BENEFIT-COST ANALYSIS TECHNICAL MEMORANDUM

April 14, 2016

PROJECT DESCRIPTION AND INTRODUCTION

The interchange of Port of Tacoma Road with Interstate 5 (I-5) is located just east of the Puyallup River Bridge in the City of Fife (City). This interchange is an integral element of the freight and truck operations of both the City and the Port of Tacoma (Port). As its name suggests, Port of Tacoma Road is the main access between the Port and I-5; the road also connects to major roadways and arterials, such as State Route 509 (SR 509) (South Frontage Road) and Pacific Highway East. Between SR 509 and 20th Street East, Port of Tacoma Road is a principal arterial fronting local businesses.

The existing interchange of Port of Tacoma Road with I-5 is a One Quad Parclo B interchange, with a single loop ramp in the southeast quadrant, which serves the northbound I-5 to northbound Port of Tacoma Road movement. Problems with the current configuration include closely spaced intersections and heavy congestion. The southbound off-ramp and on-ramps of the Port of Tacoma Road interchange are geometrically deficient with substandard alignments for exiting and entering I-5 at freeway speeds. High truck volumes, coupled with very closely spaced intersections, make it difficult for vehicles and freight to access this area.

This document is intended to serve as a guide to the methodologies and results in the analysis spreadsheet, "i5_port_of_tacoma_interchange_benefits_and_costs_analysis_2016.xlsx". The narrative of this memorandum, particularly the "Project Benefits" section, attempts to document our analysis in a way that is both transparent and reproducible.

APPROACH

To the extent possible with available data, this benefit-cost analysis reflects quantifiable societal benefits related to three of the five long-term outcomes specified in *Selection Criteria*, including:

- Economic Competitiveness
- Safety
- Environmental Sustainability

The societal benefits driving these outcomes would include travel time savings (economic competitiveness), prevented collisions (safety), and reduced emissions (environmental sustainability). Detailed data related to other societal costs and benefits, such as increased accessibility, operating costs savings, or maintenance and repair savings, were not readily available in existing project plan documents.

As noted in the narrative of the Application, the funding request would enable the construction of the full project (Phases 1 and 2). For this reason, our analysis measured both the costs and benefits of completing both phases. We assumed that project benefits would begin accruing in 2020 after full completion of the project and extend through the 2050 design year.

MAJOR REFERENCE DOCUMENTS

In gathering data and making assumptions for this analysis, our primary source was the *Port of Tacoma Road Interchange with I-5 Final Interchange Justification Report* (February, 2012) – hereafter referred to as "IJR." The IJR provides an analysis of AM and PM peak hour safety and capacity deficiencies at the present interchange under observed 2006, 2020 forecast, and 2040 forecast conditions. Additionally, it documents the improvements expected by implementing the full reconstruction project under 2020 and 2040 conditions. As of April 2016, the methods, assumptions, results, and recommendation documented within the IJR have been fully reviewed and approved by the Washington State Department of Transportation (WSDOT) and FHWA.

PROJECT BENEFITS

As previously mentioned, the Port of Tacoma Road/I-5 interchange reconstruction project would add capacity and reduce travel times through an existing interchange that currently has insufficient capacity to accommodate growing automobile and truck volumes. Traffic operations along the adjacent Port of Tacoma Road corridor and nearby portions of Pacific Highway East would also improve as a result of the reconstruction. In addition to reducing travel times and improving operations, the reconstruction would have multiple safety benefits. As a secondary result of improving interchange operations, the emission of criteria pollutants would decrease.

The following sections describe in detail how societal benefits related to travel time savings, prevented collisions, and emissions reductions were calculated. Where noted, the text refers to tabs, rows, columns, and cells in the spreadsheet used for analysis, "i5_port_of_tacoma_interchange_benefits_and_costs_analysis_2016.xlsx."

Travel Time Savings

Traffic volume and congestion in the project area are expected to increase in the next 30 years due to increased trade activities at the Port and Port of Seattle, as well as regional growth in population and employment throughout the Puget Sound. As mentioned in the Application narrative and documented, the interchange reconstruction would improve PM peak hour traffic operations dramatically, increasing study area speeds by 16%, reducing the vehicle hours of delay by 33%, and dropping the average delay per vehicle from 214 to 139 seconds. Delays for freight trucks at the intersection of Port of Tacoma Road and Pacific Highway East would decrease by 42 seconds, compared to 226 seconds of delay under no-build conditions. Comparable improvements to AM peak hour traffic operations would also occur.

The value of travel time savings experienced by roadway users over the lifetime of the interchange reconstruction project was estimated using traffic simulation data from the FHWA-approved IJR analysis. Total vehicle-hours of delay during the AM and PM peak periods were taken from study area simulation outputs reported in IJR for existing year, 2020 no-build, 2020 build, 2040 no-build, and 2040 build conditions (See spreadsheet tab "MOEs from POTR IJR")[1]. This data was summarized in the IJR Appendix B, pp. 39-41, and describes delay at the following locations relevant the proposed improvements:

- I-5 from I-705 to SR 18
- Port of Tacoma Road from SR 509 to 20th Street
- 54th Avenue E from 12th Street to 20th Street (adjacent I-5 interchange)
- Pacific Highway from Port of Tacoma Road to 54th Avenue E
- 20th Street from Port of Tacoma Road to 54th Avenue E

It is possible that additional locations in vicinity to the IJR simulation study area would also experience travel time savings due to the interchange reconstruction. Our analysis was limited to a set of locations in the immediate vicinity of the interchange to draw a conservative estimate of travel time benefits.

Total vehicle-hours of delay during the AM and PM peak periods were aggregated for each condition (See spreadsheet tab "Travel Time Summary," Table 1). Combined peak period person-hours of delay for each year between 2006 and 2050 were calculated for the no-build and build conditions by the following process (See spreadsheet tab "Travel Time Summary," Table 2, columns "F" and "G"):

[1] The VISSIM model was validated to existing conditions using the criteria suggested in Guidelines for Applying Traffic Microsimulation Modeling Software (FHWA, 2003). The calibrated and validated model was used to generate performance measures that are consistent with the Highway Capacity Manual (HCM) (Transportation Research Board, 2000). The validated VISSIM model served as the basis for future conditions models. The future-year VISSIM models were revised based on planned roadway improvements and forecasted traffic demand volumes.

- Linear interpolation was used to estimate person-hours between the 2006, 2020, and 2040 values provided by the IJR.
- In 2018 and 2019, construction efforts would cause person-hours in the build condition to exceed that of the no-build. Since no data on the typical increase in congestion due to interchange reconstruction was available, a conservative increase factor of 50% was applied to the vehicle-hours of delay.
- In 2020, it was assumed that construction would finish and travel time savings would begin to accrue due to the added interchange capacity from the completed project.
- As a conservative estimate, both no-build and build person-hours between 2040 and 2050 were assumed to grow at 1% per year.

After year-by-year no-build and build peak period vehicle-hour of delay estimates were developed, values were converted to daily person-hours for car and truck vehicle classifications by the following calculation:

$$modal\ person\ hours\ of\ delay\ =\ (vehicle\ hours\ of\ delay) * (persons\ per\ vehicle) * (mode\ \%\ of\ total\ traffic)$$

National averages for car occupancy are reported in the 2009 National Household Travel Survey (NHTS). Because the specific mix of vehicle trips by purpose within the study area is not known, the lowest of all measures reported by the 2009 NHTS (1.13 persons per vehicle for trips to and from work) was used to maintain a conservative estimate. The percent of total traffic by mode (car or truck) was taken from the IJR, which reported 7 – 10% of all vehicle traffic within the study area consisting of heavy trucks (p. 1-3). The value of 7% heavy trucks was used for the calculation with all trucks assumed to be single-occupant. Calculation results are provided in spreadsheet tab "Travel Time Summary," Table 2, columns "H" through "K").

After conversion to daily person-hours, an annual conversion was performed using a work-day year of 250 days (See spreadsheet tab "Travel Time Summary," Table 2, columns "L" through "O"). The use of 250 days to annualize the data assumes that the peak period vehicle-hours of delay reported in the IJR do not accurately reflect weekend traffic conditions, which are typically less-congested than weekday conditions. A decrease in vehicle-hours of delay could be expected during the weekend with the proposed interchange improvements, but the monetized value of this benefit cannot be accurately calculated with the available data.

No-build and build person-hour estimates were monetized using values from the 2001 National Household Travel Survey recommended by the *2016 BCA Resource Guide* – $13.45 per person-hour for local travel and $26.68 per person-hour for truck drivers (both in 2014 dollars). Next, the annual values of car and truck delay time were combined. The values under build conditions were subtracted from the no-build values to arrive at monetized values of travel time savings for all vehicle travel (See spreadsheet tab "Travel Time Summary," Table 2, column "V"). Finally, automobile and truck savings were converted from 2013 to 2015 dollars (column "W"). The total, undiscounted, value of travel time savings between 2015 and design year 2050 is expected to be $296 million. This is a conservative estimate because travel time savings would likely also accrue on days other than the 250 work days per year considered in our analysis.

Collision Reductions

The design of the full project build-out, including Phases 1 and 2, would have multiple safety benefits, both along I-5 and the Port of Tacoma Road corridor. According to the *Port of Tacoma Road Interchange with I-5 Project Interchange Justification Report (IJR)* (2012, p. viii), the southbound off-ramps and on-ramps of the interchange are geometrically deficient and have substandard alignments that prevent traffic from safely entering and exiting the I-5 mainline at freeway speeds. The reconstructed interchange would shift the alignments of the northbound and southbound ramps to contemporary geometric standards and allow traffic to more safely accelerate and decelerate when entering and exiting the freeway. Capacity improvements at the ramp intersections would alleviate queuing and spillback onto the I-5 mainline in periods of high demand. Converting Port of Tacoma Road and 34th Avenue East into a one-way couplet system would also create safety benefits by easing corridor congestion and reducing the number of conflict points at intersections.

To estimate the annual number of collisions reduced by the interchange reconstruction, the expected annual collisions under no-build conditions through 2050 were first calculated to set a baseline. This calculation was previously performed for the IJR using 2002–2008 collision data (pp. 1-20, 1-23, 1-24, and 1-26). In the interest of using more current data for this BCA calculation, annual collision rates were re-calculated based on January 2004 – March 2015 collision data provided by the Washington State Department of Transportation (WSDOT) and roadway characteristics such as average daily traffic (ADT) and length of facility already documented in the IJR.

As had been previously done for the IJR, collision totals from 2004 – 2015 (property damage only [PDO], injury, and fatality) were developed for various locations related to the Port of Tacoma Road interchange, including interchange ramps; the portions of the I-5 mainline adjacent to the ramps; the Port of Tacoma Road and Pacific Highway E corridors; and six corridor intersections. Specific locations included:

- **I-5 Freeway Mainline Segments** (see spreadsheet tab "Collision Data 2004 – 2015," Table 1A)
    - Northbound
        - Port of Tacoma Road SB off-ramp to Port of Tacoma Road NB off-ramp
        - Port of Tacoma Road NB off-ramp to North to Port of Tacoma Road on-ramp
        - Port of Tacoma Road on-ramp to 54th Avenue E off-ramp
    - Southbound
        - 54th Avenue E on ramp to Port of Tacoma Road off-ramp
        - Port of Tacoma Road off ramp to Port of Tacoma Road on-ramp
        - Port of Tacoma Road on ramp to E 27th Street off ramp
- **Interchange Ramps** (see spreadsheet tab "Collision Data 2004 – 2015," Table 2A)
    - Northbound
        - Port of Tacoma Road SB off-ramp

        - Port of Tacoma Road NB off-ramp
        - Port of Tacoma Road on-ramp
    - Southbound
        - Port of Tacoma Road off-ramp
        - Port of Tacoma Road on-ramp
- **Arterial Roadways** (see spreadsheet tab "Collision Data 2004 – 2015," Table 3A)
    - Port of Tacoma Road from 12th Street E to 20th Street E
    - Pacific Highway E from Port of Tacoma Road to 34th Avenue E
- **Port of Tacoma Road Intersections** (see spreadsheet tab "Collision Data 2004 – 2015," Table 4A)
    - Pacific Highway E
    - 20th Street E
    - I-5 SB off-ramp
    - I-5 SB on-ramp
    - I-5 NB off-ramp
    - I-5 NB on-ramp

It is possible that additional locations documented in the 2004-2015 collision data would also benefit from the safety improvements of the interchange reconstruction. Our analysis was limited to the set of location in the above bulleted list to draw a conservative estimate of safety gains.

For each of the four facility types bolded above, an aggregated annual collision rate was calculated for PDO, injury, and fatal collisions. Roadway segments (freeway mainline, interchange ramps, and roadway corridors) collision rates were calculated in terms of million vehicle miles (MVM) by the following formula:

$$annual\ collisions\ per\ MVM = \frac{(total\ collisions\ along\ roadway) \times 1{,}000{,}000}{(average\ daily\ traffic) \times 365 \times (years\ of\ data) \times (length\ of\ roadway\ in\ miles)}$$

Intersection collision rates were calculated in terms of million entering vehicles (MEV) by the following formula:

$$annual\ collisions\ per\ MEV = \frac{(total\ collisions\ at\ intersection) \times 1{,}000{,}000}{(average\ daily\ traffic) \times 365 \times (years\ of\ data)}$$

Calculations of existing year rates for PDO, injury, and fatal collisions, aggregated by facility type, are shown in spreadsheet tab "Collision Data 2004 – 2015," Tables 1A, 2A, 3A, and 4A. Calculation results are aggregated facility type characteristics (ADT and total length) are summarized in spreadsheet tab "Collision Summary," Tables 1 and 2.

Next, estimates for future year collisions under no-build conditions were calculated assuming that existing MEV and MVM rates would not change significantly but facility ADT would grow. Future year ADT was approximated by applying a conservative traffic growth factor of 0.5% a year to the 2006 observed ADTs reported in the IJR. Future year ADTs were also reported in the IJR as derived from 2020 and 2040 no-build versions of the Puget Sound Regional Council travel demand model (PSRC model). Because the level of detail inherent to PSRC model inputs, assumptions, calculations, and outputs is not easily reproducible by spreadsheet, the straightforward growth assumption of 0.5% was chosen to approximate future year no-build ADT. By comparison, the combined 2040 ADTs produced by growth factor are over 12% lower than those developed from the travel model (see spreadsheet tab "Collision Data 2004 – 2015," Table 5).

The future year ADT estimates produced by applying the 0.5% annual growth factor can be seen in column "F" of the "Collision Summary" tab, Tables 3, 4, 5, and 6. These ADT estimates were multiplied by the observed collision rates in Table 1 to generate annual collision estimates for the no-build condition.

Because the safety benefits of the interchange reconstruction would be different for the four facility types, collision reduction estimates were developed using a different set of assumptions for each facility type. Assumptions and results of those exercises are discussed in the following sections.

Freeway Mainline Collision Reductions

As previously mentioned, the geometrically deficient ramps at the existing interchange prohibit optimum acceleration and deceleration for vehicles entering and exiting the freeway. Additionally, peak period traffic demand and signal delays at the off-ramp intersections with Port of Tacoma Road can cause vehicle queues that back up onto the freeway mainline (IJR, p. 1-4).

The proposed ramp geometric improvements would prevent a portion of sideswipe collisions on the mainline from vehicles entering and exiting the freeway at sub-optimum speeds. By improving the signal phasing at the ramp terminals and eliminating peak hour vehicle queues, a number of rear-end collisions related to vehicle queues backing up onto the mainline would also be prevented. According to the 2004 – 2015 collision data, 77% of I-5 mainline collisions in the vicinity of the project were rear-end or sideswipe collisions (see spreadsheet tabs "Collision Cause – I5 NB" and "Collision Cause – I5 SB" for calculation; summarized in spreadsheet tab "Collision Data 2004 – 2015," Table 6). We assumed a moderate number of these read-end and sideswipe collisions would be prevented on an annual basis after reconstructing the interchange – approximately 20%. As can be seen in spreadsheet tab "Collision Summary," Table 3, this reduction resulted in six PDO and three injury collisions prevented in the first year of operation and one additional prevented PDO collision from 2029 through horizon year 2050.

Interchange Ramp Collision Reductions

Ramp geometric improvements and the elimination of excess delay and traffic queuing at the ramp terminal intersections would reduce the number of single vehicle collisions with ramp appurtenances, as well as congestion-related rear-end collisions. According to the 2004 – 2015 collision data, 59% of Port of Tacoma Road interchange ramp collisions were single vehicle appurtenance or rear-end collisions (see spreadsheet tabs "Collision Cause – Ramps"; summarized in spreadsheet tab "Collision Data 2004 – 2015," Table 7). We assumed that roughly a third of these collisions would be prevented on an annual basis after improving ramp geometry and ramp intersection operations. As can be seen in spreadsheet tab "Collision Summary," Table 4, this reduction resulted in one PDO collision prevented each year between opening year 2020 and horizon year 2050.

Corridor Collision Reductions

As previously described, the interchange reconstruction project would convert Port of Tacoma Road and 34th Avenue East (extended to cross I-5 between Pacific Highway East and 20th Street East) into a one-way couplet system to ease arterial congestion and to improve access into and out of the Port. Because relatively few one-way street conversions have occurred since the 1970s and the safety benefits of conversions have generally been assumed by modern practice, contemporary studies on the extent of collision reduction are not common. Studies from the era of one-way conversion state various collision reductions:

- Collisions were reduced by 45% in Portland, Oregon, when business district streets were converted to one-way, despite an 8% rise in traffic volumes.[2]
- One-way conversions in eight Oregon cities resulted in a 26.8% reduction in collisions, despite a 23.4% increase in vehicle miles traveled.[2]
- One-way conversions have resulted in collision reductions between 15% and 30% with very few exceptions, according to a 1966 study.[3]

With consideration to these studies and the expected safety gains of the Port of Tacoma Road corridor conversion, we used a mid-range reduction of 30%. As can be seen in spreadsheet tab "Collision Summary," Table 5, this assumption resulted in five PDO and two injury collisions prevented in the first year of operation and one additional prevented PDO collision from 2026 through horizon year 2050.

Intersection Collision Reductions

The interchange reconstruction and the establishment of a one-way couplet system on Port of Tacoma Road and 34th Avenue East would create four intersections made up of two one-way approaches. Each intersection would have simple geometry and phasing, with only five conflict points and two signal phases per intersection. By contrast, the existing (and no-build) condition has

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[2] Automotive Safety Foundation. (1963). *Traffic Control & Roadway Elements – Their Relation to Highway Safety*, p. 74.
[3] Research Triangle Institute. (1976). *The National Highway Safety Needs Study, Appendix A*, p. A-162. (DOT-HS-5-01069).

11 conflict points and five signal phases for the southbound ramp intersections and six conflict points for the northbound ramp intersections (IJR, p. 3-10). Additionally, five intersections along the corridor at 20th Street East, Pacific Highway East, and the SR 509 on/off-ramps would have a one-way north-south approach after construction.

As mentioned in the preceding section, the conversion of a two-way street into a one-way street could reduce collisions by 15% to 45%. With regards to the specific intersection safety improvement described in the previous paragraph, we used a mid-range collision reduction factor of 30% for our analysis. As can be seen in spreadsheet tab "Collision Summary," Table 6, this assumption resulted in a reduction of two PDO collisions and one injury collision in each year between the 2020 opening and horizon year 2050.

Monetized Value of Collision Reductions and Benefit Summary

The available 2004 – 2015 collision data was not classified by the KABCO scale. Rather, it was sorted by three categories: collisions that involved property damage only (PDO), collisions that resulted in some form of injury, and collisions that resulted in a fatality. Because of this simplified classification system, future year no-build collision estimates as well as the estimated number of reductions under build conditions were only classified as PDO or injury (existing fatality collision rates were not significant). The following process was used to monetize the estimated collision reductions while remaining compatible with the Abbreviated Injury Scale (AIS) methodology specified by the *2016 BCA Resource Guide*:

- A distribution of collision severity following AIS classification was developed for the future year injury collision reductions (see spreadsheet tab "Value of Injury and PDO," Tables 1 and 2). This distribution used injury severity data reported in the *2013 Washington State Annual Collision Summary* for Pierce County roadways.
- Based on the severity distribution, AIS value of statistical life, and AIS unit value, an average unit value per injury collision was determined – $246,624.00 (see spreadsheet tab "Value of Injury and PDO," Tables 1 and 2).
- Each PDO collision reduction was assigned a value of $4,198 (see spreadsheet tab "Value of Injury and PDO," Table 3).

The value of all collisions reduced between 2016 and 2050 was calculated and converted to 2016 dollars (see spreadsheet tab "Collision Summary," Tables 3, 4, 5, and 6, columns "P" through "Q"). Total collision reduction benefits for all facility types are summarized in the "Collision Summary" tab, Table 7. The total, undiscounted, value of collision reductions between 2016 and 2050 is expected to be approximately $47.9 million.

EMISSIONS REDUCTIONS

As noted in the Application narrative, the proposed interchange reconstruction project would transform the Port of Tacoma Road/I-5 interchange into a more efficient means of travel for cars and trucks entering and exiting I-5. The project would improve intersections operations and reduce the vehicle-hours of delay experienced by corridor traffic. With more efficient intersection and corridor operations, the amount of time spent idling per vehicle would decrease, resulting in fewer emissions of criteria pollutants. This section details the reductions in CO_2, NO_x, and VOC emissions expected under project build conditions and assigns a value to those reductions.

The emission reductions calculation assumed that the reduction in annual peak period vehicle-hours of delay between no-build and proposed project conditions (described previously in the Travel Time Savings section) would directly translate to a reduction in vehicle time spent idling. Person-hours of delay for cars and trucks were taken directly from the travel time savings calculation and converted to vehicle-hours of delay using a car occupancy of 1.13 and truck occupancy of one. The resultant annual vehicle-hours of delay savings for cars and trucks are shown in spreadsheet tab "Emissions Summary," Table 2, columns "R" and "S".

The process of estimating and monetizing CO_2, NO_x, and VOC emissions from annual vehicle-hours of delay savings is described in the following sub-sections

CO_2 Emission Reduction

The value of CO2 emission savings was calculated by the following steps:

- Vehicle-hours savings were translated to fuel consumption savings using passenger car and heavy trucks rates for gallons of fuel consumed per hour spent idling (see spreadsheet tab "Emissions Summary," Table 1). Passenger cars were assumed to be fully unloaded. Heavy truck vehicle-hour were assumed to be spent half loaded and half unloaded, as truck trips related to Port of Tacoma would likely be an equal mix of inbound deliveries and outbound pick-ups. Fuel consumption savings by mode is shown in spreadsheet tab Table 2, columns "T" and "U".
- Annual fuel savings were converted to annual metric tons of CO_2 savings using an emissions rate of 8,887 grams of CO_2 per gallon gasoline for passenger cars and 10,180 grams of CO_2 per gallon of diesel fuel for heavy trucks (column "V" and "W").[4] Car and truck annual savings were combined in column "AB".
- Savings were monetized using 3% social cost of carbon rates recommended by the *2016 BCA Resource Guide* (columns "AE" and "AF"). Savings were also converted to 2016 dollars,

[4] EPA. (May 2014). Greenhouse Gas Emissions from a Typical Passenger Vehicle. Retrieved from: http://www.epa.gov/otaq/climate/documents/420f14040a.pdf, p. 1

and future year values were discounted by 3% net present value, resulting in respective lifetime CO_2 savings of $4.8 million and $2.3 million (columns "AG" and "AH").

NO_x and VOC Emission Reductions

The values of NO_x and VOC emission savings were calculated by the following steps:

- Annual vehicle-delay hour savings were converted to annual prevented metric tons of NO_x and VOC using idling vehicle emission rates for cars and trucks provided by the US EPA (see spreadsheet tab "Emissions Summary," Table 1, rows 7 and 8).[5] Car and truck annual savings were combined in columns "AC" and "AD".
- The annualized values of emissions savings were monetized using the NO_x and VOC rates recommended by the *2016 BCA Resource Guide* (columns "AI" and "AJ").
- The combined NO_x and VOC savings were converted to 2016 dollars (columns "AK" and "AL").

Based on this analysis, the interchange modification would be expected to save approximately $604 thousand in NO_x and VOC emission over the lifetime of the project.

PROJECT COSTS

Project implementation is expected to cost a total of $63.56 million. For the purposes of our analysis, work completed with existing funds, $9.72 million total, was accounted for in existing year 2016. The remaining cost of $53.84 million was allocated in equal quantities to years 2017, 2018, and 2019. These installments of $17.95 million would approximately account for remaining non-construction costs such as right-of-way and design in 2017 and the costs of construction during 2018 and 2019. Project completion would occur before 2020, but the schedule of costs between 2017 and 2019 would likely differ slightly from our assumptions. For this reason, we chose to measure total, undiscounted costs, against discounted benefits. This removed any bias that incorrectly assumed details about the project cost schedule could have created.

In addition to implementation costs, our BCA incorporates operation and maintenance (O&M) costs for each year between project opening and horizon year 2050. These life cycle costs are intended to capture the total annual O&M costs resulting from only the added project improvements (see spreadsheet tab "Life Cycle Summary," Table 1). The life cycle costs do not account for O&M costs that would result with the existing facilities in a no-build condition. In general, these costs were determined from previous projects and estimates similar in scope and size, conversations with

[5] EPA. (2008). Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy Duty Trucks. Retrieved from: http://www.epa.gov/otaq/consumer/420f08025.pdf, p. 4

people/agencies experienced with these types of facilities, industry standards, or other sources as listed below:

- **Asphalt Rehabilitation Costs (Overlay & Reconstruction)**: Hot mix asphalt (HMA) roads typically last about 15 years before needing to be resurfaced. The O&M costs for the pavement included the costs of the HMA require the placement of a 2.5 inch overlay every 15 years and reconstruct the 9 inch section every 30 years. These costs only account for the net new HMA surfaces added by the project (new pavement areas – existing pavement being removed = net new).
- **Traffic Signals:** Typical traffic signal O&M costs were obtained from WSDOT's website.[6] The costs included are only for the signals added by the project (7 total).
- **Stormwater Facilities:** The stormwater O&M costs are intended to capture the costs to maintain the added facilities for the project (without accounting for replacements of existing facilities which would require O&M in the no-build condition). With project costs include a number of new grassed swales, media filter strips, ditches, and culverts that must be maintained to continue to operate as designed and permitted. The typical costs came from agency websites and sources such as the Washington State Department of Ecology.[7]

Using a life cycle of 75 years for project infrastructure and an interest rate of 4.5%, we estimated that the annual O&M costs resulting from the added improvements of this project would be approximately $117,610 (see spreadsheet tab "Life Cycle Summary," Table 1, cell S25).

Analysis Results and Summary

Total project benefits and costs are summarized in the "BCA Summary" tab. Total project costs are expected to be $66.37 million including implementation, operation, and maintenance costs (column "F"). Final, discounted benefit totals were calculated by the following steps:

- Benefits not related to CO_2 emissions were summarized in columns "G" through "I" and totaled in column "J." We discounted these benefits at both 3% and 7% net present value rates (columns "J" through "L").
- CO_2 emission benefits had already been discounted at 3% (see tab "Emissions Summary," Table 2, column "AH"). Federal social cost of carbon guidance does not recommend using a 7% discount rate, as noted in the *2016 BCA Resource Guide*.
- The 3% discounted CO_2 benefits were then combined with 3% discounted other benefits in column "P" and the 7% discounted in column "Q."

[6] WSDOT. (Date unknown). Traffic Signals. Retrieved from: http://www.wsdot.wa.gov/Operations/Traffic/signals.html

[7] Washington State Department of Ecology. (2012). Puget Sound Stormwater BMP Cost Database. Retrieved from: http://www.ecy.wa.gov/programs/eap/toxics/docs/PugetSoundStormwaterBMPCostDatabase.pdf

As shown in cells P44 and Q44, the project benefit/cost ratio would be 2.64 under the 3% discount and 1.18 under the 7% discount.

In practice, the lifetime benefits generated by the interchange project should be higher than our estimates. Our valuation of societal benefits could be considered conservative for the following reasons:

- Our annual travel time savings analysis was limited to a set of locations in the immediate vicinity of the interchange, though other nearby roadway segments and intersections would likely experience benefits as well.
- Because network delay savings data was only available for the AM and PM peak periods, annual travel time savings were only calculated over a limited portion of the day for the approximate 250 yearly work days. Travel time savings would likely also accrue during other portions of a typical weekday (such as the midday travel peak) and during weekends and holidays.
- To calculate future year collision estimates using exiting rates, future year average daily traffic (ADT) was approximated by applying a conservative traffic growth factor of 0.5% a year to the 2006 observed ADTs reported in the IJR. Future year ADTs were also reported in the IJR as derived from 2020 and 2040 no-build versions of the Puget Sound Regional Council travel demand model (PSRC model). Because the level of detail inherent to PSRC model inputs, assumptions, calculations, and outputs is not easily reproducible by spreadsheet, the straightforward growth assumption of 0.5% was chosen to approximate future year no-build ADT. By comparison, the combined 2040 ADTs produced by growth factor are over 12% lower than those developed from the travel model.
- Historical collision data did not provide information regarding the severity of injuries. A conservative distribution of collision severity following AIS classification (based on aggregate injury severity data reported in the *2013 Washington State Annual Collision Summary* for Pierce County roadways) was assumed for the future year injury collision reductions.
- The emission savings calculation had the same data constraints as the travel time savings analysis. Only emission savings related to vehicle idling during the AM and PM peak hours on a typical weekday were counted. In reality, emission savings due to decreased vehicle idling would also accrue during other portions of a typical weekday, as well as weekends and holidays.