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# ST3 Regional High-Capacity Transit System Plan Benefit-Cost Analysis Methodology Report



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Document Tracking History		
	Date	Initials
Authors	4/15/15	AK, KR
QA/QC	4/16/15	TBB
Edit	4/16/15, 6/10/15	TBB, AK
Check	6/11/15	TBB
Responded to comments	7/16/15	TBB
Minor edits further responding to comments	8/26/15	TBB
Check	8/27/15	AK

August 27, 2015



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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

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# 1 Introduction

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

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

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

## 2 Background and Current Practice

The basic paradigm for estimating benefits, transportation B/C studies, is consumer 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.

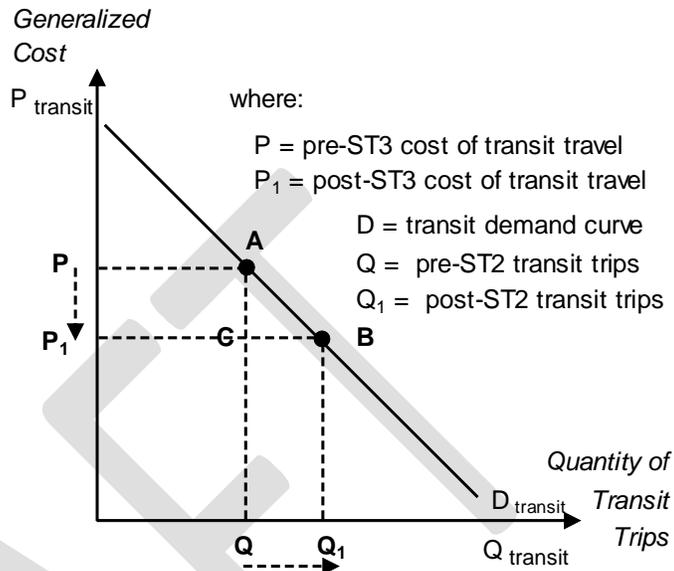
The downward sloping line D represents the travel demand curve or function for transit — at lower generalized travel costs, people travel more often and/or more people travel via transit. In this example, the existing transit infrastructure would accommodate Q trips at generalized travel cost P (travel time plus out-of-pocket costs) prior to the ST3 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 P<sub>1</sub>, 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 Q<sub>1</sub>. Area PABP<sub>1</sub> is the increase in consumer surplus, which includes gains to both existing riders/level of travel Q (the rectangular area bounded by PACP<sub>1</sub>) in the form of lower costs (e.g., time savings) and the benefits to new transit riders/additional travel Q<sub>1</sub> minus Q (the triangular area bound by ABC).

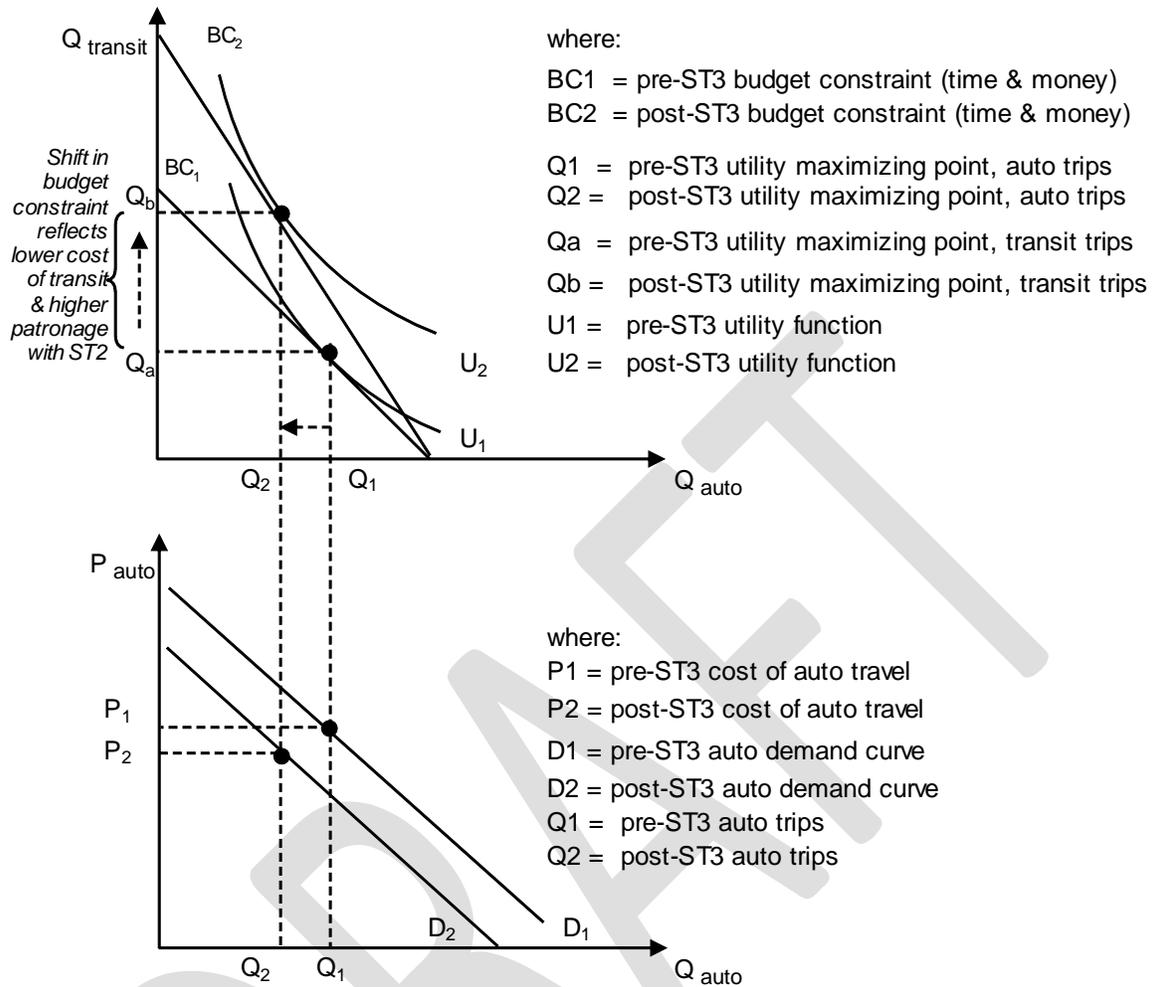
For comparison, Exhibit 2 illustrates the pre- and post-transit investment impacts on auto travel demand and the corresponding changes in consumer surplus from the mode shift to transit.

Exhibit 1 - Change in Transit

used almost universally in surplus. People will travel to



1 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.

2

3 The top graph in Exhibit 2 shows a median traveler's utility function (U1) subject to a transportation time  
 4 and monetary budget constraint (BC1), and how the modal split would change when the generalized cost of  
 5 transit use decreases due to the ST3 investments. The resultant mode shift to transit with ST3 is reflected in  
 6 BC2 (at a lower cost, utility is maximized with more transit trips and less auto trips). The change in transit  
 7 trips from Qa to Qb matches that shown for the transit demand curve in Exhibit 1. The bottom graph in  
 8 Exhibit 2 shows the impact on the demand for auto travel as the transit mode is substituted for some auto  
 9 trips. This is represented by the inward shift in the auto demand curve, which reflects that at any given price  
 10 or cost for auto travel, there would be a lower level of auto trips after the ST3 improvements. The mode  
 11 shift from auto to transit combines with the decline in highway congestion to lower the overall cost of auto  
 12 travel for those trips that remain. The net gain in consumer surplus or benefit to remaining auto travel is  
 13 represented by the area calculated as  $(P_1 - P_2) \times Q_2$ .

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



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## 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 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., 2014) 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 2014 dollars. Cost estimates are provided in 2014 dollars while figures used to calculate the dollar values of benefits that are based in other (historical) years are converted to 2014 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 0.6% reflects the presently low real interest rates, which averaged 0.8% from 2010 to 2014 (30-year rate) as the economy recovered from the great recession.

Choosing an appropriate discount rate is essential to appropriately assessing the costs and benefits of a project. The higher the 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 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.

Historically, federal guidance required present value discounting using a real discount rate of 3% and this requirement was maintained despite presently low real interest rates. For instance, the real interest rate stated by the Office of Management and Budget (OMB) is often used as a source for the real discount rate (United States Office of Management and Budget, 2014) and applied to B/C analysis criteria for federal grants, including TIGER discretionary grants. In the ST2 analysis a real discount rate of 3%, was applied, consistent with the OMB circular in 2008; however the OMB published a revised rate of 1.9% in 2014. Despite the lower rate stated in the OMB Circular, the real discount rate proposed for evaluating the ST3 investments

1 remains at 3.0% for consistency with long-term historical averages and federal direction on TIGER grants.  
 2 Given current interest rates for risk free investments in the present economy, the rate may be regarded as  
 3 high, and thus conservative in terms of estimating the present value of future benefits.

4 **3.2 Evaluation Period**

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

11 For the ST3 B/C analysis, the evaluation period includes the relevant (post-design) construction period  
 12 during which capital expenditures are undertaken, plus 40 years of operations beyond project completion  
 13 within which to accrue benefits. A sensitivity test assesses what an additional 10 years of operations would  
 14 contribute to the findings.

15 For the purposes of this study, it has been assumed that construction of the ST3 investments will begin in the  
 16 year 2021 and will be completed and fully operational by the end of 2032. As a simplifying assumption, all  
 17 benefits and costs are assumed to occur at the end of each year. Since some investments will come on-line in  
 18 an incremental manner, generating partial benefits and operating costs prior to the first year of full system  
 19 operations in 2033, a three-stage approach to the calculation of the annualized B/C was employed. Exhibit 4  
 20 belowError! Reference source not found. provides a description of each of the three stages.

21 Exhibit 4 — Evaluation Period Stages

Stage	Measure	Values or Assumptions
<u>Stage 1:</u>	Timeline	From 2021 through 2028
	Benefits	None Modeled
	Costs	Yearly capital construction costs.
<u>Stage 2:</u>	Timeline	From 2029 through 2032
	Benefits	Escalating partial system rail benefits (as a simplifying assumption, linear interpolation is used to ramp-up benefits from a partial system in mid 2029 to the full system by 2033).
	Costs	Yearly construction capital costs and escalating partial system LRT O&M costs.
<u>Stage 3:</u>	Timeline	From 2033 through 2072
	Benefits	Full rail benefits.
	Costs	LRT O&M costs; periodic R&R expenditures; and residual value (negative) costs at the end of the evaluation period.

22  
 23

1 3.3 Study Region Definition

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

9 Exhibit 5 — Sound Transit District Map



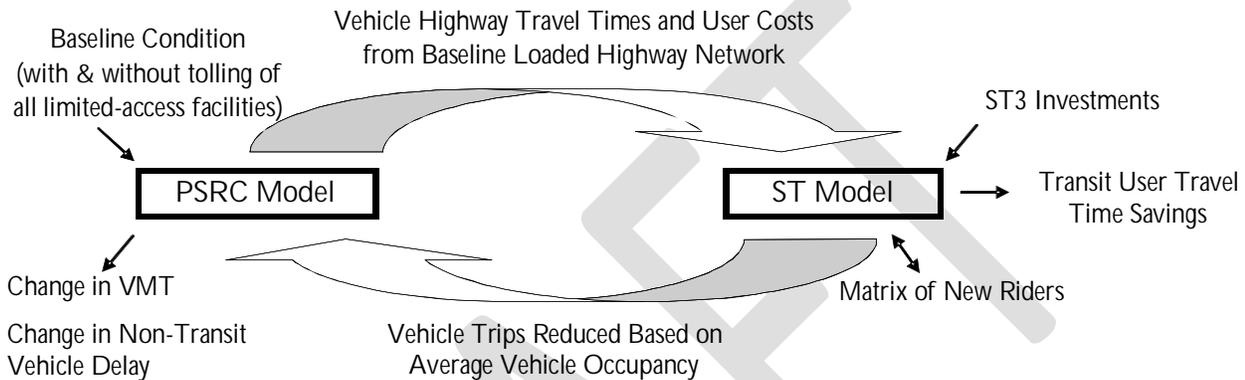
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### 3.4 Travel Data Sources and Forecast Years for Transit and Highway Benefits

#### 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 two future years, 2025 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 rail investments over the Stage 2 (2029-32) and Stage 3 (2033-72) 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, extrapolation of Stage 3 benefits through 2072 will apply a 0.75 adjustment factor to the growth rates interpolated between the 2025 and 2040 model runs. 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 current planning horizon.

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.

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

## 6 3.6 Travel Time Savings Considerations and Value of Time Assumptions

### 7 3.6.1 General Discussion of Travel Time Savings and Reliability

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

12 Reliability is an important characteristic of transit service. It has a direct impact on service quality, travelers'  
13 perceptions, mode choice, travel time budgets, and user benefits. In essence, reliability refers to the  
14 consistency of travel times and wait times. If travel time for a trip is unpredictable, then travelers will need to  
15 allow for extra time, effectively making the overall cost of the trip higher.

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

- 19 • From Bus to Rail -- The Mid-Ohio Regional Planning Commission (MORPC) travel demand model  
20 estimates reliability via an indirect calculation of extra time associated with unreliability through  
21 transit wait time curves developed for different modes/service types. In this example, these curves  
22 increased transit user benefits by 20-30% on average (PB 2004). Buses are less reliable than rail  
23 (unless they use dedicated lanes) because buses operate in traffic. As a result, bus boarding and  
24 alighting delays are compounded by traffic congestion, reducing reliability.
- 25 • From Auto to Rail -- Though research on the reliability effects of mode shift from auto to rail is  
26 sparse, a consensus opinion among travel demand modelers is that auto-to-rail reliability gain is equal  
27 to approximately half the bus-to-rail amount (per trip) if the rail operates in a separate right-of-way.  
28 In over-congested conditions, the lack of auto reliability would approach that of bus; in un-congested  
29 conditions, there is probably no reliability gain in most cases.

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

34 The ST and PSRC travel demand models — like most of their counterparts — provide only expected value  
35 outputs, and are not capable of predicting the additional benefits due to improving reliability. Accordingly,  
36 the ST3 B/C analysis estimates user benefits conservatively and ignores potential travel time reliability  
37 benefits for the ST3 investments.

### 38 3.6.2 Value of Time Assumptions

39 Travel time savings must be converted from hours to dollars in order for benefits to be aggregated and  
40 compared against costs in the analysis. This is normally performed by assuming that travel time is valued as a  
41 percentage of the average wage rate, with different percentages for different trip purposes. For this analysis,

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1 assumptions for value of time (VOT) estimates, as percentages of the average wage rate, were derived from a  
2 review of other studies.<sup>1</sup> This typically involves valuing travel time for personal travel for a work commute  
3 purpose higher than a trip for a non-work or discretionary purpose. However, transit trips are not available  
4 explicitly by trip purpose in the ST model. As such, peak period travel has been adopted as a proxy for the  
5 work commute trip purpose, and off-peak travel is assumed to represent non-work/discretionary trip  
6 purposes.

7 The following assumptions are used for valuing travel time savings.

- 8 • Peak Period Travel -- Time savings for personal travel (all modes) occurring during the peak period  
9 is assumed to be valued at 60% of the average wage rate within the central Puget Sound region  
10 (King, Pierce and Snohomish Counties). For auto travel, peak period time savings are assumed to  
11 apply to all vehicle occupants.
- 12 • Off-Peak Period Travel -- Time savings for personal travel (all modes) occurring during the off-  
13 peak times is assumed to be valued at 50% of the average wage rate within the central Puget Sound  
14 Region. For auto travel, off-peak period time savings are assumed to apply only to the vehicle driver.

15 The average wage rate is estimated using Washington State Employment Security Department (ESD)  
16 employment counts and data on wages and salaries paid for 2012, which is the most recent calendar year  
17 available. Estimating the wage rates separately for each county, the weighted average is \$25.01 per hour for  
18 the three-county region. Escalating this figure to 2014 dollars using the Seattle-Tacoma-Bremerton MSA  
19 Consumer Price Index, the average hourly wage rate becomes \$25.78 per hour, indicating a peak VOT of  
20 \$15.47 and an off-peak VOT of \$12.89.

### 21 3.6.3 Commercial Trip Assumptions

22 In addition, it is acknowledged that commercial or business-related travel tends to have a much higher value  
23 of time than personal travel, whether for discretionary or commute purposes. To account for the different  
24 travel behavior and values of time among the various types of commercial trips, the average wage rate-based  
25 values of time and the commercial shares of total VMT are evaluated by three sub-categories. The PSRC  
26 model provides trip and VMT shares for relative to the total number of trips and VMT by three distinct  
27 commercial vehicle sub-categories: commercial and business-related travel in two axle cars and light trucks;  
28 medium trucks (two and three axle delivery trucks); and heavy trucks (tractor-trailer vehicles with four or  
29 more axles). The shares are based on model outputs and are contingent on the accuracy of underlying data  
30 reporting and travel classification by vehicle class<sup>2</sup>, and may not fully capture some business-related travel in  
31 company/fleet vehicles. As such, this approach may represent conservative outcomes in potentially  
32 understating the commercial travel VMT shares.

33 As shown in Exhibit 8, the percentage shares of total VMT associated with each sub-category varies between  
34 the peak and off-peak hours, with overall commercial VMT shares of 12.5% and 13.9%, respectively. Two  
35 axle commercial vehicles represent the largest share of overall commercial VMT and are assumed to primarily  
36 consist of business-related travel. Separate values of time are applied to each of the three commercial travel  
37 classes as follows :

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<sup>1</sup> See the citations for Oregon DOT (2004); USDOT, (1997; Revised February 2003); Parsons Brinckerhoff (2004); ECONorthwest and Parsons Brinckerhoff (2002).

<sup>2</sup> 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.

- 1 • Two-Axle Commercial Vehicles — The value of time for two axle commercial trip time savings is  
2 assumed to be the weighted average hourly wage rate of \$25.78 (in 2014 dollars) derived from ESD  
3 data plus an additional 20% for the fringe benefit costs to reflect the marginal burdened costs  
4 incurred by the business owner or enterprise, for a total hourly rate of \$30.94.
- 5 • Medium Trucks — The value of time saved for medium trucks represent approximately 2% of total  
6 commercial vehicle VMTs and are assumed to primarily consist of two to three axle local delivery  
7 vehicles. According to ESD data, the hourly wage rate for light truck or delivery services drivers for  
8 the Seattle-Bellevue-Everett-Tacoma metropolitan area was \$18.33 (in 2014 dollars) plus 20% for the  
9 fringe benefit costs incurred by the business owner for a total hourly rate of \$22.00.
- 10 • Large Trucks — The value of time saved for large trucks represent approximately 1.5-1.7% of total  
11 commercial vehicle VMTs and are assumed to primarily consist of longer distance freight  
12 movements. According to ESD data, the hourly wage rate for heavy and tractor trailer truck drivers  
13 for the Seattle-Bellevue-Everett-Tacoma metropolitan area was \$21.71 (in 2014 dollars) plus 20% for  
14 the fringe benefit costs incurred by the business owner for a total hourly rate of \$26.05.

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

Commercial Vehicle Categories	Shares of Total Modeled VMT (2014)		Applied Hourly Wage Rate (2014 \$)	Adjustment for Benefits	Applied Value of Time (2014\$)
	Peak	Off-Peak			
Two axle commercial (includes business-related travel and light trucks)	9.1%	8.9%	\$25.78	120%	\$30.94
Medium Trucks (primarily delivery vehicles)	1.9%	2.0%	\$18.33	120%	\$22.00
Heavy Trucks (primarily 4+ axle tractor-trailers)	1.5%	1.7%	\$21.71	120%	\$26.05
Average for All Commercial Vehicles	12.5%	13.9%	\$24.16 (peak), \$24.05 (off-peak)	120%	\$28.99 (peak), \$28.86 (off-peak)

16 3.6.4 Value of Time Real Growth Assumption

17 Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation.  
18 Increases in the level of wage and salary incomes per job above and beyond general inflation are referred to as  
19 real increases. Between 1970 and 2000, average wage and salary incomes in King County grew at an inflation  
20 adjusted average annual real rate of 1.25%, while the State as a whole saw average real growth of 0.73% per  
21 year.<sup>3</sup> Between 2000 and 2012, average wage and salary incomes in King County grew at an inflation adjusted  
22 average annual real rate of 1.31%, while the State as a whole saw average real growth of 0.74% per year.<sup>4</sup>

23 Based on the historical trends for real wages, the values of time derived from them are assumed to exhibit real  
24 growth of 1.0% per year from 2015 forward over the project evaluation period.

<sup>3</sup> 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.

<sup>4</sup> 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.

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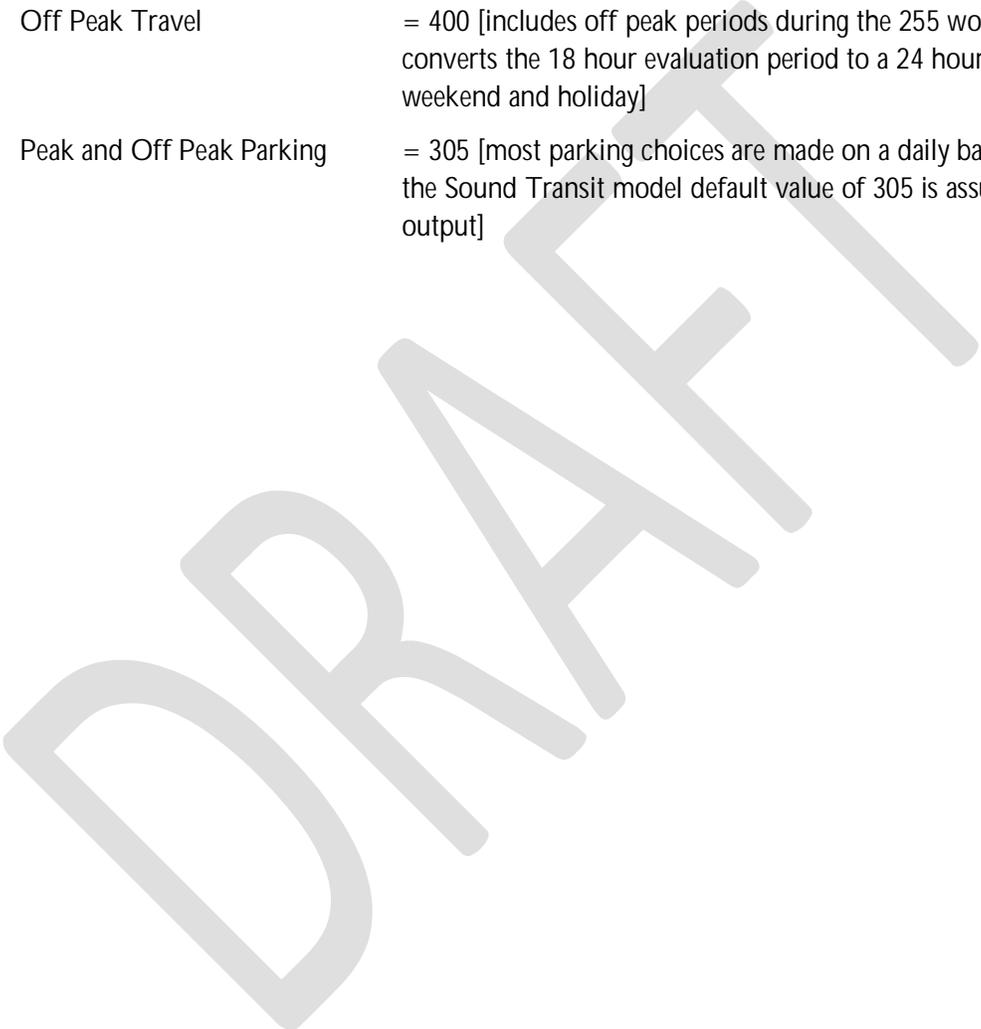
### 3.7 Annualizing Factor Assumptions

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. The following annualizing factors (days per year) are assumed:

Peak Period Travel = 255 [includes five working days per week, 52 weeks per year and 5 holidays per year]

Off Peak Travel = 400 [includes off peak periods during the 255 work days and converts the 18 hour evaluation period to a 24 hour period for each weekend and holiday]

Peak and Off Peak Parking = 305 [most parking choices are made on a daily basis. As a result, the Sound Transit model default value of 305 is assumed for this output]



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## 1 4 Economic Benefits Included in the Evaluation

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

### 4 4.1 Transit User Time Savings

5 Outputs from the ST travel demand model are used to estimate transit user time savings, which tend to  
6 comprise the majority of benefits accruing to riders. These time savings benefits are based on the consumer  
7 surplus theory/concept outlined in the Key Analytical Section. The ST model generates estimates of peak  
8 and off-peak transit travel time savings by trip origin-destination pairs at a zonal level (where there are over  
9 750 zones within the ST boundary area). This approach is consistent with the methodology recommended  
10 by FTA to calculate user benefits for New Starts transit projects. As such, it provides peak period and off-  
11 peak period summaries of travel time savings at a zone-to-zone or district-to-district level for existing riders  
12 as well as for new riders (data is generated for existing and new riders, separately).

13 Benefits associated with transit travel time savings use the value of time assumptions and growth rates  
14 outlined in the Key Analytical Assumptions section. This assumes travel time savings are worth 60 percent of  
15 the average wage rate for peak period transit trips and 50 percent of the average wage rate for off-peak period  
16 transit trips.

17 Reliability improvements generate additional benefits for transit users, but they are not included in the ST3  
18 B/C analysis.

### 19 4.2 Mobility Benefits for Non-Transit Users

20 As previously discussed, non-transit trips also receive travel time savings from the ST3 investments. The  
21 travel time savings benefits for peak period auto travelers, off-peak auto travelers, and commercial vehicles  
22 are included using the value of time assumptions outlined in the Key Analytical Assumptions section. This  
23 assumes travel time savings are worth 60 percent of the average wage rate for all peak period auto trips and  
24 50 percent of the average wage rate for off-peak period (including weekends) auto trips. Commercial travel  
25 time savings are assumed to be valued at 120 percent of selected average wage rates by subcategory as previously  
26 indicated in section 3.6.3. The values of time are to be used in conjunction with the output from the PSRC  
27 model (i.e., change in VMT and vehicle delay by time period) to estimate the mobility benefits for non-transit  
28 users.

### 29 4.3 Reductions in Vehicle Operating Costs and Auto Ownership Costs

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

35 In addition to the ST3 capital investments, the modeling assumes that all limited-access highways within the  
36 ST district will be tolled by 2040. For modeling purposes, this has been interpreted as mileage based  
37 congestion pricing, with the 2040 cost varying by levels of congestion up to \$0.25 per mile (in constant 2014  
38 dollars). This tolling would help to reduce congestion on the primary highways in the region, thereby

1 reducing some costs attributable to congestion and lost time but increasing overall out of pocket operating  
 2 costs, and contributing to additional congestion on arterial routes and existing transit service.

3 In terms of costs, shifting from driving to transit reduces overall vehicle miles traveled, which provides  
 4 savings in the marginal operating costs of auto travel (fuel, tolls, maintenance and tires). Based on a fuel price  
 5 of \$3.28 per gallon, which represented average U.S. fuel prices in 2014, the American Automobile Association  
 6 estimates the variable, out-of-pocket cost for fuel, maintenance and tires at \$0.19 per mile in 2014 dollars.<sup>5</sup>  
 7 Additional costs attributed to tolling of limited-access roadways will be projected separately.

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

13 The ST3 B/C analysis assumes that the total reduction in VMT is attributable to reductions in vehicle usage,  
 14 saving some variable costs associated with vehicle ownership (e.g., depreciation and finance charges). In  
 15 addition, 10 percent of the reduction in VMT is assumed to be attributable to reductions in auto ownership,  
 16 which is worth more because it also eliminates the fixed costs associated with ownership (e.g., insurance,  
 17 licensing, and registration). The analysis uses the values (in 2014 dollars) cited in Exhibit 9 to estimate the  
 18 benefits of reduced vehicle ownership.<sup>6</sup>

19 **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)	\$2,442	\$3,481	\$4,607	\$4,578	\$4,032	\$3,828
Average annual finance charges*	\$613	\$846	\$1,083	\$1,076	\$1,076	\$939
Cost per year	\$3,055	\$4,327	\$5,690	\$5,654	\$5,108	\$4,767
Cost per mile	\$0.20	\$0.29	\$0.38	\$0.38	\$0.34	\$0.32
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	\$981	\$1,007	\$1,081	\$1,025	\$939	\$1,007
License, registration, taxes	\$480	\$640	\$802	\$797	\$675	\$679
Cost per year	\$1,461	\$1,647	\$1,883	\$1,822	\$1,614	\$1,686
Cost per mile	\$0.97	\$0.11	\$0.13	\$0.12	\$0.11	\$0.11

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

20

<sup>5</sup> "Your Driving Costs" (2014); this value is consistent with others reviewed in current literature.

<sup>6</sup> The recommended values were calculated assuming that vehicles drive 15,000 miles per year on average.

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

3 In equation form:

4 Vehicle Operating Cost Savings = (Total VMT savings \* 100%) \* \$ 0.19

5 Vehicle Ownership Savings = [(Total VMT savings \* 100%) \* \$ 0.32] +  
6 [(Total VMT Savings \* 10%) \* \$0.11]

#### 7 4.4 Vehicle Collision Cost Savings

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

15 The state-of-the-practice in B/C analyses is to estimate collision cost savings for each of three types of events  
16 (fatality collisions, injury collisions, or property damage only collisions) using the change in highway VMT.<sup>7</sup>  
17 Some studies perform more disaggregate estimates of the collision cost savings, applying different savings  
18 rates to different types of roadways (e.g., interstate, highway, arterial).

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

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

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<sup>7</sup> National Safety Council (2014)

1 Exhibit 10 — Vehicle Collision Rate by Facility and Event Type

Facility Type/Classification	Accident Rates by Type per 100 million VMT		
	Fatality Collisions	Injury Collisions (Non Fatal)	Property Damage Only Collisions
Interstate Highways <sup>8</sup>	0.39	32.0	70.0
Combined Principal & Minor Arterials <sup>9</sup>	1.21	59.0	107.5

2

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

8 Exhibit 11 shows comprehensive economic costs for avoiding collisions by accident severity, which reflect  
 9 the willingness to pay for avoidance (these costs are in 2012 dollars).<sup>10</sup> The costs are stated on a per-incident  
 10 basis and may include more than one person and/or property owner per incident. Collision benefits are equal  
 11 to the crash rate multiplied by the value of collision avoidance.

12 Exhibit 11 — Dollar Values of Accidents by Event

Accident Severity		Comprehensive Economic Cost of Avoidance (2012\$)
Fatality Collisions	Death	\$4,538,000
Injury Collisions	Nonfatal Disabling Injury	78,900
	Incapacitating Injury	230,000
	Non-incapacitating evident injury	58,700
	Possible Injury	28,000
Property Damage Collisions	Property Damage Crash (including non-disabling injuries)	8,900

National Safety Council (2012)

13

14 In 2014 dollars, fatality collisions are valued at \$4,677,900, injury collisions related to nonfatal disabling injury  
 15 \$81,300, incapacitating injury \$237,100, non-incapacitating evident injury \$60,500, possible injury \$28,900,  
 16 and property-damage only collisions \$9,200.

<sup>8</sup> Source WSDOT, based on data for 2011.

<sup>9</sup> Reflects a VMT average of Principal and Minor Arterials: Source WSDOT, based on 2011 data only.

<sup>10</sup> The Nonfatal Disabling Injury is a weighted average of the sub-sections incapacitating Injury, non-incapacitating evident injury, and possible injury.

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## 4.5 Energy Conservation and Reduced Air, Noise, and Water 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 VMT basis. Exhibit 12 summarizes the estimated average energy, air, and noise pollution costs that total \$0.06 per VMT (in 2014 dollars) of various vehicles. Previous assumptions used in ST2 provided a similar value of \$0.06 (in 2006 dollars or \$0.08 in 2014 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 FTA has approved these values and provides regular updates to them for future application.

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

Pollutant	\$/VMT in 2014\$
Air Quality: Volatile Organic Compounds (VOCs)	\$0.002
Air Quality: Mono-Nitrogen Oxides (NOx)	\$0.012
Air Quality: Volatile Organic Compounds (VOCs)	\$0.002
Air Quality: Particulate Matter (PM2.5)	\$0.010
Greenhouse Gases (Carbon Dioxide Equivalent [CO2e])	\$0.020
Energy Use (British Thermal Units [BTU])	\$0.013
Noise	\$0.001
Total Environment Cost Savings (Benefits) for Autos	\$0.060

(FTA 2014)

In 2014 dollars, the average environmental cost savings from reducing VMT is 6 cents or \$0.06 per VMT.

The ST3 investments can also contribute to reductions in greenhouse gases that contribute to climate change by encouraging travelers to switch from auto to rail. Similar to other environmental benefits, a cost per VMT 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.

Because disaggregate estimates of the change in VMT for each of the vehicle and area types are not available, the ST3 B/C analysis uses 6 cents per mile as the average environmental benefit associated with auto VMT reductions. Additionally, this analysis assumes the environmental costs from light rail are offset by the environmental savings from reduced bus VMT.

## 4.6 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 bus to rail, on aggregate would walk approximately the same distance.

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1 Health benefits for transit users have been evaluated in various studies and are typically monetized by  
2 multiplying the average minutes or miles of additional walking to and from a transit service by a set dollar  
3 value representing the typical reduction in health care costs associated with people who regularly take transit  
4 compared to those who typically drive. Based on a review of various studies that were recently conducted in  
5 the US, a range of 8-15 minutes per day per new transit rider was found to be a reasonable assumption for the  
6 number of additional minutes of walking.<sup>11</sup> The health care cost savings and improved well being attributed  
7 to those who regularly get more exercise (such as walking 30 minutes per day to/from transit) compared with  
8 those who regularly get less exercise have been quantified in a half dozen studies which have been  
9 consolidated in a report published by the Transportation Research Board. From a range of \$19 to \$1,175 in  
10 annual health benefits from walking an additional 30 minutes per day found in the various studies, a median  
11 value of \$128 per year was determined to be a reasonable assumption for the purposes of monetizing the  
12 health benefits.<sup>12</sup> Values were provided in 2006 dollars and escalated by the consumer price index for all  
13 urban consumers (CPI-U) to derive a value of \$150 per year per person in 2014 dollars. This annual value  
14 assuming 30 minutes of additional walking per day equates to \$0.014 per minute.

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

18 In equation form:

19  $\$ \text{ Health Benefits Attributed to Transit Riders} = \text{Total increase in walking minutes} * \$0.014/\text{minute}.$

20

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<sup>11</sup> Rissel (2012)

<sup>12</sup> Transportation Research Board (2006)

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## 1 5 Economic Benefits Not Included in the Evaluation

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

### 4 5.1 Reliability

5 As mentioned previously, the ST3 B/C analysis estimates transit user benefits conservatively and does not  
6 include reliability benefits in the quantitative evaluation. In other metropolitan areas that have studied transit  
7 reliability extensively, light-rail (LRT) reliability improvements have been estimated to increase transit user  
8 benefits by 20-30% on average for riders who previously used bus service. Similarly, LRT reliability gains are  
9 estimated to equal half the bus-to-LRT amount (per trip) on average when LRT operates in a separate right-  
10 of-way. Accordingly, ST3 benefits may be underestimated considerably by excluding reliability improvements  
11 from the B/C analysis.

12 Any potential reliability improvements for non-transit users are also excluded from the B/C analysis.

### 13 5.2 Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of 14 Transit Operating and Maintenance Expenditures

15 Transit operations are traditionally labor intensive and transit expenditures tend to provide more jobs and  
16 local economic activity than most other transportation investments. For example, one study estimated that  
17 each million dollars of transit capital investment generated between 30 and 60 additional jobs.<sup>13</sup> Despite the  
18 significant direct and multiplier effects of the investment on the local economy, it is unlikely that these  
19 impacts would represent net benefits to the region unless O&M expenditures were financed from federal  
20 dollars that otherwise would not have been distributed to the region. If locally funded O&M expenditures  
21 were not used by Sound Transit, these same dollars would be put to some other productive economic use  
22 within the region, which would also generate economic activity, jobs, and employment earnings (albeit at a  
23 potentially lower multiplier). Therefore, the employment, income, and output effects of transit O&M  
24 expenditures are excluded from the ST3 B/C analysis.

### 25 5.3 Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of 26 Transit Construction Expenditures

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

34 Multipliers derived from an input-output model are usually used to estimate the total impact on output,  
35 employment, and earnings from the direct construction expenditures. Output, employment, and income  
36 multipliers represent a quantitative expression of the extent to which the construction of a transit project may  
37 generate additional economic activity and employment through interdependencies associated with some  
38 assumed and/or empirically established, "endogenous" inter-industry linkage system. While these levels of

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<sup>13</sup> ECONorthwest and Parson Brinckerhoff (2002).

1 employment and income are tangible and clearly beneficial to many individual economic sectors (particularly  
 2 the construction industry), the validity of including such benefits in a formal B/C analysis has been  
 3 questioned by a number of economic analysts, on the premise that construction spending represents a  
 4 transfer of income from taxpayers to the transit agency, or from other public investment purposes. Put  
 5 another way, like in the above O&M case, the money would be spent by consumers and/or the public sector  
 6 on other things, generating similar multiplier effect on the local economy, albeit with a different distribution.

7 A case could be made for considering the portion of construction supported by federal grant dollars under  
 8 the presumption that without the project, the region or state would not receive this funding. Similarly, a case  
 9 could also be made for considering additional future federal funds that the project will generate for the region  
 10 because it increases the region's fixed-guideway miles, which are used in a formula to calculate region's share  
 11 of (federal) Section 5309 fixed-guideway modernization funds. However, multiplier benefits are excluded  
 12 from the B/C analysis because discretionary federal funds have not been identified for the ST3 investments.

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

#### 19 5.4 Increased Property Values near Stations

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

24 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)

25  
 26 Despite the evidence of increased property values near stations, it is reasonable to exclude these effects  
 27 because property value increases may be viewed as a market response to reduced transportation costs, among  
 28 other factors, in which travel time benefits are capitalized into the value of adjacent property. As a result,  
 29 including property value increases would comprise at least some degree of benefit double counting.

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## 1 5.5 Transit Fares

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

## 5 5.6 Induced Transit Travel

6 Additional transit travel can be disaggregated into two types – ‘redistributive’ and ‘generative’.<sup>14</sup> For the ST3  
7 investments, the majority of the redistributive travel is captured via the outputs generated by the ST and  
8 PSRC travel demand models - i.e. additional transit travel that occurs as a result of less auto travel caused by  
9 the mode shift.

10 The generative, or ‘induced’, effects are harder to capture than the redistributive effects. Because the ST3  
11 investments lower the generalized cost of travel, they will likely induce additional travel (i.e., create trips that  
12 simply were not made prior to the transit improvements). Although travel demand modeling capabilities  
13 prohibit formal inclusion of ST3 induced transit travel in the quantified evaluation, benefits associated with  
14 additional travel are expected.<sup>15</sup>

## 15 5.7 Parking Cost Savings

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

21 While the ST model produces an estimate of parking cost savings based upon the mode shift to transit for  
22 trips to zones with paid parking (e.g., zones within downtown Seattle), the reduced parking expenditures  
23 realized by those making a mode shift are not considered a benefit in the same way that the transit fare they  
24 pay instead is not counted as a disbenefit of transit use. Both are considered to be transfer payments that do  
25 not impact societal benefits and costs. Rather, the potential parking cost savings benefits would be limited to  
26 those that accrue to the remaining auto users that collectively now comprise a (slightly) lower level of demand  
27 for parking. However, there is no reasonable way to estimate the demand function to assess how this might  
28 lower the cost of parking. The assessment of parking cost savings benefits are further clouded by the fact  
29 that not all parking is paid for by the user. Many employers provide free parking to their employees. This is  
30 often described in two parts: (1) costs of parking included in price of goods and services or an employee  
31 benefit; and (2) cost of on street free parking and municipal and institutional off-street parking. According to  
32 Delucchi, these costs are about 8 cents/VMT and about 2 cents/VMT, respectively.<sup>16</sup>

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

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<sup>14</sup> Cervero (2001).

<sup>15</sup> 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.

<sup>16</sup> Delucchi (1996)

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1 5.8 Unpriced Parking

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

DRAFT

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## 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 2014 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 Error! Reference source not found.. These cost estimates,<sup>17</sup> 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.<sup>18</sup> 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., 2014 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.<sup>19</sup> 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 cost of operating and maintaining the proposed rail investments is included in the analysis. Operations and maintenance activities apply to several assets, including rolling stock, stations, track, and

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<sup>17</sup> 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.

<sup>18</sup> 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.

<sup>19</sup> 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.

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1 support facilities. Additional incremental agency expenses are also included. The costs include regular and  
2 ramp-up O&M expenses beginning in 2029, with full ST3 O&M costs achieved in 2033 and continuing  
3 through the end of the evaluation period.

4 The ST3 financial plan provides annual O&M costs for much of the B/C evaluation period from 2033  
5 through 2072. These values will be deflated from YOE dollars to constant 2014 dollars. For evaluation  
6 period years beyond those included in the financial plan, O&M costs will be assumed to exhibit real growth  
7 (in excess of normal inflation), matching the growth rates assumed for transit ridership and benefits growth.  
8 This assumption is likely conservative, as real (after inflation) operating costs for many items would remain  
9 constant or scale up at a lower rate than by which ridership grows.

### 10 6.3 Periodic Capital Equipment Rehabilitation and Replacement Costs

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

- 15 • 30% of initial construction expenditures are replaced every 80 years (no rehabilitation required during  
16 the ST3 evaluation period);
- 17 • 70% of initial construction expenditures are replaced every 30 years at cost of no less than 50% of  
18 the initial constant expense, adding 30 years of life; and
- 19 • Rail vehicles are replaced every 30 years at a cost of 100% of the initial constant dollar expense. In  
20 addition, they are assumed to undergo a midlife rebuild/overhaul in year 15 at a cost equal to 15% of  
21 the initial constant dollar expense.

### 22 6.4 Residual Value (Cost Offset or Negative Cost)

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

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

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

32 For simplicity, it is assumed that all life-cycles begin in the first year of full operations, 2033. To illustrate,  
33 light rail vehicles are assumed to be replaced (at 100% of their initial cost) in 2062, and if the evaluation  
34 period ends in 2072, the residual value is 2/3 of the initial rail vehicle cost.

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## 1 7 Economic Costs Not Included in the Evaluation

### 2 7.1 Federal Funds (Cost Offset or Negative Cost)

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

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

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## 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 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 its 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.,  $B/C \text{ Ratio} = PVB / PVC$ . 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

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

#### 4 8.4 Sensitivity Analysis

5 To test the robustness of the estimated NPV, ERR, and B/C Ratio, the economic analysis also conducts  
6 several sensitivity tests, where the estimated measures are re-calculated under varying scenarios (i.e.  
7 assumptions). These scenarios may include:

- 8 Scenario 1: 15% increase in all calculated benefits
- 9 Scenario 2: 15% decrease in all calculated benefits
- 10 Scenario 3: 10-year increase in the evaluation period (from 40 to 50 years of full operations)
- 11 Scenario 4: No real wage growth in value of time calculation
- 12 Scenario 5: 15% increase in initial capital costs
- 13 Scenario 6: 15% decrease in initial capital costs
- 14 Scenario 7: Decrease real discount rate by 1 percentage point
- 15 Scenario 8: Increase real discount rate by 1 percentage point
- 16 Scenario 9: Evaluation without the assumption that all limited access facilities are tolled in 2040

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18 In the scenario where the evaluation period is increased to 50 years, it is assumed that all growth rates are also  
19 extended, i.e., continue to grow at the same rate during the additional evaluation years.

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## 9 SUMMARY

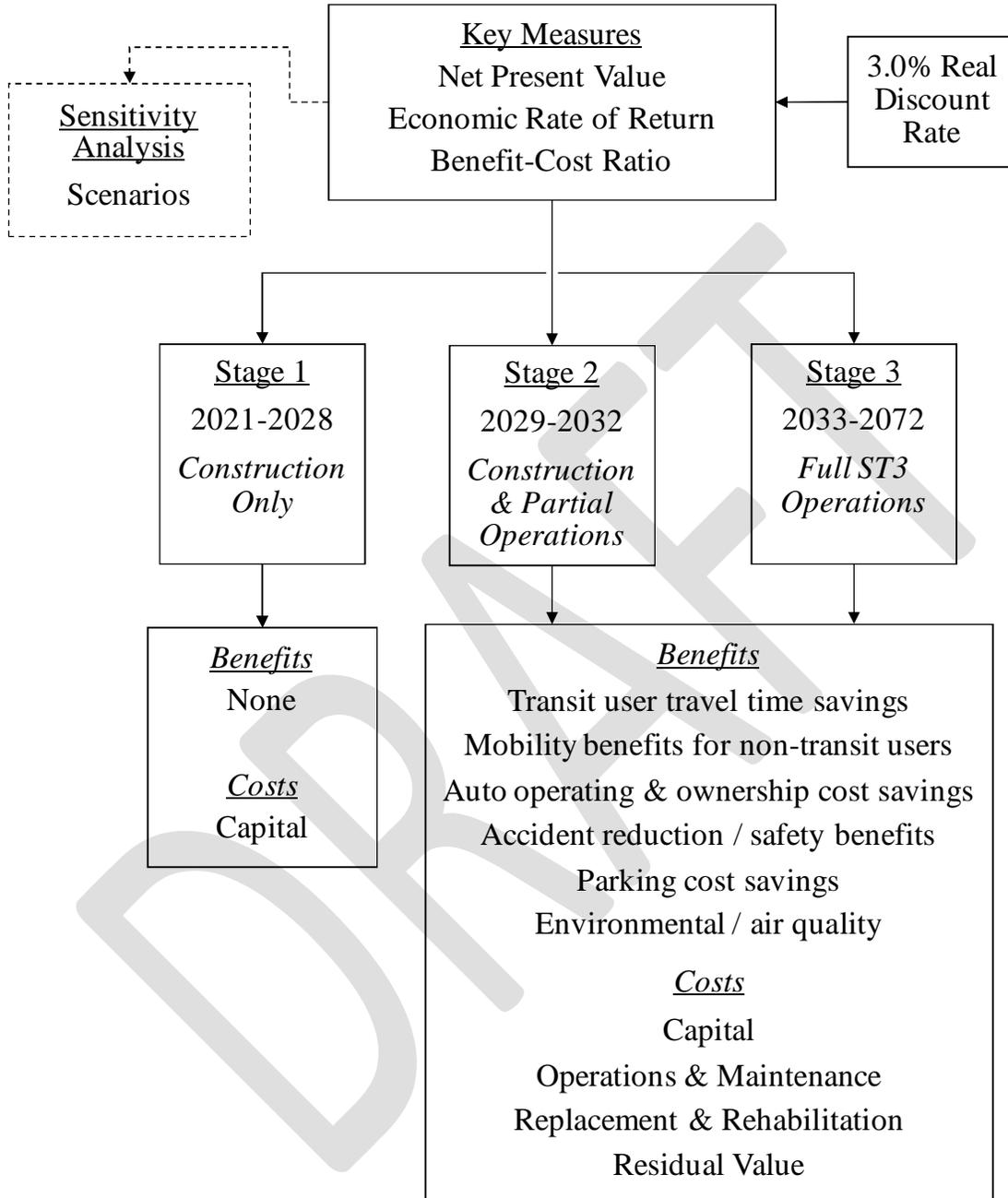
The key benefit-cost analysis assumptions are summarized in Exhibit 14.

### Exhibit 14 — Key Assumptions

Unit of Expression	2014 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	3.0%
Evaluation Period	
Stage 1 - Primarily Construction	2021-2028
Stage 2 - Partial Operations & Benefits	2029-2032
Stage 3 - Full Operations & Benefits	2033-2072
Study Region	King, Pierce, and Snohomish Counties
Real Benefits Growth Rate	Linear ramp-up 2029-32; model interpolated or extrapolated rates 2033-72
Real Wage Growth Rate	1.0% per year
Real O&M Cost Growth Rate	Per ST3 Financial Plan 2021-32; 1.3% per year 2033-72
Induced Highway Travel	None
<b>Benefits</b>	
Transit Travel Time Savings	Consumer surplus calculation from ST model outputs
Peak (Commute) Trips	Value of time = 60% 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	19 cents/mile for operating cost savings 32 cents/mile for vehicle ownership cost savings tied to reduced usage 11 cents / mile for vehicle ownership cost savings tied to reduced vehicle ownership and applied to 10% of VMT reduction
Accident Rates	
Fatal	0.39 – 2.41 per 100 million VMT
Injury	32 – 118 per 100 million VMT
Property Damage Only	70 – 215 per 100 million VMT
Accident Costs	
Fatal	\$4,677,900 / accident
Injury	\$28,900 - \$237,100 / accident
Property Damage Only	\$9,200 / accident
Parking Cost Savings	Estimated by ST model
Environmental Cost Savings	\$0.06 per VMT
Reliability	Excluded
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
<b>Costs</b>	
Initial Project Investment	
Residual Value	
Periodic Replacement & Rehabilitation	Estimates provided by ST
Regular Operating & Maintenance	
Federal Funds	Excluded

1 Exhibit 15 summarizes the ST3 B/C evaluation process.

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



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# *Appendix A*

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