APPENDIX A
BENEFIT-COST ANALYSIS DISCUSSION

1. Executive Summary

This memorandum summarizes the approach used for conducting a Benefit-Cost Analysis (BCA) for *Access I-95: Driving Baltimore City's Growth*. Table 1 shows the project matrix, which describes baseline conditions, proposed improvements, types of impacts to all users/population affected by them, a summary of results, and a page reference in this memorandum. The cost effectiveness results show that with discount rate of 7%, the project is expected to generate $553 million in benefits, which leads to a net present value of $407 million. With that same discount rate, the benefit-cost ratio equals 3.79. The largest share of benefits is travel time savings, which amount to roughly 90% of the total. This result is driven by the sizable hours of vehicle delay in the no-build scenario of the travel demand model 2040 forecast. Other benefits include vehicle operating cost savings, health and mode diversion benefits from improved pedestrian accessibility and walk mode share, improved safety due to rail relocation, avoided emissions, and avoided maintenance costs. A sensitivity analysis was performed in order to test whether assumptions in the cost effectiveness assessment could significantly alter the direction and magnitude of results. The sensitivity analysis shows that all tested alternatives lead to healthy benefit-cost ratios and that the project remains cost effective.

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Table 1: Project Matrix

Current Status & Problem	Changes to Baseline	Types of Impacts	Population Affected	Economic Benefit	Summary of Results (7% disc.)
Limited Interstate 95 access to and from the Port Covington site Roadway connectivity within Port Covington as it relates to the existing CSX track Limited Pedestrian access to and from the Port Covington site and the adjacent neighborhoods Current roadway facilities do not support the rapid development expected in the Port Covington site.	Widening of Mccomas street to a three- to four lane divided street from Hanover street to Key highway Additional lane along Key Highway at the intersection of McComas Street Widening of I-95 off ramp to Key Highway I-95 Southbound and I-95 Northbound off ramps to McComas Street CSX Track Relocation	Increased capacity Increased travel speeds and travel time Reduced Vehicle Operating Costs Improved Accessibility	Corridor users: (AADT) trucks and autos in 2020 and 2040	Monetized Value of Reduced Travel Time	$508,281,464
				Monetized Value of Change in Vehicle Operating Costs	$28,372,103
		Reduced costs of collisions from Rail Relocation	Local, state and national population	Monetized Value of Reduced Collisions	$124,975
		Improved Pedestrian Access Shift to active mode of transportation	Local population	Monetized health benefits and benefits from auto diversion	$10,932,482
		Reduced air emissions generated by motor vehicles	Local, state, region, and national population	Monetized Value of Reduced Carbon Emissions	$2,959,753
				Monetized Value of Reduced Non-Carbon Emissions	$3,234,432
		Avoided Costs for State of Good Repair (ramps)	Government	Monetized Value of Maintenance Costs	$120,242
		Additional Jobs from project construction and operations	Local and regional population	Economic Impact of Jobs	2,383 job years

2. Project Background

The Maryland Transportation Authority and the City of Baltimore are jointly seeking to improve access to and from I-95 in the vicinity of the Port Covington redevelopment area. The Port Covington project is located on 266 acres on the tip of the south Baltimore peninsula. This roadway infrastructure project is critical to support the significant economic growth expected from the Port Covington redevelopment, which is already underway, and protect the surrounding communities as well as the economic efficiency of the city, state, and region.

The Port Covington redevelopment project will revitalize 266 acres of under-utilized industrial land. The site is located on a peninsula bound by I-95 and the Middle Branch of the Patapsco River. Without critical infrastructure improvements for access to and from I-95 and the connecting roadway system, it is likely that the traffic produced by the development will cause disruptions and delays that will adversely impact operations at the Port of Baltimore and the neighboring communities.

The following project components are part of Phase I, for which FASTLANE grant funding is being requested in order to improve the infrastructure of the roadway network:

a) McComas Street at Key Highway Intersection: The existing two lane section of Key Highway will be widened to accommodate a third southbound lane in order to alleviate an existing bottleneck for traffic to/from I-95. The existing CSX bridge, which will need to be reconstructed as a result of the I-95 southbound Off-Ramp to Key Highway, will be reconstructed in order to accommodate the widening along Key Highway. This improvement will also allow for enhanced pedestrian and bicycle access along Key Highway;

b) I-95 Southbound Off-Ramp to Key Highway: The exit ramp to Key Highway will widen to a two-lane Off-Ramp after splitting off from I-95 to merge with McComas Street, where it will become a three-lane road, which will facilitate better traffic flow, reduce congestion from the interstate to Port Covington and the surrounding area, and avoid spill-back on the main I-95 lanes;

c) Hanover Street North of McComas Street: Existing Hanover Street north of the McComas Street intersection is a four to five lane undivided roadway. Proposed improvements include widening Hanover Street in order to accommodate the widening of the Hanover Street On-Ramp to I-95 southbound, in addition to enhanced pedestrian facilities which extend north into the surrounding residential neighborhoods.

d) Relocated McComas Street between Hanover Street and Key Highway: Existing McComas Street between Hanover Street and Key Highway consists of a three to four lane divided section Proposed improvements include shifting McComas Street south of I-95 in its entirety, including pedestrian facilities. Additional lanes will be added to the typical section in order to accommodate future traffic demand and connections to I-95;

e) I-95 Southbound and I-95 Northbound off ramps to McComas Street: Off-Ramps to Hanover Street from I-95 (Southbound and northbound) will provide better interstate access for traffic from Port Covington;

f) CSX Track Relocation: A proposed CSX track will cross over the I-95 Fort McHenry Tunnel and will act as a service track to existing Maryland Port Authority facilities. The rail relocation will allow for the existing CSX sidetrack south of I-95 to be removed which will eliminate two existing at-grade crossings within Port Covington, and prevent the creation of nine additional at-grade crossings.

3. Cost Effectiveness Analysis

This section describes the methodology for estimating benefits and costs of the Grand Parkway Segment I-2 project. In calculating the benefit-cost analysis, Cambridge Systematics Inc. (CS) followed Federal guidance regarding evaluation criteria, discount and monetization rates, and evaluation methods prescribed in the 2016 TIGER and FASTLANE guidance and supporting documents.

The BCA provides monetary benefits and costs, in present day dollars, associated with the project over a 40-year analysis period. The estimated benefits have been categorized by the five long-term outcomes listed in the BCA Resource Guide as follows: State of Good Repair, Economic Competitiveness, Quality of Life, Environmental Sustainability, and Safety. An effort was made to comply with all BCA guidelines and a conservative approach has been used for all assumptions.

3.1 Travel Demand

A Travel Demand Model (TDM) was estimated for the project area in Port Covington with a baseline (2012) and a no-build scenario (2040). The model was developed by the team conduction the National Environmental Policy Act (NEPA) evaluation, and was run by Cambridge Systematics in VISSIM software. The model encompasses the entire study area. A variety of metrics were estimated for impacted trips: for PM peak and AM peak times with existing conditions (2012) and in the no-build scenario (2014), the model metrics included vehicle miles traveled (VMT), vehicle hours traveled (VHT), vehicle hours of delay (VHD) for autos, trucks, and buses.

The results show a 2040 no-build scenario that is severely congested, with delays both in the network and outside of the simulated network, with potential peak spreading. Comparing total peak hour delay for 2012 and 2040, the travel demand model shows that it more than quadruples (from 1,772 to 7,417 hours of delay in the PM peak hour). This significant result is driven by the profound changes expected in the Port Covington site due to the new development planned in the area.

Truck traffic is also expected to be strongly affected in a no-build scenario. Truck delay also more than quadruples in the study area (from 187 to 769 delay hours in the PM peak), an outcome that does not even include potential spill-back delays in areas of I-95 outside of the simulation model. The model forecasts an 8% share of truck trips in the simulation study areas in 2040.

In order to the estimate the project benefits or costs, auto delay was broken down between commuting and leisure trips, using travel rates by trip purpose data from the 2009 National Household Travel Survey (NHTS)[1]. Breaking down trip purpose is important for the analysis as commuting trips are annualized using business days per year, and have a higher cost of travel time as indicated in the FASTLANE Benefit-Cost Analysis guidance[2].

Annual figures for vehicle hours of delay were calculated by type of trip and by type of vehicle for 2012 and 2040, using the following formula:

$$VHD_{TT} = (PeakHours\_pm * VHD\_pm + PeakHours\_am * VHD\_am) * Annualization_{TT}$$

Where $TT = \{Commute, Leisure, Truck\}$, VHD is annual vehicle hours of delay, VHD_pm and VHD_am are the number of hours of delay in the AM or PM peak hour, $PeakHours\_pm$ and $PeakHours\_am$ are the number of

[1] Summary of Travel Trends: 2009 National Household Travel Survey. Available at: http://nhts.ornl.gov/2009/pub/stt.pdf

[2] 2016 TIGER Benefit-Cost Analysis (BCA) Resource Guide supplement to the 2016 Benefit-Cost Analysis Guidance for Grant Applicants. Table 1. Recommended Monetized Values

congested hours in the PM and AM peak, which are equal to 2 in the AM and 2 in the PM according to data from the regional travel demand model, and $Annualization$ is the number of days per year for each trip type (365 for leisure and truck, and 250 for commuting trips). Annual trip delay for the 2012 baseline and 2040 no-build scenario were linearly interpolated in order to estimate delay for years in between both scenarios.

In order to estimate the impact of project, the assumptions for the Transportation Impact and Economic Return System (TIERS) tool, developed by Cambridge Systematics Inc., were used. The tool standardizes the approach to measuring project benefits at the planning-level when TDM data is unavailable based on ITE guidelines. The methodology classifies operational projects into minor, moderate, and major, as detailed in Table 2. For a project such as Access I-95, the impact is considered to be moderate, as it includes components such as adding turning lanes, interchange reconstruction, and adding a though lane.

Table 2: Operational Project Type and Impact Level Assumptions in TIERS

Project Type	Operational	
	Impact Level	Delay Reduction
Increase Length of Turn Bay	Minor	15%
Increase the Turn Radius	Minor	15%
Striping Changes	Minor	15%
Signal Timing/Phasing Changes	Minor	15%
Prohibit Left-Turn Movements	Minor	15%
Prohibit On-Street Parking	Minor	15%
Adding Turn Lanes	Moderate	30%
Adding a Through Lane	Moderate	30%
Add a Traffic Signal	Moderate	30%
Add a Roundabout	Moderate	30%
Bridge Replacement	Moderate	30%
Interchange Reconstruction	Moderate	30%
Innovative Intersection (Continuous Flow Interchange, etc.)	Major	60%
Grade Separation	Major	60%

Source: TIERS Tool User Guide

Having identified the expected impact of the project on traffic delay during congested hours, a build scenario for 2040 using the expected delay reduction was estimated. Annual VHD by type of trip in the build scenario were calculated for years between 2022 (when all components of the project are expected to be opened to traffic) and 2040. A summary of vehicle hours of delay is shown in Table 3.

Table 3: Vehicle Hours of Delay (model years=2012 and 2040)

Year	Baseline		Build		Delay Savings	
	Auto Delay (hours daily)	Truck Delay (hours daily)	Auto Delay (hours daily)	Truck Delay (hours daily)	Total hours daily (auto+truck)	Total hours annual (auto+truck)
2012	**5,540**	**665**	**5,540**	**665**	**-**	**-**
2013	6,178	740	6,178	740	**-**	**-**
2014	6,815	816	6,815	816	**-**	**-**
2015	7,453	891	7,453	891	**-**	**-**
2016	8,091	966	8,091	966	**-**	**-**
2017	8,729	1,042	8,729	1,042	**-**	**-**
2018	9,366	1,117	9,366	1,117	**-**	**-**
2019	10,004	1,193	10,004	1,193	**-**	**-**
2020	10,642	1,268	10,642	1,268	**-**	**-**
2021	11,280	1,344	11,280	1,344	**-**	**-**
2022	11,918	1,419	8,342	993	-4,001	-1,382,427
2023	12,555	1,495	8,789	1,046	-4,215	-1,456,356
2024	13,193	1,570	9,235	1,099	-4,429	-1,530,285
2025	13,831	1,645	9,682	1,152	-4,643	-1,604,214
2026	14,469	1,721	10,128	1,205	-4,857	-1,678,143
2027	15,107	1,796	10,575	1,257	-5,071	-1,752,071
2028	15,744	1,872	11,021	1,310	-5,285	-1,826,000
2029	16,382	1,947	11,468	1,363	-5,499	-1,899,929
2030	17,020	2,023	11,914	1,416	-5,713	-1,973,858
2031	17,658	2,098	12,361	1,469	-5,927	-2,047,787
2032	18,296	2,174	12,807	1,522	-6,141	-2,121,716
2033	18,933	2,249	13,253	1,574	-6,355	-2,195,645
2034	19,571	2,325	13,700	1,627	-6,569	-2,269,573
2035	20,209	2,400	14,146	1,680	-6,783	-2,343,502
2036	20,847	2,475	14,593	1,733	-6,997	-2,417,431
2037	21,485	2,551	15,039	1,786	-7,211	-2,491,360
2038	22,122	2,626	15,486	1,838	-7,425	-2,565,289
2039	22,760	2,702	15,932	1,891	-7,639	-2,639,218
2040	**23,398**	**2,777**	**16,379**	**1,944**	**-7,853**	-2,713,147

The project useful life was considered to be approximately 30 years, therefore the estimation of the benefits and costs starts off in current time until year 2050. Since no demand model data is available beyond year 2040, no growth in delay beyond 2040 until 2050 was assumed, thus resulting in a conservative estimate of future delay.

3.2 Travel Time Savings

Travel Time savings were calculated based on the differences in annual delay by trip type between build and no-build scenarios. The following formula was used for calculating travel time savings for each year between 2022 and 2050 (in 2015 $):

$$TTS_{TT} = \Delta VHD_{TT} * AVO_{TT} * VOT_{TT}$$

Where TTS is Travel Time Savings, VHD is annual vehicle hours of delay, AVO is Average Vehicle Occupancy (for which 2015 American Community Survey (ACS) data for Baltimore Metropolitan Statistical Area was used for auto commuting trips, 2009 NHTS data used for non-work auto trips, and 1 was assumed for truck trips), and VOT is Value of Time, for which the recommended values in the FASTLANE BCA Resource Guide were used and expressed in 2015 dollars. In the formula, the types of trip include $TT = \{Commute, Leisure, Truck\}$. Table 4 summarizes the results in term of Travel Time Savings:

Table 4: Travel Time Savings

Year	Calendar Year	Change in Travel Delay in Hours (Build – No-build)	Monetary Value of Travel Time Cost Saved/Wasted (in 2015$)	NPV of Travel Time Savings	
				3%	7%
				NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
5	2022	-1,382,427	$36,953,588	$31,876,490	$26,347,398
6	2023	-1,456,356	$38,929,751	$32,603,054	$25,940,537
7	2024	-1,530,285	$40,905,914	$33,260,252	$25,474,147
8	2025	-1,604,214	$42,882,077	$33,851,508	$24,957,759
9	2026	-1,678,143	$44,858,240	$34,380,106	$24,399,910
10	2027	-1,752,071	$46,834,403	$34,849,194	$23,808,236
11	2028	-1,826,000	$48,810,566	$35,261,791	$23,189,548
12	2029	-1,899,929	$50,786,729	$35,620,790	$22,549,915
13	2030	-1,973,858	$52,762,892	$35,928,962	$21,894,724
14	2031	-2,047,787	$54,739,055	$36,188,964	$21,228,749
15	2032	-2,121,716	$56,715,218	$36,403,340	$20,556,205
16	2033	-2,195,645	$58,691,381	$36,574,528	$19,880,801
17	2034	-2,269,573	$60,667,543	$36,704,862	$19,205,791
18	2035	-2,343,502	$62,643,706	$36,796,575	$18,534,012
19	2036	-2,417,431	$64,619,869	$36,851,809	$17,867,932
20	2037	-2,491,360	$66,596,032	$36,872,608	$17,209,680
21	2038	-2,565,289	$68,572,195	$36,860,934	$16,561,083
22	2039	-2,639,218	$70,548,358	$36,818,659	$15,923,693
23	2040	-2,713,147	$72,524,521	$36,747,576	$15,298,822
24	2041	-2,713,147	$72,524,521	$35,677,259	$14,297,964
25	2042	-2,713,147	$72,524,521	$34,638,115	$13,362,583
26	2043	-2,713,147	$72,524,521	$33,629,238	$12,488,396
27	2044	-2,713,147	$72,524,521	$32,649,746	$11,671,398
28	2045	-2,713,147	$72,524,521	$31,698,782	$10,907,848
29	2046	-2,713,147	$72,524,521	$30,775,517	$10,194,251
30	2047	-2,713,147	$72,524,521	$29,879,142	$9,527,337
31	2048	-2,713,147	$72,524,521	$29,008,876	$8,904,054
32	2049	-2,713,147	$72,524,521	$28,163,957	$8,321,545
33	2050	-2,713,147	$72,524,521	$27,343,648	$7,777,145
Totals =		**-$66,039,416**	**$1,765,287,249**	**$987,916,281**	**$508,281,464**

3.3 Vehicle Operating Cost Savings

The reduction in vehicle delay in the build scenario is also expected to generate a decline in Vehicle Operating Costs (VOC). This is made possible by a decrease in the time vehicle engines need to be idle in congestion, which leads to a decrease in fuel use. The following formula was used in order to capture such savings for each year between 2022 and 2050:

$$VOCS_{VT} = \Delta VHD_{VT} * IdleCons_{VT} * FuelCost_{VT}$$

Where $VT = \{Auto, Truck\}$, $VOCS$ is Vehicle Operating Cost Savings, VHD is Vehicle Hours of Delay, $IdleCons$ is a measured in gallons of fuel consumed per hour of engine idling for an average auto and truck (as provided by the U.S. Office of Energy & Renewable Energy[3]), and $FuelCost$ is the forecasted price of gas and diesel in 2015 $ (as provided by the U.S. Energy Information Administration, EIA). The monetized results are shown in Table 5:

[3] Average idling consumption for vehicle with load and with no load, for average auto and truck size. Data made available by the Office of Energy & Renewable Energy available at: http://energy.gov/eere/vehicles/fact-861-february-23-2015-idle-fuel-consumption-selected-gasoline-and-diesel-vehicles.

Table 5: Vehicle Operating Cost (VOC) Savings

Year	Calendar Year	Idling Cost Savings ($ 2015)			NPV of Vehicle Idling Savings	
					3%	7%
		Auto	Truck	Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
5	2022	$1,255,995	$488,554	$1,744,549	$1,504,864	$1,243,840
6	2023	$1,344,407	$523,094	$1,867,500	$1,564,002	$1,244,394
7	2024	$1,425,546	$557,951	$1,983,496	$1,612,764	$1,235,222
8	2025	$1,512,794	$595,715	$2,108,508	$1,664,476	$1,227,171
9	2026	$1,615,263	$636,401	$2,251,663	$1,725,713	$1,224,756
10	2027	$1,713,173	$675,945	$2,389,117	$1,777,728	$1,214,506
11	2028	$1,804,514	$713,764	$2,518,278	$1,819,258	$1,196,416
12	2029	$1,905,810	$756,276	$2,662,086	$1,867,134	$1,181,998
13	2030	$1,999,632	$795,281	$2,794,913	$1,903,200	$1,159,790
14	2031	$2,112,077	$841,924	$2,954,001	$1,952,943	$1,145,612
15	2032	$2,232,859	$891,304	$3,124,162	$2,005,281	$1,132,340
16	2033	$2,357,722	$941,875	$3,299,597	$2,056,200	$1,117,688
17	2034	$2,482,823	$994,008	$3,476,831	$2,103,540	$1,100,676
18	2035	$2,583,516	$1,042,703	$3,626,219	$2,130,022	$1,072,867
19	2036	$2,717,692	$1,098,731	$3,816,423	$2,176,453	$1,055,273
20	2037	$2,831,090	$1,145,888	$3,976,978	$2,201,956	$1,027,727
21	2038	$2,977,961	$1,204,990	$4,182,950	$2,248,542	$1,010,237
22	2039	$3,117,458	$1,261,410	$4,378,867	$2,285,298	$988,368
23	2040	$3,277,163	$1,327,266	$4,604,428	$2,333,026	$971,290
24	2041	$3,277,163	$1,327,266	$4,604,428	$2,265,074	$907,747
25	2042	$3,277,163	$1,327,266	$4,604,428	$2,199,101	$848,362
26	2043	$3,277,163	$1,327,266	$4,604,428	$2,135,049	$792,862
27	2044	$3,277,163	$1,327,266	$4,604,428	$2,072,863	$740,992
28	2045	$3,277,163	$1,327,266	$4,604,428	$2,012,489	$692,516
29	2046	$3,277,163	$1,327,266	$4,604,428	$1,953,872	$647,211
30	2047	$3,277,163	$1,327,266	$4,604,428	$1,896,963	$604,870
31	2048	$3,277,163	$1,327,266	$4,604,428	$1,841,712	$565,300
32	2049	$3,277,163	$1,327,266	$4,604,428	$1,788,070	$528,317
33	2050	$3,277,163	$1,327,266	$4,604,428	$1,735,990	$493,754
Totals =		**$74,039,119**	**$29,765,735**	**$103,804,853**	**$56,833,580**	**$28,372,103**

3.4 Health Benefits from Induced Walk Trips

The Access I-95 project will provide pedestrian-friendly facilities, improving connectivity in Port Covington for internal walking trips and external walking trips to and from adjacent communities in South Baltimore. Currently, there are no pedestrian facilities in the study area, and the project seeks to enhance the walking accessibility in the redevelopment area. This active mode of transportation is known to improve public fitness and health, which generates benefits to walkers and as an externality to the healthcare system.

In order to calculate such benefits, the following equation was estimated for each year between 2022 and 2050:

$$HB = \frac{\%Walking}{\%Auto} * AutoTrips * WalkDistance * Health$$

Where HB represents monetized health benefits, $\frac{\%Walking}{\%Auto}$ is the ratio between the walking mode share to the auto mode share in Baltimore City (roughly 10%, according the 2015 ACS), $AutoTrips$ is the estimated number of annual auto trips to/from the project site, $WalkDistance$ is the average distance of a walking trip [estimated at 0.3 miles, according to Litman (2016)[4]], and $Health$ refers to the estimated dollar value (roughly $0.50 in 2015 dollars) of health benefits from an additional mile walked [also in Litman (2016)].

The number of annual auto trips from/to the project site were calculated based on the PM peak hour traffic volumes in two main intersections in Port Covington (Hanover Street southbound and northbound at McComas Street and McComas Street westbound and eastbound at Key Highway). A planning analysis hour factor (or k-factor) of 0.1 was used to estimate average daily trips, excluding truck traffic. The same annualization factors as indicated previously for commuting and leisure trips were employed to calculate total annual auto trips. Trips were calculated for existing traffic volume data (2015) and for future volumes (2040) using information from the TDM. Such trip estimation was necessary since the number of aggregate total trips estimated by the TDM, as a source for the calculation of other benefits, includes trips in links that were not directly associated with trips within the project site, and this could overestimate the magnitude of the walking benefits.

The benefit estimation assumes that the walk mode share in the Port Covington site, with a significantly enhanced pedestrian accessibility, will increase from zero (since pedestrian facilities are almost non-existent in current conditions) to the levels observed on average in the city of Baltimore (2015 ACS data). The results are shown in Table 6.

[4] Litman (2016) Evaluating Transport Benefits and Costs: Guide to Valuing Walking and Cycling Improvements and Encouragment Programs.

Table 6: Health Benefits Associated with Increase in Walk Mode Share

Year	Calendar Year	Monetary Value of Health Benefits (in 2015$)	NPV of Auto Trip Diversion Benefits	
		All Trips	3%	7%
		Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
5	2022	$379,394	$327,269	$270,503
6	2023	$390,359	$326,919	$260,113
7	2024	$401,324	$326,313	$249,924
8	2025	$412,289	$325,465	$239,956
9	2026	$423,254	$324,389	$230,222
10	2027	$434,219	$323,100	$220,735
11	2028	$445,184	$321,610	$211,504
12	2029	$456,149	$319,934	$202,536
13	2030	$467,114	$318,082	$193,836
14	2031	$478,079	$316,066	$185,407
15	2032	$489,044	$313,899	$177,252
16	2033	$500,009	$311,589	$169,370
17	2034	$510,974	$309,148	$161,761
18	2035	$521,939	$306,584	$154,423
19	2036	$532,904	$303,908	$147,352
20	2037	$543,869	$301,127	$140,546
21	2038	$554,834	$298,250	$134,000
22	2039	$565,799	$295,286	$127,708
23	2040	$576,764	$292,241	$121,667
24	2041	$576,764	$283,730	$113,707
25	2042	$576,764	$275,466	$106,268
26	2043	$576,764	$267,442	$99,316
27	2044	$576,764	$259,653	$92,819
28	2045	$576,764	$252,090	$86,747
29	2046	$576,764	$244,748	$81,072
30	2047	$576,764	$237,619	$75,768
31	2048	$576,764	$230,698	$70,811
32	2049	$576,764	$223,979	$66,179
33	2050	$576,764	$217,455	$61,849
Totals =		**$14,851,134**	**$8,454,056**	**$4,453,348**

3.5 Benefits from Avoided Auto Trips as a Result of Induced Walk Trips

Benefits of transportation modes other than auto often include the externalities of avoided auto trips. In other words, additional walking trips divert trips from motorized vehicles. Therefore, Litman (2016) shows that the benefits of reduced vehicle travel include vehicle operating cost savings (user savings from reduced vehicle ownership and use), congestion reduction (reduced traffic congestion from automobile travel on congested roadways), avoided emissions (benefits from reduced energy consumption), and roadway cost savings (reduced maintenance and operating costs).

In order to monetize the above described benefits, Vehicle Miles Diverted (VM_Div) were calculated using the formula below, in which $\overline{AVO}$ is the Average Vehicle Occupancy for commuting trips and leisure trips overall. The remaining variables in the equation are the same as described in the formula used to calculate health benefits in 3.3.

$$VM\_Div = \frac{\%Walking}{\%Auto} * AutoTrips * WalkDistance \Big/ \overline{AVO}$$

Using Vehicle Miles Diverted for each year of the project's life cycle allows us to calculate congestion alleviation. Litman (2016) reports that the marginal congestion cost of VMT imposed on other motorists is on average $0.20 at the peak hour and $0.05 at an off-peak hour in an urban area in 2015 dollars, which was used to monetize congestion alleviation benefits from walking trips. In addition, a similar approach to savings of Vehicle Operating Costs as section 3.3 was followed. In order to calculate the avoided damage of additional miles on road surface, the marginal pavement cost of auto VMT in 2015 dollars (FHWA, 1997[5]) was used (roughly $0.001 in 2015 dollars). Finally, in order to estimate the benefits in terms of non-carbon emission avoided, the same methodology as that employed in 3.7 was followed. The benefits of avoided carbon emissions are calculated separately in 3.6. The results are presented in Table 7 below:

[5] Source: 1997 Federal Highway Cost Allocation Study, Final Report, Table V-22

Table 7: Benefits of Avoided Auto Trips as a Result of Increase in Walk Mode Share

Calendar Year	Monetary Value of Congestion Alleviation (in 2015$)	Monetary Value of Vehicle Operating Cost Savings (in 2015$)	Monetary Value of Pavement Mainten. Savings (in 2015$)	Monetary Value of Non-Carbon Emissions Avoided (in 2015$)	Grand Total (in 2015$)	NPV of Auto Trip Diversion	
	All Trips	All Trips	All Trips	All Trips	All Trips	3%	7%
	Total	Total	Total	Total	Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
2022	$56,909	$484,428	$1,044	$8,831	$551,212	$475,481	$393,007
2023	$58,554	$498,429	$1,075	$9,086	$567,143	$474,973	$377,911
2024	$60,199	$512,429	$1,105	$9,341	$583,074	$474,092	$363,109
2025	$61,843	$526,430	$1,135	$9,596	$599,005	$472,860	$348,626
2026	$63,488	$540,430	$1,165	$9,852	$614,935	$471,297	$334,484
2027	$65,133	$554,431	$1,195	$10,107	$630,866	$469,424	$320,700
2028	$66,778	$568,432	$1,226	$10,651	$647,086	$467,469	$307,426
2029	$68,422	$582,432	$1,256	$10,913	$663,024	$465,032	$294,390
2030	$70,067	$596,433	$1,286	$11,176	$678,962	$462,340	$281,745
2031	$71,712	$610,434	$1,316	$11,438	$694,900	$459,410	$269,494
2032	$73,357	$624,434	$1,346	$11,700	$710,837	$456,259	$257,640
2033	$75,001	$638,435	$1,376	$11,963	$726,775	$452,902	$246,184
2034	$76,646	$652,435	$1,407	$12,225	$742,713	$449,354	$235,124
2035	$78,291	$666,436	$1,437	$13,631	$759,794	$446,299	$224,796
2036	$79,936	$680,437	$1,467	$13,917	$775,756	$442,403	$214,503
2037	$81,580	$694,437	$1,497	$14,203	$791,718	$438,355	$204,595
2038	$83,225	$708,438	$1,527	$14,490	$807,680	$434,168	$195,065
2039	$84,870	$722,438	$1,558	$14,776	$823,642	$429,853	$185,907
2040	$86,515	$736,439	$1,588	$15,063	$839,604	$425,420	$177,112
2041	$86,515	$736,439	$1,588	$15,063	$839,604	$413,029	$165,525
2042	$86,515	$736,439	$1,588	$15,063	$839,604	$400,999	$154,696
2043	$86,515	$736,439	$1,588	$18,113	$842,655	$390,734	$145,101
2044	$86,515	$736,439	$1,588	$18,113	$842,655	$379,354	$135,609
2045	$86,515	$736,439	$1,588	$18,113	$842,655	$368,305	$126,737
2046	$86,515	$736,439	$1,588	$18,113	$842,655	$357,577	$118,446
2047	$86,515	$736,439	$1,588	$18,113	$842,655	$347,163	$110,697
2048	$86,515	$736,439	$1,588	$18,113	$842,655	$337,051	$103,455
2049	$86,515	$736,439	$1,588	$18,113	$842,655	$327,234	$96,687
2050	$86,515	$736,439	$1,588	$18,113	$842,655	$317,703	$90,362
Totals =	**$2,227,670**	**$18,962,628**	**$40,882**	**$397,990**	**$21,629,170**	**$12,306,540**	**$6,479,134**

3.6 Avoided CO_2 emissions

The benefits from avoided CO_2 emissions can be calculated from two sources for this project. First, an expected outcome is that the reduction in vehicle delays will lead to a decline in vehicle idling and hence lower use of motor fuel and lower carbon emissions. Second, diverted motorized trips to walking also allows a reduction in CO_2 emissions. The following equation was used to calculate the first source of avoided social costs of carbon for years between 2022 and 2050:

$$CO_{2\,VT}^{1} = \Delta VHD_{VT} * IdleCons_{VT} * CO_2ER_{TT} * SCC$$

Where $CO_{2\,VT}^{1}$ is equal to the monetized value of carbon emission avoided from the first source (reduced vehicle hours of delay), ΔVHD is the change in vehicle hours of delay, $IdleCons$ is the rate of fuel consumption in gallons per hour of idling engine (as explained in 3.3), CO_2ER is equal to the CO_2 emission rate per gallon of fuel (gasoline for autos or diesel for trucks) in metric tons, and SCC is the social cost of carbon per metric ton, for which the recommended monetized value in the FASTLANE Benefit-Cost Analysis guidance was used (with values that change in time up to 2050).

The second source of avoided carbon emission is trip diversion, which can be calculated using the following equation for years between 2022 and 2050:

$$CO_{2\,VT}^{2} = VM\_Div * CO_2ER_{Speed} * SCC$$

Where $CO_{2\,VT}^{2}$ is equal to the monetized value of carbon emission avoided from the second source (motorized trip diversion), VM_Div is the annual number of vehicle miles diverted, CO_2ER_{Speed} is equal to the CO_2 emission rate per gallon of gas for a given speed (system average for each year, as estimated in the TDM) in metric tons (with data from MOVES 2014[6]), and SCC, as described above, is the social cost of carbon.

Table 8 summarizes the results and it is presented only with a 3% discount rate per FASTLANE Benefit-Cost Analysis guidance.

[6] https://www.epa.gov/air-pollution-transportation.

Table 8: Avoided Social Cost of CO_2 Emissions

Year	Calendar Year	CO2 Emissions Avoided Cost – Reduction in Vehicle Delay (3% SCC) (in 2015$)	CO2 Emissions Avoided Cost –Increased Walk Mode Share (3% SCC) (in 2015$)	NPV of SCC Emissions Avoided
		All Trips	All Trips	3%
		Total	Total	NPV = [J/(1+3%)^A]
5	2022	$71,763	$14,767	$74,641
6	2023	$77,139	$15,504	$77,587
7	2024	$82,672	$16,258	$80,439
8	2025	$88,362	$17,030	$83,197
9	2026	$94,208	$17,819	$85,859
10	2027	$100,210	$18,625	$88,425
11	2028	$106,369	$20,867	$91,918
12	2029	$110,672	$21,381	$92,619
13	2030	$119,156	$22,691	$96,591
14	2031	$125,784	$23,631	$98,781
15	2032	$132,569	$24,590	$100,874
16	2033	$139,510	$25,567	$102,871
17	2034	$146,608	$26,564	$104,771
18	2035	$153,862	$30,811	$108,476
19	2036	$161,272	$31,966	$110,201
20	2037	$168,839	$33,142	$111,832
21	2038	$176,563	$34,338	$113,370
22	2039	$187,238	$36,094	$116,555
23	2040	$195,352	$37,343	$117,905
24	2041	$198,225	$37,892	$116,154
25	2042	$198,225	$37,892	$112,771
26	2043	$201,098	$46,093	$114,621
27	2044	$203,971	$46,752	$112,873
28	2045	$206,844	$47,410	$111,128
29	2046	$209,716	$48,069	$109,390
30	2047	$215,462	$49,386	$109,114
31	2048	$218,335	$50,044	$107,348
32	2049	$221,208	$50,703	$105,593
33	2050	$224,081	$51,361	$103,849
Totals =		$71,763	$14,767	**$2,959,753**

3.7 Avoided Non-CO_2 emissions

Non-Carbon vehicle emissions that were considered in this cost-effectiveness analysis include: Volatile Organic Compounds (VOC), Particular Matter (PM) and Nitrogen Oxides (NOX). The project is expected to lower emissions in the Port Covington site due to the decline in the use of motor fuel as a result of a reduction in vehicle idling caused

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by the decrease in vehicle delay. The emission savings can be calculated with the following equation for years between 2022 and 2050:

$$ES_{ET,VT} = \Delta VHD_{VT} * IdleCons_{VT} * ER_{ET,VT} * EC$$

Where $ES_{ET,VT}$ is the total emission savings by type of emission and type of vehicle, ΔVHD is the change in vehicle hours of delay, $IdleCons_{VT}$ is the rate of fuel consumption in gallons per hour of idling engine (as explained in 3.3), ER is the emission rate in short tons per gallon of fuel at engine idle made available by the EPA[7], and EC is the emission cost per short ton, as indicated in the FASTLANE Benefit-Cost Analysis guidance. Table 9 describes the monetized benefits by emission type.

[7] Source: U.S. Environmental Protection Agency (EPA), Office of Transportation and Air Quality, Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks, page 4. (EPA420-F-08-025, October 2008)

Table 9: Avoided Non-Carbon Emission Costs

Year	Calendar Year	VOC Emissions Avoided Cost	NOx Emissions Avoided Cost	PM Emissions Avoided Cost	Grand Total	NPV of Non-Carbon Emission Cost Saved/Wasted	
		All Trips	All Trips	All Trips	All Trips	3%	7%
		Total	Total	Total	Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
5	2022	$7,783	$76,566	$62,632	$146,982	$126,788	$104,796
6	2023	$8,199	$80,649	$65,962	$154,811	$129,652	$103,157
7	2024	$8,615	$84,732	$69,292	$162,640	$132,241	$101,284
8	2025	$9,032	$88,815	$72,622	$170,469	$134,570	$99,214
9	2026	$9,448	$92,898	$75,952	$178,298	$136,651	$96,982
10	2027	$9,864	$96,981	$79,282	$186,127	$138,496	$94,618
11	2028	$10,280	$101,064	$82,612	$193,956	$140,118	$92,147
12	2029	$10,696	$105,147	$85,942	$201,785	$141,528	$89,595
13	2030	$11,112	$109,230	$89,272	$209,614	$142,737	$86,982
14	2031	$11,528	$113,313	$92,602	$217,443	$143,756	$84,328
15	2032	$11,945	$117,396	$95,932	$225,272	$144,594	$81,649
16	2033	$12,361	$121,479	$99,262	$233,101	$145,261	$78,960
17	2034	$12,777	$125,561	$102,592	$240,931	$145,767	$76,272
18	2035	$13,193	$129,644	$105,922	$248,760	$146,120	$73,599
19	2036	$13,609	$133,727	$109,252	$256,589	$146,329	$70,949
20	2037	$14,025	$137,810	$112,582	$264,418	$146,402	$68,331
21	2038	$14,441	$141,893	$115,912	$272,247	$146,346	$65,751
22	2039	$14,858	$145,976	$119,242	$280,076	$146,169	$63,217
23	2040	$15,274	$150,059	$122,572	$287,905	$145,879	$60,733
24	2041	$15,274	$150,059	$122,572	$287,905	$141,630	$56,759
25	2042	$15,274	$150,059	$122,572	$287,905	$137,505	$53,046
26	2043	$15,274	$150,059	$122,572	$287,905	$133,500	$49,576
27	2044	$15,274	$150,059	$122,572	$287,905	$129,612	$46,333
28	2045	$15,274	$150,059	$122,572	$287,905	$125,837	$43,302
29	2046	$15,274	$150,059	$122,572	$287,905	$122,171	$40,469
30	2047	$15,274	$150,059	$122,572	$287,905	$118,613	$37,821
31	2048	$15,274	$150,059	$122,572	$287,905	$115,158	$35,347
32	2049	$15,274	$150,059	$122,572	$287,905	$111,804	$33,035
33	2050	$15,274	$150,059	$122,572	$287,905	$108,548	$30,873
Totals =		**$371,777**	**$3,653,531**	**$2,985,166**	**$7,010,473**	**$3,923,781**	**$2,019,125**

3.8 Safety Benefits of Rail Relocation

One of the project components involves rail relocation, which is expected to eliminate two existing at-grade crossing and avoid the need for nine additional ones. In order to estimate the safety benefits associated with this rail relocation, the methodology laid out by FHWA (2007)[8] was used to calculate safety benefits (also employed by Benefit-Cost analysis tool GradeDEC). The model relies on specific characteristics of the rail crossings, such as:

[8] http://safety.fhwa.dot.gov/xings/com_roaduser/07010/sec03.htm

average daily traffic, average trains daily at the crossing, maximum timetable speed, and through trains per day. Since there are only 2 train movements per day during late night, the safety benefits estimated are relatively small compared to other benefits. Table 10 shows the estimated rail relocation benefits.

Table 10: Rail Relocation Safety Benefits

Year	Calendar Year	Monetary Value of Rail Relocation (in 2015$)	NPV of Rail Relocation Benefits	
		All Trips	3%	7%
		Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
5	2022	$11,138	$9,607	$7,941
6	2023	$11,740	$9,832	$7,823
7	2024	$11,927	$9,698	$7,428
8	2025	$12,184	$9,618	$7,091
9	2026	$12,611	$9,665	$6,859
10	2027	$12,891	$9,592	$6,553
11	2028	$11,803	$8,527	$5,608
12	2029	$13,268	$9,306	$5,891
13	2030	$13,622	$9,276	$5,653
14	2031	$13,755	$9,093	$5,334
15	2032	$13,951	$8,954	$5,056
16	2033	$13,951	$8,694	$4,726
17	2034	$14,310	$8,658	$4,530
18	2035	$14,310	$8,406	$4,234
19	2036	$14,450	$8,241	$3,996
20	2037	$14,310	$7,923	$3,698
21	2038	$14,759	$7,933	$3,564
22	2039	$15,113	$7,887	$3,411
23	2040	$15,113	$7,658	$3,188
24	2041	$15,113	$7,435	$2,979
25	2042	$15,113	$7,218	$2,785
26	2043	$15,113	$7,008	$2,602
27	2044	$15,113	$6,804	$2,432
28	2045	$15,113	$6,605	$2,273
29	2046	$15,113	$6,413	$2,124
30	2047	$15,113	$6,226	$1,985
31	2048	$15,113	$6,045	$1,855
32	2049	$15,113	$5,869	$1,734
33	2050	$15,113	$5,698	$1,621
Totals =		**$406,334**	**$233,890**	**$124,975**

3.9 Avoided Maintenance Costs

The Access I-95 project will also have an impact in terms of avoided scheduled maintenance costs for the I-95 ramps to/from McComas Street. The scheduled maintenance of such ramps is shown in Table 11. The 407additional

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maintenance cost of the new facilities is estimated as part of the operating and maintenance costs of the projects described in 3.10.

Table 11: Avoided Maintenance Costs

Year	Calendar Year	Monetary Value of Avoided Maintenance (in 2015$)	NPV of Avoided Maintenance Costs	
		All Trips	3%	7%
		Total	NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
0	2017	$243,499	$243,499	$243,499
15	2032	$243,499	$156,293	$88,255
30	2047	$243,499	$100,318	$31,988
Totals =		**$730,497**	**$500,110**	**$363,742**

3.10 Costs

The total capital costs of the project amount to $183.3 million, and ramp maintenance is expected to happen in year 2039 with a cost of $243,000. The discounted project costs are $149.9 million using a 7% discount rate, and $166 million using a 3% discount rate, as described in Table 12.

Table 12: Project Life Cycle Cost Analysis

Year	Calendar Year	Capital Costs (in 2015$)	O&M Costs (in 2015$)	NPV of Total Costs	
				3%	7%
				NPV = [J/(1+3%)^A]	NPV = [J/(1+7%)^A]
0	2017	$1,691,333		$1,691,333	$1,691,333
1	2018	$1,691,333		$1,642,071	$1,580,685
2	2019	$8,179,667		$7,710,120	$7,144,438
3	2020	$91,318,567		$83,569,425	$74,543,152
4	2021	$71,786,175		$63,781,086	$54,765,329
5	2022	$8,621,925		$7,437,348	$6,147,313
22	2039		$243,499	$127,080	$54,961
Totals =		**$183,289,000**	**$243,499**	**$165,958,465**	**$145,927,212**

4. Summary of Benefits

The aggregation of all benefits expected to be generated by the Access I-95 project, as well as their costs are shown in Table 13 below, with discount rates of 7%, 3%, and undiscounted. All metrics show large benefits, with a benefit-cost ratio of 3.79 and a net present value of $407 million using a disco.1unt rate of 7%. The biggest share of benefits is driven by travel time savings, which are made possible by the very high delays in the project site, as predicted by the travel demand model in the 2040 no-build scenario.

Table 13: Summary of Benefit-Cost Analysis

Metrics	Monetary Value		
	Undiscounted	**Discount Rate 3%**	**Discount Rate 7%**
Avoided Maintenance Costs	$730,497	$500,110	$363,742
Travel Time Savings	$1,765,287,249	$987,916,281	$508,281,464
Vehicle Operating Cost Saving	$29,765,735	$56,833,580	$28,372,103
Health Benefits from Walking Trips	$14,851,134	$8,454,056	$4,453,348
Avoided Auto Trips from Walking Trips	$21,629,170	$12,306,540	$6,479,134
Avoided Social Cost of Carbon Emissions	$4,535,311	$2,959,753	$2,959,753
Avoided Non-Carbon Emission Costs	$7,010,473	$3,923,781	$2,019,125
Rail Relocation (Avoided Collisions)	$406,334	$233,890	$124,975
Total Benefits =	**$1,844,215,903**	**$1,073,127,991**	**$553,053,646**
Capital Costs	$183,289,000	$165,831,384	$145,872,251
O&M Costs	$243,499	$127,080	$54,961
Total Costs =	**$183,532,499**	**$165,958,465**	**$145,927,212**
NET PRESENT VALUE =		**$907,169,526**	**$407,126,434**
BENEFIT-COST RATIO =		**6.47**	**3.79**

In addition to the default analysis, four sensitivity analyses (shown in Table 14) were performed by changing key parameters in the model, they all show that regardless of the underlying assumptions, the project continues to have a strong Benefit/Cost Ratio of at least 2.2 (1.3) with a discount rate of 3% (7%). The first change in assumptions alters the horizon year from 2050 to 2040, which leads to Benefit-Cost ratios between of 2.98 and 4.41. The second change involves changing the type of project from moderate to minor, according to the methodology proposed by TIERS (which describes that a moderate impact level generates a 30% delay reduction, while for a minor impact level the delay savings are of 10%). Changing this assumption reduces the magnitude of travel time savings, however, the project remains with positive net present values and with healthy benefit-cost ratios. The third change in assumptions removes all benefits derived from the expected increase in the walk mode share, and the B/C metrics remain almost unchanged with respect to the default value. Finally, the fourth assumption considers that all auto travel is made of leisure trips (and time is valued at a lower cost), and that only business days have road congestion and hence travel delays. With this result, the B/C ratio remains 1.77 and 3.02 with the 7% and 3% discount rates.

Table 14: Sensitivity Analysis

	Analysis (1)	Analysis (2)	Analysis (3)	Analysis (4)	Analysis (5)
Horizon Year	2050	2040	2050	2050	2050
Delay Savings Impact	Moderate	Moderate	Minor	Moderate	Moderate
Walk Mode Shift Allowed	Yes	Yes	Yes	No	Yes
Maintain Travel Assumptions†	Yes	Yes	Yes	Yes	No
B/C Ratio (3% disc.)	6.47	4.41	2.24	6.34	3.02
B/C Ratio (7% disc.)	3.79	2.98	1.32	3.72	1.77
NPV (3% disc., millions)	$907	$565	$206	$886	$336
NPV (7% disc., millions)	$407	$289	$46	$396	$113

† Only weekdays are delayed and all auto travel is valued at leisure travel time.