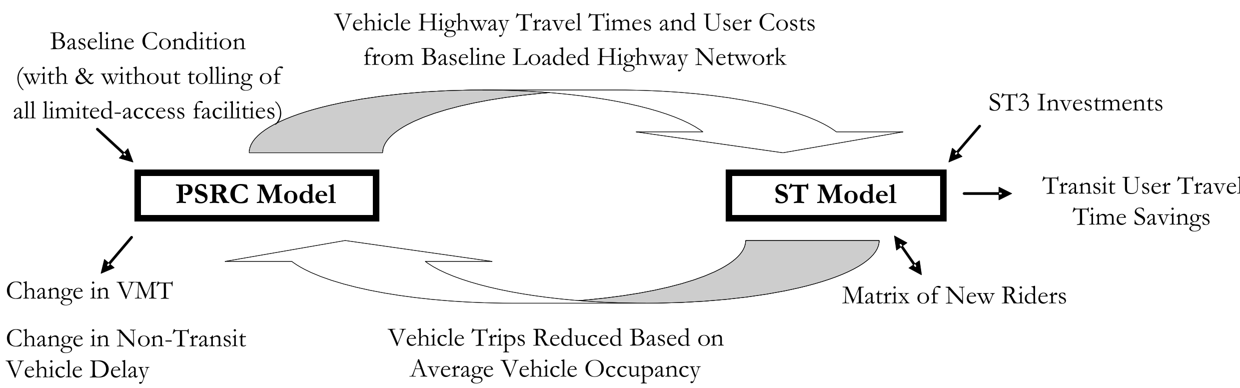
Exhibit 5 — Sound Transit District Map

## 3.4 Travel Data Sources and Forecast Years for Transit and Highway Benefits

### 3.4.1 Travel Demand Models

The Sound Transit and PSRC regional travel demand models are used in tandem to forecast future travel patterns by mode, and to estimate transit and highway user benefits, respectively. The ST travel demand model provides the transit ridership and cost data for calculating direct transit user benefits as changes in travel time between the ST3 investment case and the no-build basis of comparison. Exhibit 6 provides a graphical summary of how the two models are linked together to provide multi-modal travel data.

Exhibit 6 — ST and PSRC Model Linkages for Producing Multi-Modal Travel Data




The baseline highway conditions including travel times and user costs from the PSRC model are fed into the ST model. This results in differing travel behaviors before and after the ST3 investments, from which the change in consumer surplus or transit user benefits may be calculated. To the extent that the ST3 investments cause a mode shift from autos to transit, person-trips using autos (and hence, vehicle-trips) will be reduced. In addition, the transition from selected tolling of those facilities currently authorized to tolling of all limited-access facilities in 2040 will require modeling baseline highway conditions and ST3 ridership under both future tolling conditions in order to simulate the phase-in of full tolling. The reduction in vehicle trips is fed back to the PSRC model to provide overall changes in VMT at an aggregate link level, and the change in (non-transit) vehicle travel times due to improved flow conditions. These outputs form the basis for calculating the indirect and external benefits of the transit investments, which are covered in detail in the next section.

### 3.4.2 Time Periods, Forecast Years, and Discounting/Extrapolation Assumptions

The assessment of highway and transit user mobility benefits will rely on PSRC and ST model results for three future years, 2025, 2035, and 2040, under multiple future conditions, as shown in Exhibit 7. Different combinations of these model results will be used to determine growth rates for various benefit categories to allow the interpolation and extrapolation of such benefits generated from light rail investments over the Stage 2 (2025-2039) and Stage 3 (2040-72) evaluation periods. Stage 2 benefits will reflect a ramp-up of the ST3 investments coming on-line over time. For the Stage 3 period, completed system benefit estimation will consider the aforementioned transition to full tolling of all limited access facilities by 2040. Beyond the 2040 model year a constant growth rate of 1.5% per year is assumed for both ridership and associated operation and maintenance costs. This assumption is made to reflect the additional uncertainty associated with growth in more distant years with the possibility of distant future regional growth being less than the rates predicted for the final phases of ST3 buildout of approximately 4% per year (2035-40).

Exhibit 7 — Model Forecast Years and Cases Used for Interpolating and Extrapolating Growth in Benefits

| Model and Case / Forecast Year | ST Transit Ridership Model | | PSRC Regional Model | |
|---|---|---|---|---|
| | *No Build Basis of Comparison / Existing ST2 Only* | *Build Case / Full ST3 Investments* | *Existing & Authorized Toll Facilities Only* | *Road User Charges, 4 cents offpeak, 6 cents peak (2014 $)* |
| **2025** | ✓ | ✓ | ✓ | ✓ |
| **2040** | ✓ | ✓ | ✓ | ✓ |

## 3.5 Highway Impacts of Mode Shift to Transit

ST3 investments are expected to encourage some auto travelers to switch to transit (i.e., cause a mode shift from highway to transit travel). Under congested highway conditions, this mode shift would likely result in one or both of two types of impacts. The first impact is that the new auto "spaces" in the highway network created by fewer auto trips would improve traffic flow and speed conditions, thereby generating time savings for the remaining highway users and creating other benefits associated with reduced VMT. The second impact is that latent demand would fill the vacated highway spaces with new auto trips—increasing the overall number of trips in the region—and the level of highway congestion would not change in the long term. Travel is beneficial, and new (induced) auto trips would occur because the generalized cost of travel would be lowered in the short term such that the beneficial value of new highway travel would equal or exceed their cost of making a trip.

If the analysis were to recognize that the vacant spaces would be completely filled by new auto users, it would not be appropriate to also include benefits associated with higher highway speeds and reduced aggregate VMT, as these initial benefits would not be sustained. Instead, benefits would be characterized as the total benefits of travel accruing to the net new highway users rather than the additional benefits accruing to continuing highway users and the external (social) benefits of reduced auto travel. In reality, probably a mix of both impacts would occur — there would be some highway mobility improvements due to the transit mode shift, and some induced highway demand.

While the users' economic value of induced highway trips could, in theory, be estimated (e.g., the value of a newly induced auto trip is greater than or equal to the total time and costs of the trip), the current state-of-the-practice is to assume that no additional highway trips are generated as the result of a transit investment. In other words, any increase in highway capacity resulting from a mode shift to an improved transit system would NOT be immediately replaced by new auto users. Most studies opt for this simplifying assumption, partly due to constraints in travel demand model outputs (i.e., most travel demand models are unable to capture induced highway auto trips). There is industry debate regarding the existence of induced highway demand, but most experts agree that vacated highway spaces will be filled by other vehicles in the long term. If it were accepted that induced demand occurs, the available tools for estimating the level of induced travel as well as for estimating the overall combined impact of the two potential reactions (flow improvement and induced trips) have limitations. The PSRC travel demand model is similar to other regional travel demand models in that it cannot directly estimate the level of induced highway demand. Moreover, the benefits of highway flow improvement could ultimately be very similar to the benefits of new trips with no change in flow conditions.

Accordingly, the ST3 B/C analysis excludes the potential new auto trips and associated benefits induced by vacant spaces on the highway network, and focuses on the highway benefits of improved flow for remaining travelers after a transit mode shift, acknowledging that the actual combined effect of induced trips and flow benefits, if predictable by the current modeling tools, would likely equal or exceed the predicted mobility benefits arising from improved flow conditions only.

## 3.6 Travel Time Savings Considerations and Value of Time Assumptions

### 3.6.1 General Discussion of Travel Time Savings and Reliability

Travel time savings include walk time, wait time, and in-vehicle travel time savings. Travel time is considered a cost to users, and its value depends on the disutility (cost or disbenefit) that travelers attribute to time spent traveling. A reduction in travel time would translate into more time available for work, leisure, or other activities, which travelers value.

Travel time reliability is also valued by users and reliability is an important beneficial characteristic of light rail transit service. It has a direct impact on service quality, travelers' perceptions, mode choice, travel time budgets, and user benefits. In essence, reliability refers to the consistency of travel times and wait times. If travel time for a trip is unpredictable, then travelers will need to allow for extra time, effectively making the overall cost of the trip higher.

As a result of having an exclusive right-of-way, the proposed ST3 improvements will enhance travel time reliability for light rail travelers who previously traveled either by bus transit or auto. Accordingly, reliability improvements could be realized by ST3 travelers if they make the following mode shifts:

- **From Bus to Rail** -- The Mid-Ohio Regional Planning Commission (MORPC) travel demand model estimates reliability via an indirect calculation of extra time associated with unreliability through transit wait time curves developed for different modes/service types. In this example, these curves increased transit user benefits by 20-30% on average (PB 2004). Buses are less reliable than rail (unless they use dedicated lanes) because buses operate in traffic. As a result, bus boarding and alighting delays are compounded by traffic congestion, reducing reliability.

- **From Auto to Rail** -- Though research on the reliability effects of mode shift from auto to rail is sparse, a consensus opinion among travel demand modelers is that auto-to-rail reliability gain is equal to approximately half the bus-to-rail amount (per trip) if the rail operates in a separate right-of-way. In over-congested conditions, the lack of auto reliability would approach that of bus; in un-congested conditions, there is probably no reliability gain in most cases.

In most travel demand models and corresponding user benefits calculations, reliability is not estimated explicitly; level of service is characterized by average time and cost components. Such approaches, which tend to compensate for missing measures of reliability with artificially inflated constants (often characterized as "rail biases" in mode choice) lead to an underestimation of user benefits.

The ST and PSRC travel demand models — like most of their counterparts — provide only expected value outputs, and do not directly provide outputs for estimating the additional user benefits due to improved reliability. Accordingly, the ST3 B/C analysis estimates of user time savings benefits would be understated if they relied solely on the changes in travel times derived from the demand models and excluded any potential travel time reliability benefits. However, the ST3 B/C analysis incorporates a demand model post-processing method for conservatively estimating the additional benefits accruing to light rail transit users from improved travel time reliability.

### 3.6.2 Value of Time Assumptions

Travel time savings must be converted from hours to dollars in order for benefits to be aggregated and compared against costs in the analysis. This is normally performed by assuming that travel time is valued as a percentage of the average wage rate, with different percentages for different trip purposes. For this analysis, assumptions for value of time (VOT) estimates, as percentages of the average wage rate, were derived from a review of other studies.[2] This typically involves valuing travel time for personal travel for a work commute purpose higher than a trip for a non-work or discretionary purpose. However, transit trips are not available explicitly by trip purpose in the ST model. As such, peak period travel has been adopted as a proxy for the work commute trip purpose, and off-peak travel is assumed to represent non-work/discretionary trip purposes.

The following assumptions are used for valuing travel time savings.

- **Peak Period Travel** -- Time savings for personal travel (all modes) occurring during the peak period is assumed to be valued at 66.7% (2/3) of the mean wage rate within the central Puget Sound region (King, Pierce and Snohomish Counties). For auto travel, peak period time savings are assumed to apply to all vehicle occupants, which is factored into the model results. For commercial travel an occupancy factor of 1.15 is assumed.

- **Off-Peak Period Travel** -- Time savings for personal travel (all modes) occurring during the off-peak times is assumed to be valued at 50% of the mean wage rate within the central Puget Sound Region. For auto travel, off-peak period time savings are assumed to apply to all vehicle occupants, which is factored into the model results. For commercial travel an occupancy factor of 1.15 is assumed.

The mean hourly wage rates by county are provided by the Washington State Employment Security Department (ESD) employment and wage data for 2014, which is the most recent calendar year available, and factors in adjustments for part-time workers. Weighting each county's average wage by its employment level, the applicable average wage rate is $37.03 per hour for the three-county region. Escalating this figure to 2015 dollars using the Seattle-Tacoma-Bremerton MSA Consumer Price Index factor of 0.12%, the mean hourly wage rate increases slightly to $37.07 per hour, and yields an adjusted peak VOT of $24.71 and an adjusted off-peak VOT of $18.53.

### 3.6.3 Commercial Trip Assumptions

In addition, it is acknowledged that commercial or business-related travel tends to have a much higher value of time than personal travel, whether for discretionary or commute purposes. To account for the different travel behavior and values of time among the various types of commercial trips, the average wage rate-based values of time and the commercial shares of total VMT are evaluated by three sub-categories. The PSRC model provides trip and VMT shares for relative to the total number of trips and VMT by three distinct commercial vehicle sub-categories: commercial and business-related travel in two axle cars and light trucks; medium trucks (two and three axle delivery trucks); and heavy trucks (tractor-trailer vehicles with four or more axles). The shares are based on model outputs and are contingent on the accuracy of underlying data reporting and travel classification by vehicle class[3], and may not fully capture some business-related travel in

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[2] See the citations for Oregon DOT (2004); USDOT, (1997; Revised February 2003); Parsons Brinckerhoff (2004); ECONorthwest and Parsons Brinckerhoff (2002).

[3] VMT percentage shares were derived from PSRC highway model using the PSRC's latest land-use trip-end data. ST highway model is a version of PSRC's regional travel forecasting model used for major WSDOT projects (e.g., SR 520 FEIS) with additional network refinements.

company/fleet vehicles. As such, this approach may represent conservative outcomes in potentially understating the commercial travel VMT shares.

As shown in Exhibit 8, the percentage shares of total VMT associated with each sub-category varies between the peak and off-peak hours, with overall commercial VMT shares of 12.96% and 11.1%, respectively. Two axle commercial vehicles represent the largest share of overall commercial VMT and are assumed to primarily consist of business-related travel. Separate values of time are applied to each of the three commercial travel classes as follows:

- **Two-Axle Commercial Vehicles** — The value of time for two axle commercial trip time savings is assumed to be the weighted average hourly wage rate of $42.58 (in 2014 dollars) derived from ESD data plus an additional 20% for the fringe benefit costs to reflect the marginal burdened costs incurred by the business owner or enterprise, for a total hourly rate of $51.10 in 2014 dollars and $51.16 when converted to 2015 dollars.
- **Medium Trucks** — The value of time saved for medium trucks represent approximately 2.5% of total commercial vehicle VMTs and are assumed to primarily consist of two to three axle local delivery vehicles. According to ESD data, the hourly wage rate for light truck or delivery services drivers for the Seattle-Bellevue-Everett-Tacoma metropolitan area was $18.33 (in 2014 dollars) plus 20% for the fringe benefit costs incurred by the business owner for a total hourly rate of $22.00 in 2014 dollars and $22.02 when converted to 2015 dollars.
- **Large Trucks** — The value of time saved for large trucks represent approximately 2% of total commercial vehicle VMTs and are assumed to primarily consist of longer distance freight movements. According to ESD data, the hourly wage rate for heavy and tractor trailer truck drivers for the Seattle-Bellevue-Everett-Tacoma metropolitan area was $21.71 (in 2014 dollars) plus 20% for the fringe benefit costs incurred by the business owner for a total hourly rate of $26.06 in 2014 dollars and $26.09 when converted to 2015 dollars.

Exhibit 8 — Commercial Trip VMT Shares by Sub-Category and Applicable Hourly Wage Rate-Based Values of Time

| **Commercial Vehicle Categories** | **% of Total Modeled VMT (2035)** | | **Applied Hourly Wage Rate (2015$)** | **Adjust-ment for Benefits** | **Applied Value of Time (2015$)** |
|---|---|---|---|---|---|
| | **Peak** | **Off-Peak** | | | |
| Two axle commercial (includes business-related travel and light trucks) | 7.99% | 6.51% | $42.63 | 120% | $51.16 |
| Medium Trucks (primarily delivery vehicles) | 2.69% | 2.36% | $18.35 | 120% | $22.02 |
| Large Trucks (primarily 4+ axle tractor-trailers) | 2.28% | 2.23% | $21.74 | 120% | $26.09 |
| **Average for All Commercial Vehicles** | **12.96%** | **11.10%** | **$33.92 (peak), $33.27 (off-peak)** | **120%** | **$40.70 (peak), $39.93 (off-peak)** |

### 3.6.4 Value of Time Real Growth Assumption

Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation. Increases in the level of wage and salary incomes per job above and beyond general inflation are referred to as real increases. Between 1970 and 2000, average wage and salary incomes in King County grew at an inflation adjusted average annual real rate of 1.25%, while the State as a whole saw average real growth of 0.73% per

year.[4] Between 2000 and 2012, average wage and salary incomes in King County grew at an inflation adjusted average annual real rate of 1.31%, while the State as a whole saw average real growth of 0.74% per year.[5]

Based on the historical trends for real wages and U.S. DOT guidance the use of a real growth rate of 1.2% per year is assumed from 2015 forward over the project evaluation period.[6]

## 3.7 Annualizing Factor Assumptions

Regional travel demand models produce outputs on a weekday daily or sub-daily basis. For example, the ST Transit model evaluates travel conditions for a three hour peak period (representative of both a.m. and p.m. peak conditions, for a total of six hours out of the day), and an 18-hour off-peak period. Accordingly, annualizing factors are necessary to convert the travel demand outputs associated with each evaluation period to yearly values. For the purposes of ST3 light rail investments, a factor of 320 was applied to the modeled results, consistent with the approach used to derive annual ridership forecast values for the ST3 project.

[4] Calculated from wage and salary data obtained from the Washington State Employment Security Department and price level data from the U.S. Bureau of Economic Analysis' Implicit Price Deflator for personal consumption.

[5] Calculated from wage and salary data obtained from the Washington State Employment Security Department and price level data from the U.S. Bureau of Economic Analysis' Implicit Price Deflator for personal consumption.

[6] Office of the Secretary of Transportation. (2014). *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis (Revision 2),* p. 14. (http://www.dot.gov/sites/dot.gov/files/docs/USDOT%20VOT%20Guidance%202014.pdf)

# 4 Economic Benefits Included in the Evaluation

The following identifies and groups the benefits that are included in the economic evaluation of the ST3 investments.

## 4.1 Transit User Time Savings

Outputs from the ST travel demand model are used to estimate transit user time savings, which tend to comprise the majority of benefits accruing to riders. These time savings benefits are based on the consumer surplus theory/concept outlined in the Key Analytical Section. The ST model generates estimates of peak and off-peak transit travel time savings by trip origin-destination pairs at a zonal level (where there are over 750 zones within the ST boundary area). This approach is consistent with the methodology recommended by FTA to calculate user benefits for New Starts transit projects. As such, it provides peak period and off-peak period summaries of travel time savings at a zone-to-zone or district-to-district level for existing riders as well as for new riders (data is generated for existing and new riders, separately).

Benefits associated with transit travel time savings use the value of time assumptions and growth rates outlined in the Key Analytical Assumptions section. This assumes travel time savings are worth 66.7 percent of the average wage rate for peak period transit trips and 50 percent of the average wage rate for off-peak period transit trips.

Travel time reliability improvements generate additional benefits for transit users and are described in more detail in section 4.8.

## 4.2 Mobility Benefits for Non-Transit Users

As previously discussed, non-transit trips also receive travel time savings from the ST3 investments. The travel time savings benefits for peak period auto travelers, off-peak auto travelers, and commercial vehicles are included using the value of time assumptions outlined in the Key Analytical Assumptions section. This assumes travel time savings are worth 66.7 percent of the average wage rate for all peak period auto trips and 50 percent of the average wage rate for off-peak period (including weekends) auto trips. Commercial travel time savings are valued at 120 percent of selected average wage rates by subcategory as previously indicated in section 3.6.3. The values of time are to be used in conjunction with the output from the PSRC model (i.e., change in VMT and vehicle delay by time period) to estimate the mobility benefits for non-transit users.

## 4.3 Reductions in Vehicle Operating Costs and Auto Ownership Costs

The proposed ST3 investments would not only affect travel times, but they would also reduce vehicle operating and ownership costs for non-transit users. Because some drivers will instead choose to use transit, there will be fewer automobiles on the road, and thus, fewer vehicle miles traveled (VMT). Aside from reducing congestion and increasing vehicle speeds, lower VMT results in quantifiable vehicle operating cost savings. It may also encourage some transit users to own fewer vehicles.

In addition to the ST3 capital investments, the modeling assumes that all limited-access highways within the ST district will be tolled by 2040. For modeling purposes, this has been interpreted as mileage based congestion pricing, with the 2040 cost varying by levels of congestion up to $0.25 per mile (in constant 2015 dollars). This tolling would help to reduce congestion on the primary highways in the region, thereby reducing some costs attributable to congestion and lost time but increasing overall out of pocket operating costs, and contributing to additional congestion on arterial routes and existing transit service.

In terms of costs, shifting from driving to transit reduces overall vehicle miles traveled, which provides savings in the marginal operating costs of auto travel (fuel, tolls, maintenance and tires). Fuel prices are based on the latest June 2016 WSDOT nominal gasoline forecast values deflated to 2015 dollars using WSDOT CPI forecast values. The American Automobile Association estimates the variable, out-of-pocket cost in 2015 dollars for maintenance and tires as 5.11 cents and 0.98 cents per mile respectively for the average sedan.[7] Additional costs attributed to tolling of limited-access roadways will be projected separately.

A reduction in VMT due to the ST3 investments also results in less vehicle depreciation (higher vehicle resale value) and reduced vehicle ownership costs for households that shift to transit. Some households will save money associated with vehicle usage, and a small share will save even more by altering their auto purchase decisions (i.e., reducing the number of vehicles owned). Households that have good transit accessibility and own multiple vehicles are strong candidates to reduce their auto ownership level.

The ST3 B/C analysis assumes that the total reduction in VMT is attributable to reductions in vehicle usage, saving some variable costs associated with vehicle ownership (e.g., depreciation and finance charges). In addition, 10 percent of the reduction in VMT is assumed to be attributable to reductions in auto ownership, which is worth more because it also eliminates the fixed costs associated with ownership (e.g., insurance, licensing, and registration). The analysis uses the values (in 2015 dollars) cited in Exhibit 9 to estimate the benefits of reduced vehicle ownership.[8]

Exhibit 9 — Vehicle Ownership Cost Savings by Vehicle Type

| **Vehicle Ownership Cost Savings Applied to All VMT Reductions** | | | | | | |
|---|---|---|---|---|---|---|
| | Small Sedan | Medium Sedan | Large Sedan | 4WD SUV | Minivan | **Average** |
| Depreciation (15,000 miles per year) | $2,515 | $3,687 | $4,759 | $4,646 | $4,039 | **$3,929** |
| Average Annual finance charges* | $473 | $675 | $858 | $848 | $694 | **$710** |
| Cost per year | $2,988 | $4,362 | $5,617 | $5,494 | $4,733 | **$4,639** |
| Cost per mile | $0.20 | $0.29 | $0.37 | $0.37 | $0.32 | **$0.31** |
| **Additional Vehicle Ownership Cost Savings Applied to 10% of VMT Reductions Resulting from Lower Vehicle Ownership Rates** | | | | | | |
| | Small Sedan | Medium Sedan | Large Sedan | 4WD SUV | Minivan | **Average** |
| Full coverage insurance | $1,071 | $1,106 | $1,167 | $1,058 | $999 | **$1,080** |
| License, registration, taxes | $489 | $671 | $836 | $827 | $688 | **$702** |
| Cost per year | $1,560 | $1,777 | $2,003 | $1,885 | $1,687 | **$1,782** |
| Cost per mile | $0.10 | $0.12 | $0.13 | $0.13 | $0.11 | **$0.12** |

* based on 5-year loan, 10% down, national average interest rate for middle three of five credit rating categories

Because VMT data disaggregated by vehicle type is not available, the ST3 B/C analysis uses the average cost per mile values to calculate vehicle operating cost and vehicle ownership savings.

[7] "Your Driving Costs" (2015); this value is consistent with others reviewed in current literature.
[8] The recommended values were calculated assuming that vehicles drive 15,000 miles per year on average.

In equation form:

Vehicle Fuel Cost Savings = [(Total VMT savings * 100%) / Average US EIA vehicle miles per gallon forecast] * (Forecasted WSDOT Gasoline Price – State and Federal gasoline tax) +

Vehicle Maintenance and Tire Cost Savings = (Total VMT savings * 100%) * ($ 0.0511 + $ 0.0098) +

Vehicle Ownership Savings = [(Total VMT savings * 100%) * $ 0.31] + [(Total VMT Savings * 10%) * $0.12]

## 4.4 Vehicle Collision Cost Savings

Reductions in VMT lower the incidence of traffic collisions or "accidents". The cost savings from reducing the number of vehicular collisions include direct savings (e.g., reduced personal medical expenses, lost wages, and lower individual insurance premiums) as well as significant avoided costs to society (e.g., second party medical and litigation fees, emergency response costs, incident congestion costs, and litigation costs). The value of all such benefits – both direct and societal – could also be approximated by the cost of service disruptions to other travelers, emergency response costs to the region, medical costs, litigation costs, vehicle damages, and economic productivity loss due to workers inactivity.

The state-of-the-practice in B/C analyses is to estimate collision cost savings for each of three types of events (fatality collisions, injury collisions, or property damage only collisions) using the change in highway VMT.[9] Some studies perform more disaggregate estimates of the collision cost savings, applying different savings rates to different types of roadways (e.g., interstate, highway, arterial).

The ST3 B/C analysis estimates the benefits associated with collision cost savings using the PSRC model's estimates of the ST3 investments' impact on VMT for (1) combined interstate and state highways and (2) combined county and city arterials. Based on output from the PSCR model, a 50-50 distributional between VMT savings on arterials and VMT savings on highways is assumed. The change in VMT for each of these roadway facility types is then used to calculate the change in the number of fatality, injury, and property damage only collisions (yielding a total of six collision savings figures) using the collision rates shown in Exhibit 10.

Additionally, this analysis assumes the collision disbenefits of the ST3 investments (i.e. some light rail track will be at-grade and may be involved in crashes) would be offset by the benefits accrued via reduced bus VMT. As such, collision costs associated with increased light rail VMT as well as offsetting benefits from reduced bus VMT have been omitted from this analysis.

[9] National Safety Council (2014)

Exhibit 10 — Vehicle Collision Rate by Facility and Event Type

| Facility Type/Classification | Collision Rates by Type per 100 million VMT | | |
|---|---|---|---|
| | Fatality Collisions | Injury Collisions (Non Fatal) | Property Damage Only Collisions |
| Interstate Highways[10] | 0.39 | 32.0 | 70.0 |
| Combined Principal & Minor Arterials[11] | 1.21 | 59.0 | 107.5 |

The benefits resulting from collision reduction are converted to monetary values using the economic cost of fatal, injury, and non-injury highway crashes cited by the National Safety Council. On a cost per collision basis, a comprehensive valuation of economic costs of collision avoidance is typically higher than the calculable costs of actual motor-vehicle crashes, the latter being limited to an accounting of wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employer costs.

Exhibit 11 shows comprehensive economic costs for avoiding collisions by collision severity, which reflect the willingness to pay for avoidance (these costs are in 2015 dollars).[12] The costs are stated on a per-incident basis and may include more than one person and/or property owner per incident. Collision benefits are equal to the crash rate multiplied by the value of collision avoidance.

Exhibit 11 — Dollar Values of Collisions by Event

| Collision Severity (MAIS Categories) | | Comprehensive Economic Cost of Avoidance (2015$) |
|---|---|---|
| **Fatality Collisions** | Death (MAIS 6) | $9,600,000 |
| **Injury Collisions** | Critical (MAIS 5) | $5,692,800 |
| | Severe (MAIS 4) | $2,553,600 |
| | Serious (MAIS 3) | $1,008,000 |
| | Moderate (MAIS 2) | $451,200 |
| | Minor (MAIS 1) | $28,800 |
| **Property Damage Collisions** | Property Damage Crash (including non-disabling injuries) | $4,198 |

US DOT TIGER Resource Guide, 2016

In 2015 dollars, fatality collisions are valued at $9,600,000, injuries related to nonfatal collisions range from $28,800 to $5,692,800, and property-damage only collisions $4,198.

[10] Source WSDOT, based on data for 2011.
[11] Reflects a VMT average of Principal and Minor Arterials: Source WSDOT, based on 2011 data only.
[12] U.S. Department of Transportation (2015), *Tiger Benefit-Cost Analysis (BCA) Resource Guide*, p.3. (http://www.dot.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf).

## 4.5 Reduced Air and Noise Pollution

The ST3 investments can create environmental benefits by reducing air, noise, and water pollution associated with automobile travel. In addition, transit travel is usually more energy efficient than auto travel (in terms of energy consumed per traveler), creating benefits associated with energy conservation. The state-of-the-practice typically expresses the energy and environmental benefits in a cost per ton basis with VMT savings converted to tons using California Environmental Protection Agency Air Resources Board conversion factors and average highway travel speeds in the region.[13] Exhibit 12 summarizes the estimated average cost per ton assumed for primary air pollutants. Previous assumptions used in ST2 provided a value based on VMT of $0.06 (in 2006 dollars or $0.08 in 2015 dollars) based on total environmental benefits provided across different vehicle types and geographic areas (suburban and urban). However, the current assumptions in Exhibit 12 are preferable as the US EIA and US DOT have approved these values and provide regular updates to them for future application.[14, 15]

Exhibit 12 — Average Environmental Cost Savings (Benefits) for Autos by Pollutant Type

| Pollutant | $/ton in 2015$ |
|---|---|
| Air Quality: Volatile Organic Compounds (VOCs) | $2,032 |
| Air Quality: Mono-Nitrogen Oxides (NOx) | $8,010 |
| Air Quality: Particulate Matter (PM2.5) | $366,414 |
| Air Quality: Sulfur Oxide (SOx) | $47,341 |
| Greenhouse Gases (Carbon Dioxide Equivalent [CO2e]) | $55 |

US DOT TIGER Resource Guide, 2016

The ST3 investments can also contribute to reductions in greenhouse gases that contribute to climate change by encouraging travelers to switch from auto to light rail. Similar to other environmental benefits, a cost per ton estimate would need to be established, however, there is not a widely accepted practice for monetizing contributions to global warming. One of the challenges associated with monetizing global warming impacts is assigning a dollar value to what is essentially a non-reversible effect. Because there is sufficient uncertainty and variability in the environmental cost estimates, the B/C analysis does not adjust the figures in Exhibit 12 to account for global warming impacts.

Reducing VMT creates environmental benefits to society in the form of noise reduction. On a per-VMT basis, these values are estimated based on a Federal Highway Administration (FHWA) cost allocation study report.[16] As the VMT reductions associated with the ST3 project improvements are assumed to result from auto users' switching to light rail, the benefits of reduced noise are based on the entire length of the auto trips that are avoided.

[13] California Environmental Protection Agency Air Resources Board. (2011). EMFAC2011 Emissions Database. (http://www.arb.ca.gov/emfac/)
[14] U.S. Environmental Protection Agency, Interagency Working Group on Social Cost of Carbon (2013), *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,* p.18., Table A1, (https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf).
[15] National Highway Traffic and Safety Administration (August 2012), *Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks*, page 922, Table VIII-16, "Economic Values Used for Benefits Computations (2010 Dollars)", http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf
[16] Federal Highway Administration, *Addendum to the 1007 Federal Highway Cost Allocation Study,* Table 13. (http://www.fhwa.dot.gov/policy/hcas/addendum.cfm ).

An urban/rural split of 94 percent and 6 percent, respectively, was used to create a weighted average of the FHWA values for those environments of $0.00117 per VMT in 2015 dollars.

## 4.6 State of Good Repair – Road Damage

As with noise pollution, reductions in VMT lead to societal benefits in the form of reduced costs of pavement damage. Fewer vehicle-miles diminish the need for maintenance on roads. The per-mile costs of these values are estimated based on the same FHWA cost allocation study report that reported estimates for the cost of noise pollution.[17]

The same urban/rural split used in the noise pollution calculations of 94 percent and 6 percent are used to create a weighted average of the FHWA values. All values are adjusted from the FHWA study's 2000 values to 2015 dollars using a CPI adjustment. The weighted average values for the reduction in road damage is $0.00117 per VMT in 2015 dollars.

## 4.7 Health Benefits Attributed to Transit Ridership

The ST3 investments can create indirect health benefits associated with increased physical activity for new transit users who switch from auto, and walk to and from transit service between their trip origins and destinations. For the purposes of this analysis, it is assumed that existing transit riders who switch between transit options, for example from bus to light rail, on aggregate would walk approximately the same distance.

Health benefits for transit users have been evaluated in various studies and are typically monetized by multiplying the average minutes or miles of additional walking to and from a transit service by a set dollar value representing the typical reduction in health care costs associated with people who regularly take transit compared to those who typically drive. Based on a review of various studies that were recently conducted in the US, a range of 8-15 minutes per day per new transit rider was found to be a reasonable assumption for the number of additional minutes of walking.[18] The health care cost savings and improved well being attributed to those who regularly get more exercise (such as walking 30 minutes per day to/from transit) compared with those who regularly get less exercise have been quantified in a half dozen studies which have been consolidated in a report published by the Transportation Research Board. From a range of $19 to $1,175 in annual health benefits from walking an additional 30 minutes per day found in the various studies, a median value of $128 per year was determined to be a reasonable assumption for the purposes of monetizing the health benefits.[19] Values were provided in 2006 dollars and escalated by the consumer price index for all urban consumers (CPI-U) to derive a value of $150.34 per year per person in 2015 dollars. This annual value assuming 30 minutes of additional walking per day equates to $0.014 per minute.

To determine the minutes of network-wide walking time associated with the proposed ST3 investments, the difference in the aggregate walk times between the build and no-build scenarios will be used as the basis for the total additional minutes walked. This value will be multiplied by the $0.014 per minute benefit.

In equation form:

$ Health Benefits Attributed to Transit Riders = Total increase in walking minutes * $0.014/minute.

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[17] Federal Highway Administration, *Addendum to the 1007 Federal Highway Cost Allocation Study,* Table 13. (http://www.fhwa.dot.gov/policy/hcas/addendum.cfm ).
[18] Rissel (2012)
[19] Transportation Research Board (2006)

## 4.8 Reliability

As described in Section 4.1, time savings realized by transit users generate economic benefits commensurate with the disutility travelers attribute to trip delays (time costs). The proposed ST3 improvements would generate substantial economic benefits by reducing travel times for existing light rail travelers, as well as for current bus and auto travelers who would mode shift to light rail.

The travel time savings detailed in Section 4.1 are calculated by comparing all users' mean trip times in the future without the proposed investments to those users' projected mean trip times following the ST3 improvements, including assumptions about the proportion of bus and auto users who would mode shift. That is, a transit user would realize a direct economic benefit equal to the amount of time he/she would save on an *average* weekday commute. Summing across all weekday users and multiplying by a defined annualization factor, provides the overall time savings benefits, as detailed in Section 3.7.

Travel time savings result not only from a reduction of time spent by a traveler in a vehicle, but also from a reduction in the amount of time that a user allows for delay in waiting for a bus or train to arrive or for traffic that may vary worse than average. A substantial body of research literature indicates that commuters incorporate their expectations for delays resulting from unreliable service or traffic when planning their daily journeys.[20] A daily commuter who must arrive at work by a fixed time (e.g., 9:00 AM) will therefore depart from home at a time that reflects his/her allowance for expected delay time, in addition to the scheduled length of his/her journey. The relative reliability (or unreliability) of the transit system and/or highway network will influence the extent to which a user will allow extra travel time for a given journey.

By improving the overall reliability of the transit system, ST3 will therefore generate travel time savings for users relative to alternatives beyond those described in Section 4.1, as users will be able to reduce the allowance made for variable delays. This B/C analysis quantifies those time savings by comparing the mean travel time users will experience in the future with the ST3 service improvements (when the system is assumed to have peak reliability) to the 80$^{th}$ percentile travel time users would experience without the ST3 investments. The 80$^{th}$ percentile travel time reflects the extra journey time (or "buffer allowance") a commuter would include in order to arrive at their destination on-time at least 80% of the time—that is, four days out of a five-day workweek.[21] These travel time savings are calculated using the ST model, as described in Section 4.1, and are monetized using the value of time figures detailed in Section 3.6.2.

The ST3 B/C analysis estimates transit user benefits conservatively here insofar as the analysis does not consider additional light rail ridership that would be induced by increased system reliability alone; this additional mode shift would generate economic benefits by reducing overall VMT and decreasing congestion. Further, in other metropolitan areas that have studied transit reliability extensively, light rail reliability improvements have been estimated to increase transit user benefits by 20-30% on average for riders who previously used bus service. In addition reduced highway congestion resulting from the ST3 investments will improve reliability for future auto users which is not captured in this analysis; accordingly, ST3 benefits may be underestimated by excluding these additional reliability improvements from the B/C analysis.

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[20] See *SHRP 2 Report S2-L05-RR-3, Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes: Technical Reference.* Transportation Research Board, 2014.

[21] As described in *SHRP 2*, many practitioners compare mean trip times to the 95$^{th}$ percentile trip time, which reflects the buffer time a user would allot in order to arrive on time 19 out of 20 work days per month. This B/C analysis uses the 80$^{th}$ percentile, for purposes of a conservative analysis.

# 5 Economic Benefits Not Included in the Evaluation

The following is a summary of other potential benefits that are excluded from the B/C analysis. The ensuing discussion describes these possible benefits and explains the rationale for their exclusion.

## 5.1 Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of Transit Operating and Maintenance Expenditures

Transit operations are traditionally labor intensive and transit expenditures tend to provide more jobs and local economic activity than most other transportation investments. For example, one study estimated that each million dollars of transit capital investment generated between 30 and 60 additional jobs.[22] Despite the significant direct and multiplier effects of the investment on the local economy, it is unlikely that these impacts would represent net benefits to the region unless O&M expenditures were financed from federal dollars that otherwise would not have been distributed to the region. If locally funded O&M expenditures were not used by Sound Transit, these same dollars would be put to some other productive economic use within the region, which would also generate economic activity, jobs, and employment earnings (albeit at a potentially lower multiplier). Therefore, the employment, income, and output effects of transit O&M expenditures are excluded from the ST3 B/C analysis.

## 5.2 Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of Transit Construction Expenditures

Similar to operations and maintenance expenditures, construction expenditures also generate additional economic activity, jobs, and employment earnings. This construction impact has three components: (1) direct impacts from expenditures on construction materials, service and labor; (2) indirect impacts from subsequent intra- and inter-industry purchases of inputs and production of outputs as a result of the initial direct expenditures/change in output of the directly affected industry; and (3) induced impacts generated from increases in household spending on goods and services that result from additional employment earnings through the direct and indirect effects.

Multipliers derived from an input-output model are usually used to estimate the total impact on output, employment, and earnings from the direct construction expenditures. Output, employment, and income multipliers represent a quantitative expression of the extent to which the construction of a transit project may generate additional economic activity and employment through interdependencies associated with some assumed and/or empirically established, "endogenous" inter-industry linkage system. While these levels of employment and income are tangible and clearly beneficial to many individual economic sectors (particularly the construction industry), the validity of including such benefits in a formal B/C analysis has been questioned by a number of economic analysts, on the premise that construction spending represents a transfer of income from taxpayers to the transit agency, or from other public investment purposes. Put another way, like in the above O&M case, the money would be spent by consumers and/or the public sector on other things, generating similar multiplier effect on the local economy, albeit with a different distribution.

A case could be made for considering the portion of construction supported by federal grant dollars under the presumption that without the project, the region or state would not receive this funding. Similarly, a case could also be made for considering additional future federal funds that the project will generate for the region because it increases the region's fixed-guideway miles, which are used in a formula to calculate region's share

[22] ECONorthwest and Parsons Brinckerhoff (2002).

of (federal) Section 5309 fixed-guideway modernization funds. However, multiplier benefits are excluded from the B/C analysis because discretionary federal funds have not been identified for the ST3 investments.

If the ST3 financial plan were to adopt an assumption for federal grant funding, then this exogenous funding could be treated in one of two ways. The direct and multiplied impacts noted above could be considered as project benefits during the construction period, but such an approach is not widely practiced. Alternatively, the federal share of the overall project cost could be deducted (excluded) from the B/C analysis since these costs would not be locally borne within the defined study region. This is the recommended approach for dealing with federal grant funding, such as FTA New Starts funding.

## 5.3 Increased Property Values near Stations

Several organizations have estimated a statistically significant positive association between proximity to light rail stations and property values, i.e., development located closer to transit stations is likely to have higher property values than development located farther from stations. Exhibit 13 shows select studies of property value impacts for different U.S. rail systems.

Exhibit 13 — Station Area Property Value Impacts from Select Studies

| System | Impact | Study |
|---|---|---|
| Atlanta, Beltline Project | Single family homes with a quarter mile of the planned loop sold at 15%-30% premium | Immergluck (2009) |
| Minneapolis, Hiawatha Line | 10% premium for single family homes in station areas after line opened | Goetz et al. (2010) |
| Portland, Westside Extension Rail Line | Vacant parcels within one-half mile of line extension sold for 31% premium | Knaap, Ding and Hopkins (2001) |
| Chicago, Midway Transit Line | 10% premium for homes with 1.5 miles of line | McMillen and McDonald (2004) |
| Phoenix, Valley Metro | Sales prices for residential properties within the transit shed outperformed by 36.8% | Becker (2013) |

Despite the evidence of increased property values near stations, it is reasonable to exclude these effects because property value increases may be viewed as a market response to reduced transportation costs, among other factors, in which travel time benefits are capitalized into the value of adjacent property. As a result, including property value increases would comprise at least some degree of benefit double counting.

## 5.4 Transit Fares

Transit fares are an economic transfer from users to the transit agency. Because they are a pecuniary transfer, they represent neither an economic benefit nor an economic cost of the project. In the B/C analysis, transit fares are excluded from both the benefit and O&M cost tabulations.

## 5.5 Induced Transit Travel

Additional transit travel can be disaggregated into two types – 'redistributive' and 'generative'.[23] For the ST3 investments, the majority of the redistributive travel is captured via the outputs generated by the ST and

[23] Cervero (2001).

PSRC travel demand models - i.e. additional transit travel that occurs as a result of less auto travel caused by the mode shift.

The generative, or 'induced', effects are harder to capture than the redistributive effects. Because the ST3 investments lower the generalized cost of travel, they will likely induce additional travel (i.e., create trips that simply were not made prior to the transit improvements). Although travel demand modeling capabilities prohibit formal inclusion of ST3 induced transit travel in the quantified evaluation, benefits associated with additional travel are expected.[24]

## 5.6 Parking Cost Savings

Reductions in the number of auto trips caused by the ST3 investments may also reduce expenditures on parking, depending on trip destinations. With additional transit use, short-term parking benefits could be manifested in terms of reduced demand for parking spaces, and hence, potentially lower parking costs for the users of those spaces. In the long run, reduced land requirements for parking facilities may free up land for other uses.

While the ST model produces an estimate of parking cost savings based upon the mode shift to transit for trips to zones with paid parking (e.g., zones within downtown Seattle), the reduced parking expenditures realized by those making a mode shift are not considered a benefit in the same way that the transit fare they pay instead is not counted as a disbenefit of transit use. Both are considered to be transfer payments that do not impact societal benefits and costs. Rather, the potential parking cost savings benefits would be limited to those that accrue to the remaining auto users that collectively now comprise a (slightly) lower level of demand for parking. However, there is no reasonable way to estimate the demand function to assess how this might lower the cost of parking. The assessment of parking cost savings benefits are further clouded by the fact that not all parking is paid for by the user. Many employers provide free parking to their employees. This is often described in two parts: (1) costs of parking included in price of goods and services or an employee benefit; and (2) cost of on street free parking and municipal and institutional off-street parking. According to Delucchi, these costs are about 8 cents/VMT and about 2 cents/VMT, respectively.[25]

Given the challenges in estimating parking cost savings benefits and the market forces that would likely make such benefits relatively small or even unsustainable, the ST3 benefit-cost analysis methodology does not include any estimate of parking cost savings.

## 5.7 Unpriced Parking

In considering unpriced parking, the ST3 investments may reduce the number of parking spaces an employer chooses to provide to its employees at no cost. While reducing the need for free (as well as priced parking) may result in societal benefits, such benefits are not included in the ST3 benefit-cost analysis methodology due to measurement challenge and reasons.

[24] The proposed descriptive analysis would make use of several ex-post rider-ship surveys, which indicate that a good number of riders using these new services are travelers who simply did not make the trip prior to the introduction of the new service, either by taxi, auto, or other transit service. Presumably these are discretionary trips, trips that were too costly or inconvenient by any mode previously, or trips by individuals who had few, if any, other travel options before.

[25] Delucchi (1996)

# 6 Economic Costs and Assumptions Included in the Evaluation

In the benefit-cost analysis, the term 'cost' refers to the additional resource costs or expenditures required to implement, perpetuate, and maintain the investments associated with the ST3 improvements.

The B/C analysis uses project costs that are estimated for the ST3 program on an annual basis, expressed in 2015 dollars. Environmental, design and other pre-construction costs which may occur prior to 2021 are assumed to occur uniformly between 2021 and 2028, consistent with the project evaluation period assumptions in section 3.2. These cost estimates,[26] which are described below, are provided by Sound Transit.

## 6.1 Initial Project Investment Costs

Initial project investment costs include engineering and design, construction, acquisition of right-of-way, vehicles, other capital investments, and contingency factors. The project capital investment costs are typically treated in one of two basic ways. The first, and most common, is to treat the project costs as up-front costs coinciding with the actual project expenditures on a pay-as-you go basis. This approach excludes financing costs from long-term borrowing as part of the investment expenditures subject to present value calculations.

An alternative approach would consider the proposed financial plan for the investments, when the plan involves long-term debt that is repaid over time with interest, and account for the financing costs as the debt is repaid. The two approaches yield essentially the same results for the discounted present value of the project investment costs.[27] As a result, the former pay-as-you-go assumption is usually adopted in recognition that a detailed financial plan typically would not yet be available at the time when a B/C analysis of project alternatives is undertaken.

To understand why debt service costs over time for financed investments equate to the same present value as up-front, pay-as-you-go investments, note that debt service amounts are expressed in nominal dollars, calculated using a nominal interest rate that includes both real and inflationary components. Because B/C analysis typically accounts all dollar amounts in constant dollars of a single year (e.g., 2015 dollars), it is necessary to convert the stream of debt service payments into constant dollars. However, once inflation is extracted from the nominal debt service payments, the remaining debt service is simply a stream of principal repayments and real interest payments.[28] Converting this stream of real debt service payments to its present value using a real discount rate cancels out the real interest paid over time, leaving the sum of the principal payments — the original level of investment. Put another way, the long term real cost of capital for public transit investments in a relatively risk free environment is essentially equal to the real discount rate.

## 6.2 Annual Operating and Maintenance Costs

The annual costs of operating and maintaining the proposed light rail investments are included in the analysis. Operations and maintenance activities apply to several assets, including rolling stock, stations, track, and

[26] The proposed analysis does not depreciate costs, since it represents a sinking fund for future replacement of an asset. If the analysis were to depreciate costs, a similar process would also have to be done on the benefit side, thereby balancing each other out.

[27] A small difference may result from financing costs such as the underwriter's fees which would not be part of pay-as-you-go investment.

[28] Assuming the project can secure debt with a solid credit rating such that there is no material risk component also factored into the borrowing interest rate. An interest rate premium for risk could result in a higher net present value cost for the project under debt financing than pay-as-you go. However, the use of tax-exempt debt with lower nominal interest rates than taxable debt may offset the real increase attributable to credit risk.

support facilities. Additional incremental agency expenses are also included. The costs include regular and ramp-up O&M expenses beginning in 2029, with full ST3 O&M costs achieved in 2040 and continuing through the end of the evaluation period.

The ST3 financial plan provides annual O&M costs for much of the B/C evaluation period from 2033 through 2072. These values will be deflated from YOE dollars to constant 2015 dollars. For evaluation period years beyond those included in the financial plan, O&M costs will be assumed to exhibit real growth (in excess of normal inflation), matching the growth rates assumed for transit ridership and benefits growth. This assumption is likely conservative, as real (after inflation) operating costs for many items would remain constant or scale up at a lower rate than by which ridership grows.

## 6.3 Periodic Capital Equipment Rehabilitation and Replacement Costs

Several types of initial asset investments will need to be replaced, rebuilt, or rehabilitated during the evaluation period. To account for this, the analysis includes rebuild/rehabilitation/replacement schedules associated with regular asset life cycles and the costs of rebuild/rehabilitation/replacement. The analysis makes the following assumptions regarding asset life cycles and the rebuild/rehabilitation/replacement costs:

- 30% of initial construction expenditures are replaced every 80 years (no rehabilitation required during the ST3 evaluation period);
- 70% of initial construction expenditures are replaced every 30 years at cost of no less than 50% of the initial constant expense, adding 30 years of life; and
- Light rail vehicles are replaced every 30 years at a cost of 100% of the initial constant dollar expense. In addition, they are assumed to undergo a midlife rebuild/overhaul in year 15 at a cost equal to 15% of the initial constant dollar expense.

## 6.4 Residual Value (Cost Offset or Negative Cost)

Because there is still an economic value to the ST3 investments at the end of the B/C evaluation period (the system will continue operating beyond 2072 and the system will not need to be completely replaced at that time), there is a residual value for some investments such as track infrastructure and right-of-way. The B/C analysis includes residual values as cost savings (i.e., negative cost) in the final year of the evaluation.

Because it does not depreciate (some might argue that it, in fact, appreciates), a residual right-of-way value equal to 100% of the initial right-of-way cost is included in the final year of the evaluation.

Constructed infrastructure and light rail vehicles are also assumed to have residual values at the end of the evaluation period. It is assumed that these assets depreciate on a straight-line basis. For example, an asset with an 80-year life-cycle is assumed to be worth 50% of the initial investment cost after 40 years.

For simplicity, it is assumed that all life-cycles begin in the first year of full operations, 2040. To illustrate, light rail vehicles are assumed to be replaced (at 100% of their initial cost) in 2062, and if the evaluation period ends in 2072, the residual value is 2/3 of the initial light rail vehicle cost.

# 7 Economic Costs Not Included in the Evaluation

## 7.1 Federal Funds (Cost Offset or Negative Cost)

New federal funding brought to the region as a result of the ST3 investments is not included in the analysis. Because the study region is defined to be the three-county ST service district, additional federal funds would be a negative (offsetting) cost of the project. Some might think of this as project benefit, but it is more appropriately classified as a cost reduction for the region. Discretionary federal funds, such as Section 5309 "New Starts" funds allocated by the Federal Transit Administration (FTA), would be new federal funding for the region. Similarly, the ST3 investments should increase the region's allocation of FTA Section 5309 Fixed-Guideway Modernization formula funding, which would also reduce the region's cost of the ST3 investments.

The ST3 B/C analysis conservatively ignores any potential new federal funding brought to the region by the ST3 investments.

# 8 Key Benefit-Cost Evaluation Measures

There are three common benefit-cost evaluation measures, each tailored to compare benefits and costs from different perspectives.

## 8.1 Net Present Value

The benefit-cost analysis converts potential gains and losses from the proposed investment into monetary units and compares them on the basis of economic efficiency, i.e., net present value (NPV). For example, NPV = PVB (present value of benefits) - PVC (present value of costs); where:

$$PVB = \sum_{t=0}^{T} B_t / (1+ r)^t; \text{ and } PVC = \sum_{t=0}^{T} C_t / (1 + r)^t$$

and the NPV of a project can be represented as:

$$NPV = \sum_{t=0}^{T} (B_t - C_t)/ (1+r)^t,$$

where $B_t$ and $C_t$ are the benefits and costs, respectively, of a project in year t; r is the real discount rate; and T is the time horizon (evaluation period). In essence, NPV gives the magnitude of the project's economic feasibility in terms of net benefits (benefits minus costs) discounted to present values using the real discount rate assumption. Under this criterion, a scenario with an NPV greater than zero may be considered "economically feasible". The NPV provides some perspective on the overall dollar magnitude of benefits not reflected by the other two measures.

## 8.2 Economic Rate of Return

The Economic Rate of Return (ERR) is the real discount rate that makes the present value of all benefits just equal to the present value of all costs, i.e., the real discount rate at which the project's NPV is zero and it's benefit-cost is unity. The ERR measures the social or economic return on investment. As an evaluation measure, it allows comparison of the proposed investment package with other similar packages and/or alternative uses of investment funds that may have different costs, different benefit flows, and/or different timing. Note that the ERR is interpreted as a real rate of return (after accounting for inflation), since the assumption is that benefits and costs are expressed in constant dollars. As such, it should not be directly compared with investment returns calculated from inflated or nominal future year dollars. In some cases, a threshold value for the ERR may be established where exceeding that threshold results in the determination of an economically justified project.

## 8.3 Benefit/Cost Ratio

The evaluation also estimates the benefit-cost ratio; where the present value of incremental benefits divided by the present value of incremental costs yields the benefit-cost ratio (B/C Ratio), i.e., B/C Ratio = PVB / PVC. In essence, the B/C Ratio expresses the relation of discounted benefits to discounted costs as a measure of the extent by which a project's benefits either exceed or fall short of their associated costs. For example, a B/C ratio of 1.5 indicates that the project generates $1.50 of benefits per $1 of cost. As such, a

ratio greater than 1 is necessary for the project to be economically worthwhile (feasible). The B/C Ratio can be useful when the objective is to prioritize or rank projects or portfolios of projects with the intent to decide how to best allocate an established capital budget, assuming equivalent classification of benefits and costs.

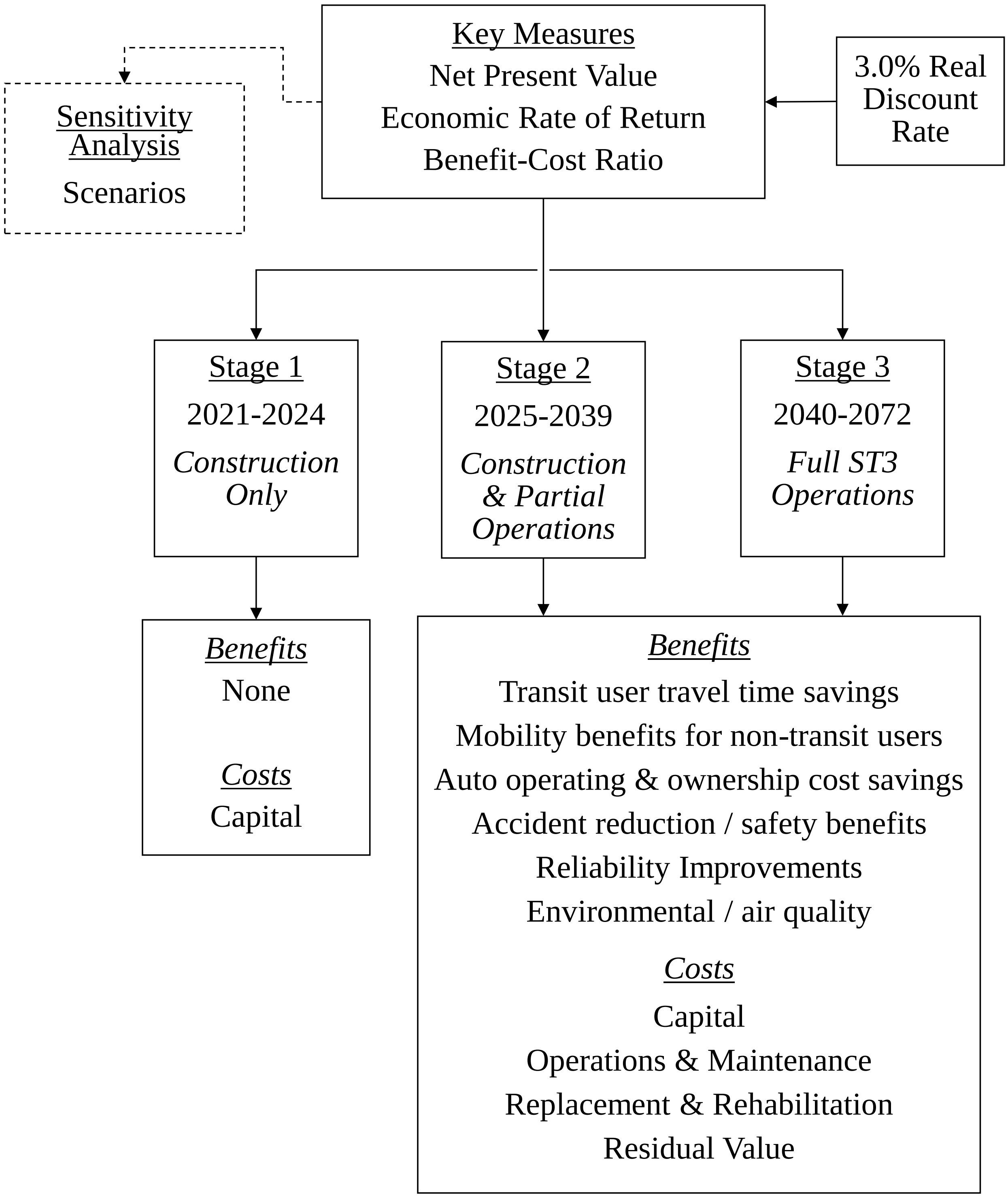
# 9 SUMMARY

The key benefit-cost analysis assumptions are summarized in Exhibit 14.

Exhibit 14 — Key Assumptions

| | |
|---|---|
| Unit of Expression | 2015 dollars |
| Historical Inflation Index (as needed) | BLS CPI-U for the Seattle-Tacoma-Bremerton MSA |
| Future Inflation Index (as needed) | ST Financial Plan Inflation Forecasts by Category |
| Real Discount Rate | 2.0% to 3.0% |
| Evaluation Period<br>Stage 1 - Primarily Construction<br>Stage 2 - Partial Operations & Benefits<br>Stage 3 - Full Operations & Benefits | <br>2021-2024<br>2025-2039<br>2040-2072 |
| Study Region | King, Pierce, and Snohomish Counties |
| Real Benefits Growth Rate | Interpolated using compound annual growth rates 2025-35, 2035-2040; and growth rates of 1.5% per year between 2041-72 |
| Real Wage Growth Rate | 1.2% per year |
| Real O&M Cost Growth Rate | Per ST3 Financial Plan 2025-59; 1.5% per year between 2060-72 |
| Induced Highway Travel | None |
| ***Benefits*** | |
| Transit Travel Time Savings | Consumer surplus calculation from ST model outputs |
| Peak (Commute) Trips | Value of time = 66.7% of average wage rate |
| Off-Peak Auto (Non-Commute) Trips | Value of time = 50% of average wage rate |
| Commercial Trips | Value of time = 120% of three sub-category specific average wage rates |
| Vehicle Operating/Ownership Cost Savings | Reduction in fuel costs based on forecasted WSDOT gasoline prices<br>6.1 cents/mile for maintenance and tires cost savings<br>31 cents/mile for vehicle ownership cost savings tied to reduced usage<br>12 cents / mile for vehicle ownership cost savings tied to reduced vehicle ownership and applied to 10% of VMT reduction |
| Collision Rates<br>Fatal<br>Injury<br>Property Damage Only | <br>0.8 per 100 million VMT<br>45.5 per 100 million VMT<br>88.75 per 100 million VMT |
| Collision Costs<br>Fatal<br>Injury<br>Property Damage Only | <br>$9,600,000 / collision<br>$451,200 - $5,692,800 / collision<br>$4,198 / collision |
| Environmental Cost Savings | varies per ton |
| Reliability | Uses same value of time assumption measures 80th percentile travel time in the no-build, less the mean travel time for the build case |
| Direct, Indirect, & Induced Effects from Construction + O&M Expenditures | Excluded |
| Increased Property Values | Excluded |
| Barrier Effect | Excluded |
| Transit Fares | Transfer payment captured in O&M costs |
| Induced Transit Travel | Excluded |
| Unpriced Parking | Excluded |
| ***Costs*** | |
| Initial Project Investment<br>Residual Value<br>Periodic Replacement & Rehabilitation<br>Regular Operating & Maintenance | Estimates provided by ST, 1.5% per year escalation in O&M costs starting in 2060 |
| Federal Funds | Excluded |

Exhibit 15 — Sound Transit Phase 3: Benefit-Cost Analysis Summary Graphic



# *Appendix A*

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# *Appendix B*

# *Benefit-Cost Analysis Results*

# Results in Brief

A benefit-cost analysis was conducted for the light rail components of Sound Transit's Phase 3 (ST3) plan as proposed in July 2016. The analysis was conducted in accordance with the methodology described in the *Sound Transit 3 Benefit-Cost Analysis Methodology Report*, to which these results are appended. The results are made available to the Puget Sound Regional Council as part of their conformity review of the ST3 plan.

For the ST3 plan "base case" scenario, the proposed light rail investments yield a net present value of $2.1 billion, which provides a real economic rate of return of 3.7%.[29] The associated benefit-cost ratio is 1.12. Exhibit B-1 presents the evaluation results for the base case and three sensitivity tests varying combinations of the real discount rate and the exclusion of travel time reliability benefits.

Exhibit B-1 — Benefit-Cost Analysis Summary Results

| Case | Net Present Value (NPV) | Economic Rate of Return | Benefit-Cost Ratio (B/C) |
|---|---|---|---|
| **Base Case** | **$2.07 B** | **3.71%** | **1.12** |
| **Sensitivity Tests** | | | |
| Scenario 1: 2% Real Discount Rate | $6.73 B | 3.71% | 1.31 |
| Scenario 2: Excluding Reliability Benefits | $1.23 B | 3.43% | 1.07 |
| Scenario 3: 2% Real Discount Rate and Excluding Reliability Benefits | $5.53 B | 3.43% | 1.26 |

All benefits and costs were estimated in constant 2015 dollars over an evaluation period extending from the start of construction in 2017 through 2072. Program start-up, construction, and closeout are anticipated to take place over 25 years (2017-42), during which benefits ramp up as sections are completed. For analysis purposes, construction is assumed to be essentially complete with full user benefits realized by 2040. The post construction phase extends through 2072 for evaluating benefits and costs.

All future amounts are discounted to their present values using a real discount rate of 3.0% in the base case. In addition to the base case three sensitivity tests were conducted. The first sensitivity test uses a lower, 2.0% real discount rate corresponding to Federal Transit Administration June 2016 guidance indicating that a real discount rate of 2.0% should be used to evaluate projects applying for New Starts, Small Starts, and Core Capacity grant funding, consistent with the FTA Standard Cost Categories (SCC) workbook. The second sensitivity test excludes benefits associated to reliability which is often excluded from benefit-cost analysis due to the difficulty in quantifying the additional allowances commuters' factor into their travel times to account for delays. The third sensitivity test uses the lower 2.0% real discount rate and excludes travel time reliability benefits. The results of those tests are provided in Exhibit B-1 and provide a range of benefit-cost ratios from 1.07 using a 3% real discount rate without reliability to a 1.31 ratio using a 2% real discount rate and including travel time reliability benefits. The economic rate of return is 3.71% including the reliability benefits and slightly lower at 3.43% when reliability is excluded. The results of the sensitivity tests confirm that the ST3 program will provide a positive economic benefit and net present value.

While the construction period for such a large investment program requires a significant period of time before full benefits can be realized, the value of providing additional transportation capacity in new right-of-

[29] The Economic Rate of Return, also referred to as the Internal Rate of Return, is the present value discount rate at which benefits equal costs and the B/C ratio is 1.0.

way is ultimately substantial, benefitting tomorrow's transportation system users and supporting the continued economic growth expected for the region's future.

# Travel Impacts

The ST3 benefit-cost analysis results are based on transit ridership forecasts prepared by Sound Transit using methods reviewed and approved by the Federal Transit Administration and the State Expert Review Panel, and road network travel impacts from the Puget Sound Regional Council (PSRC) model.

Exhibit B-2 summarizes the key travel impacts of the ST3 light rail investments as annual amounts projected for the model year 2040 using the midpoint ridership scenario.

The ST3 light rail investments are predicted to save existing and new transit riders over 18 million hours of time per year by 2040 with an additional 1.5 million of hours saved attributed to improved reliability in travel times requiring a smaller allowance by the traveler for potential delays compared to driving.

Exhibit B-2 — ST3 Travel Impacts Resulting from Light Rail Investments for Midpoint Ridership Scenario

| ST3 Travel Impact | Annual Forecast Values Year 2040 (millions) | Units |
|---|---|---|
| New Light Rail Riders | 19.39 | Riders |
| Light Rail Rider Travel Time Savings (Existing & New Riders) | 18.05 | Hours |
| Vehicle Miles of Travel Saved due to New Light Rail Riders | 296.32 | Vehicle Miles |
| Traffic Congestion Vehicle Hours Saved | 8.03 | Vehicle Hours |
| Light Rail Rider Travel Time Savings - Reliability | 1.47 | Hours |

The Sound Transit and PSRC travel demand models estimate that the ST3 light rail investments would encourage some auto travelers, especially those making relatively longer trips, to switch to transit. The models predict that the 19 million new riders or transit trips generated in 2040 would reduce, by 296 million, the annual number of vehicle miles traveled (VMT) on the central Puget Sound region road network. This reduction in VMT is expected to lower traffic congestion and improve mobility over what would have otherwise been the case. The roadway network in 2040 is predicted to be sufficiently congested by 2040 that the impact of the light rail investments will yield significant mobility benefits, resulting in 8 million vehicle-hours of time savings from reduced traffic congestion per year.

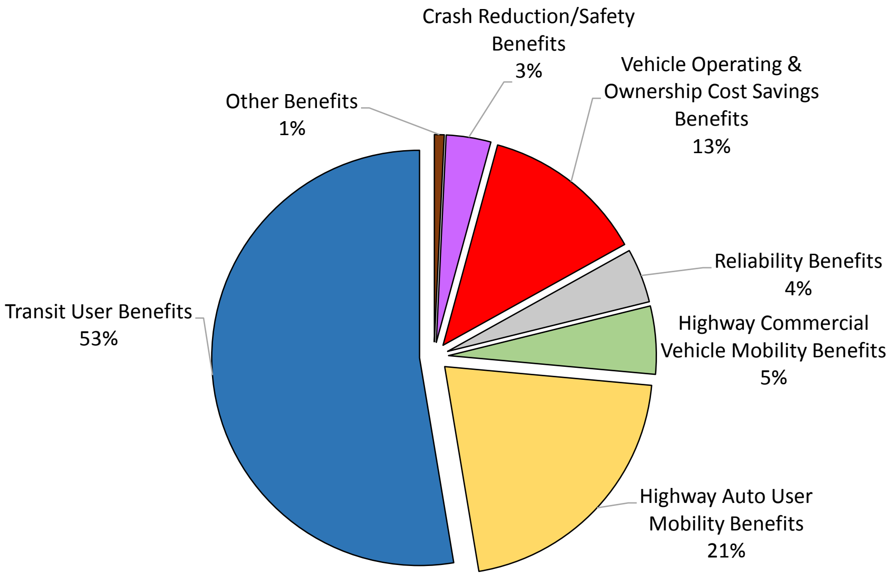
Many people assume that every new transit rider leaving their vehicle behind simply allows another auto trip to occur, resulting in no net change in the level of auto travel or congestion delay. This alternative effect is sometimes referred to as "induced demand." The ST and PSRC models, like most other regional travel demand models, follow the state of the practice by predicting reduced auto travel from new transit investments, and are not equipped to capture this potential induced demand. The assumption of induced auto travel would mean that more trips occur in the entire transportation system than without induced auto travel. However, all travel — including the induced auto trips — have very real economic value, benefitting those travelers at least as much, if not more than, the time and monetary costs they incur to make those trips. The value of induced auto travel is likely comparable to the value of the congestion relief, safety and environmental benefits that would occur in the absence of induced auto travel.

Empirical evidence suggests that attracting some auto users to transit would actually cause a combination of both highway network mobility improvements and induced highway travel. Additional information on travel demand impacts can be found in the main body of the *Sound Transit 3 Benefit-Cost Analysis Methodology Report.*

## ST3 Benefits by Category

The distribution of benefits generated by category over the full 55 year ST3 evaluation period, expressed in present value discounted 2015 dollars, and is shown in Exhibit B-3.

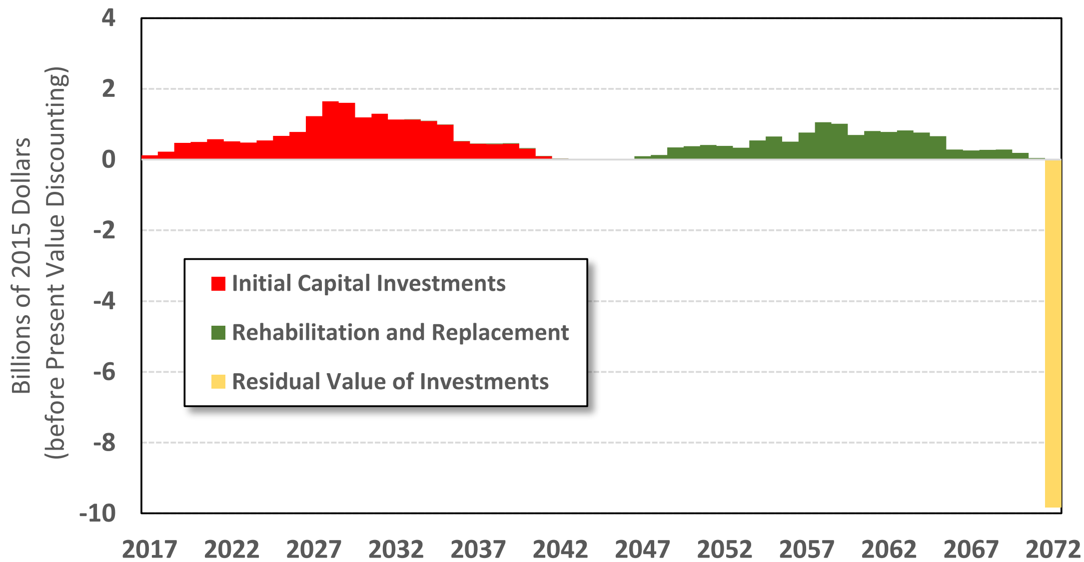
Exhibit B-3 — Cumulative Present Value of Benefits by Category




## ST3 Costs and Benefits over Time

Exhibit B-4 presents the light rail capital expenditures over time, expressed in constant 2015 dollars *before* present value discounting. The start-up, construction, and closeout costs are anticipated to take place over 25 years (2017-42) with an overall capital investments of $18.5 billion. The benefit-cost analysis assumed that the light rail vehicles as well as 70% of the initial project capital investment (excluding right-of-way) would need to be replaced or receive major rehabilitation, on average, 30 years after full project operations begin. The negative cost or cost offset spike shown in 2072 represents the residual value of the depreciated investments at the end of the economic evaluation period. This nearly $10 billion residual value at the end of 2072 equates to less than $2 billion in present value when using a 3% real discount rate.

Exhibit B-4 — Capital Expenditures in 2015 Dollars before Present Value Discounting




Annual operating and maintenance (O&M) costs over the economic evaluation period are presented in Exhibit B-5, expressed in constant 2015 dollars before present value discounting. The upward slope of the line illustrates the assumption of real growth in O&M expenditures, assumed to be 1.5% per year after 2060. This assumption reflects a combination of real growth in the O&M cost factors (labor and material costs escalating faster than general inflation) and expected growth in O&M expenditures required to keep pace with increasing ridership over time.

Exhibit B-5 — Annual O&M Costs in 2015 Dollars before Present Value Discounting

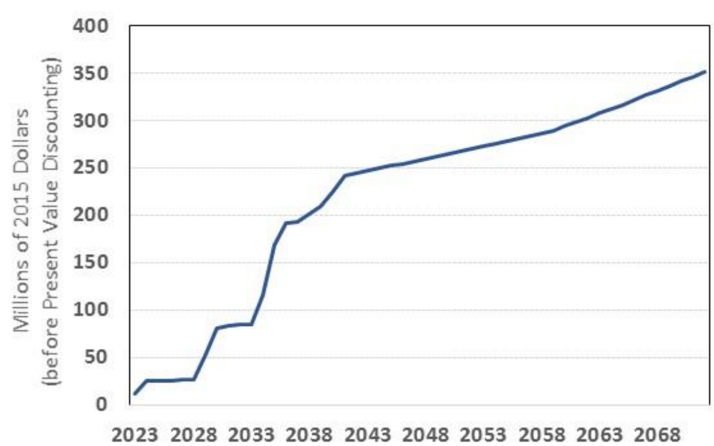
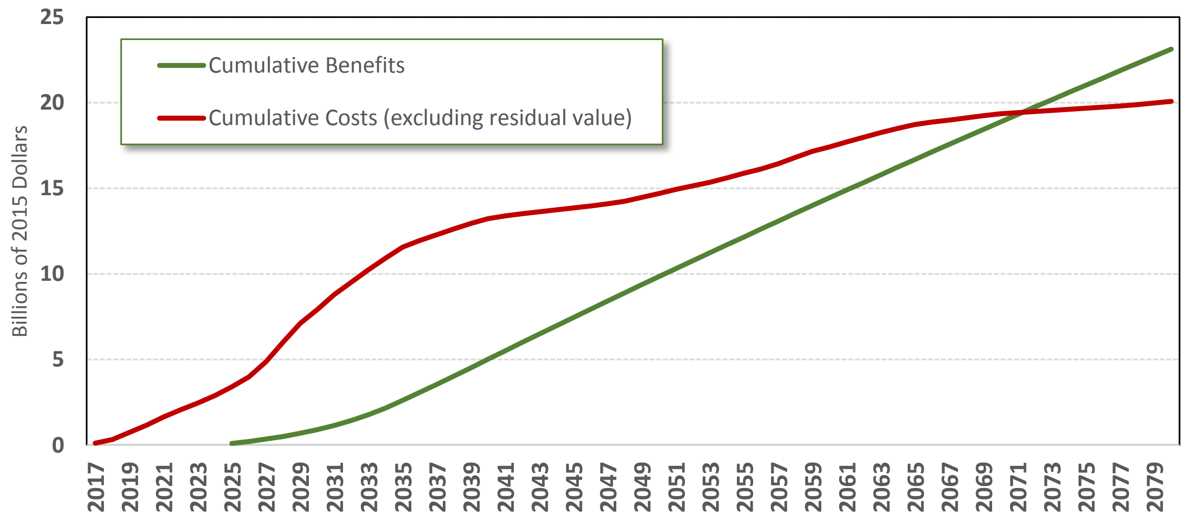



Exhibit B-6 compares the cumulative present value of benefits with the cumulative present value of costs over time for the base case scenario in Exhibit B-6. The figure shows that the cumulative discounted benefits exceed the cumulative discounted costs by the end of the evaluation period with benefits well in excess of costs after the 30 year evaluation period. The values in Exhibit B-6 do not include cost offsets associated with the residual value of the capital assets, which is assumed in FY 2072 for the purposes of the current evaluation period and benefit-cost analysis results.

Exhibit B-6 — Cumulative Present Values of Benefits and Costs




# Findings

This analysis shows that the anticipated, quantifiable benefits from the ST3 light rail transit investments exceed the anticipated costs of the investments net of their residual values. It is important to note this analysis does not include all of the potential benefits that light rail investments will contribute to region (see pages 21-23). While the construction period for such a large investment program requires a significant period of time before full benefits can be realized, the value of providing additional transportation capacity in new right-of-way is ultimately substantial, benefitting tomorrow's transportation system users and supporting the continued economic growth expected for the region's future.