Benefit-Cost Analysis Narrative

Houston METRO I-69 HOV Lanes Project

Houston METRO

August 30, 2024

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Executive Summary

The Benefit-Cost Analysis (BCA) conducted for the I-69 high-occupancy vehicle (HOV)[1] lane project compares the costs associated with the proposed investment to its monetized benefits. The project will replace the existing one-way reversable HOV lane facility on I-69, Southwest Freeway, with a permanent two-way HOV facility from downtown Houston to Edloe Street. This will be done by adding one lane within the existing right-of-way (ROW) of the HOV facility. The project will improve the transit on-time performance and travel speeds for all METRO buses affected by the I-69 HOV lane. Existing and new users of the I-69 HOV facility will benefit directly from travel time savings. Additionally, improved bus circulation on the HOV facility will reduce the number of buses needed, which in turn can then be added into service on other bus routes, improving travel time and bus reliability for additional routes. The project will also reduce travel times for passenger vehicle users who shift to I-69 from other routes and in turn reduce congestion for passenger vehicle users who remain on the alternative routes.

This analysis has monetized several types of benefits of the I-69 HOV lane project. There are several beneficiaries of the project including vehicles that shift to I-69 from an alternative route, vehicles that remain on those alternative routes, transit users on I-69 and all any routes affected by the HOV facility, and METRO. The figure below illustrates these benefits.

Figure ES-1. Project Benefits and Beneficiaries

		Beneficiaries			
		Vehicles shifting to I-69 from other routes	Transit Users	Vehicles remaining on original routes	Surrounding Community
Benefit Categories	Travel Time Savings	✓	✓		
	Road congestion reduction			✓	
	Emissions reduction (CO2, NOx, SOx, PM, and others)			✓	✓
	Accident risk reduction			✓	
	Noise reduction			✓	

Table ES-1 summarizes the changes expected from the project and the associated benefits. Project costs include preliminary engineering and design (including environmental studies), final design, and construction costs. Preliminary engineering and design spending began in 2023 and is expected run through 2024. Final design will start in 2025 and finish in 2026. Construction is expected to span from 2027 through 2034.

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[1] Note throughout this report that a high-occupancy vehicle is defined as a vehicle with two or more passengers

Costs were adjusted to constant 2022 dollars for the benefit-cost analysis (BCA) and discounted back to year 2023 (the first year of project spending). Based on BCA guidance from the US Department of Transportation (USDOT),[2] 3.1% discount rate was used for the BCA, apart from carbon dioxide (CO2) emissions, which were discounted at a 2.0% rate. This BCA follows the methodology and recommended parameters in the latest USDOT BCA Guidance. Total capital costs in undiscounted 2022 dollars are $86.3 million and total discounted capital costs are $68.4 million. Because the project will not require additional ROW acquisition, there are no incremental operations and maintenance (O&M) costs expected from this project. Annual costs estimated by METRO include cost savings from avoided gate repairs on one-way reversable lane and this amounts to about $100 thousand per year in $2023. The discounted value of cost savings amounts to about $1.0 million – these costs are reduced from the increase in capital costs to implement the project. The resulting total present value cost is $67.4 million.

Table ES-1: Summary of Improvements and Associated Benefits, Millions of $2022

Current Status or Baseline & Problems to be Addressed	Changes to Baseline / Alternatives	Benefits	Total Discounted Benefits, $millions of 2022
Overburdened roadways (I-69 and alternative routes) for vehicles, and inefficient transit operations due to bi-directional HOV lane	Convert one-way reversible lane HOV lane to two-way permanent HOV facility	Travel Time Savings to Transit Users	$25.0
		Emission Cost Savings from Transit Speed Improvement	$0.6
		Travel Time Savings for Vehicles Diverting to I-69 from Alternative Routes	$25.3
		External Cost Savings from Traffic Diverting to I-69 from Alternative Routes (includes congestion, safety, emissions, and noise)	$28.5
Total Benefits			**$79.4**

The period of analysis includes 20 years of operations after the construction is completed. This is in line with USDOT BCA Guidance which recommends a benefits period of 20 years for capacity expansion projects. This BCA finds that the project is expected to generate $79.4 million in discounted benefits, assuming constant 2022 dollars. When compared to total discounted costs of $67.4 million, this results in a Net Present Value (NPV) of $12.0 million and a Benefit-Cost Ratio (BCR) of 1.18 (see Table ES-3).

As shown in table ES-1, one benefit expected from this project is reduced emissions from transit speed improvements. Based on emission rates produced by the Environmental Protection Agency (EPA) Motor Vehicle Emission Simulator (MOVES) tool,[3] the speed improvement will result in a lower emission rate per mile traveled. Table ES-1 above lists the monetary value of

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[2] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, USDOT Office of the Secretary, December 2023. Accessed at: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

[3] MOVES was run for Harris County, TX for years 2025, 2035, and 2045. Emission rates were extracted for transit vehicles, assuming both compressed natural gas and diesel fuel types.

these emissions reductions and table ES-2 below describes the quantified emission reduction by emission type.

Table ES-2 : Emissions Reductions Estimates, 2035 and 20-Year Lifecycle

Emissions Type	Average Daily Reduction (kg/day)	20-Year Reduction Forecast (short tons)
CO2	390.1525	2,683.63
CO	6.3673	43.80
NOX	1.5091	10.38
PM10	0.0092	0.06
PM2.5	0.0083	0.06
SO2	0.0017	0.01
VOC	0.7091	4.88

Note that Table ES-2 lists seven types of emissions avoided by the project. However, the USDOT BCA Guidance only includes monetization parameters for four emissions. Therefore, the monetized value of emission cost reduction in Table ES-1 is underestimating the full cost of emissions avoided. Additionally, the project is expected to reduce emissions on alternative routes given lower traffic volumes (due to traffic diverting to I-69). This is monetized using a dollar-per-mile external cost parameter from the USDOT BCA Guidance, and so these benefits cannot be broken out by emission type. Therefore, the avoided emissions shown in Table ES-2 underestimate the full value of quantified emissions reduction from the project.

A summary of the total discounted benefits, costs, NPV, and BCR are shown below in Table ES-4, and annual results are shown below in Table ES-4.

Table ES-3 : Overall Results of the Benefit Cost Analysis, Millions of 2022 Dollars[4]

Project Evaluation Metric	Discounted, millions of $2022
Benefits	
Travel Time Savings to Transit Users	$24.99
Travel Time Savings for Vehicles Diverting to I69	$25.31
External Cost Savings from Diverted Traffic on Alt Routes	$28.51
Emission Cost Savings from Transit Speed Improvement	$0.63
Total Benefits	**$79.4**
Total Costs	$67.4
Net Present Value (NPV)	**$12.0**
Benefit-Cost Ratio (BCR)	**1.18**

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[4] Note whenever discounted benefits are shown in this report, the discount rate used is 3.1% for all benefit categories except CO2 emissions, which are discounted at a 2.0% rate as per USDOT BCA Guidance.

Table ES-4: Summary of Pertinent Data, Quantifiable Benefits and Costs, in Discounted Millions of 2022 Dollars*

CY	Travel Time Savings to Transit Users	Travel Time Savings for Vehicles Diverting to I69	External Cost Savings from Diverted Traffic from Alt Routes	Emission Cost Savings from Transit Speed Improvement	Total Benefits	Total Capital and O&M Costs	Net Present Value
2023	$0.00	$0.00	$0.00	$0.00	$0.00	$1.56	($1.56)
2024	$0.00	$0.00	$0.00	$0.00	$0.00	$1.52	($1.52)
2025	$0.00	$0.00	$0.00	$0.00	$0.00	$4.09	($4.09)
2026	$0.00	$0.00	$0.00	$0.00	$0.00	$3.97	($3.97)
2027	$0.00	$0.00	$0.00	$0.00	$0.00	$7.95	($7.95)
2028	$0.00	$0.00	$0.00	$0.00	$0.00	$7.71	($7.71)
2029	$0.00	$0.00	$0.00	$0.00	$0.00	$7.48	($7.48)
2030	$0.00	$0.00	$0.00	$0.00	$0.00	$7.25	($7.25)
2031	$0.00	$0.00	$0.00	$0.00	$0.00	$7.03	($7.03)
2032	$0.00	$0.00	$0.00	$0.00	$0.00	$6.82	($6.82)
2033	$0.00	$0.00	$0.00	$0.00	$0.00	$6.62	($6.62)
2034	$0.00	$0.00	$0.00	$0.00	$0.00	$6.42	($6.42)
2035	$0.82	$2.00	$2.36	$0.04	$5.23	($0.06)	$5.30
2036	$0.91	$1.91	$2.23	$0.04	$5.09	($0.06)	$5.15
2037	$0.98	$1.81	$2.11	$0.04	$4.94	($0.06)	$5.00
2038	$1.05	$1.72	$1.99	$0.04	$4.80	($0.06)	$4.86
2039	$1.11	$1.63	$1.88	$0.04	$4.66	($0.06)	$4.71
2040	$1.16	$1.55	$1.77	$0.04	$4.52	($0.05)	$4.57
2041	$1.21	$1.47	$1.67	$0.04	$4.38	($0.05)	$4.43
2042	$1.25	$1.39	$1.57	$0.04	$4.24	($0.05)	$4.29
2043	$1.28	$1.31	$1.47	$0.03	$4.10	($0.05)	$4.15
2044	$1.31	$1.24	$1.38	$0.03	$3.97	($0.05)	$4.02
2045	$1.34	$1.17	$1.30	$0.03	$3.84	($0.05)	$3.89
2046	$1.36	$1.11	$1.22	$0.03	$3.71	($0.05)	$3.76
2047	$1.38	$1.04	$1.14	$0.03	$3.59	($0.04)	$3.63
2048	$1.39	$0.98	$1.07	$0.03	$3.46	($0.04)	$3.51
2049	$1.40	$0.92	$1.00	$0.03	$3.34	($0.04)	$3.39
2050	$1.41	$0.88	$0.95	$0.02	$3.26	($0.04)	$3.30
2051	$1.41	$0.85	$0.91	$0.02	$3.19	($0.04)	$3.23
2052	$1.41	$0.81	$0.87	$0.02	$3.11	($0.04)	$3.15
2053	$1.41	$0.78	$0.83	$0.02	$3.04	($0.04)	$3.07
2054	$1.41	$0.75	$0.80	$0.02	$2.98	($0.04)	$3.01
Total	**$24.99**	**$25.31**	**$28.51**	**$0.63**	**$79.44**	**$67.45**	**$12.00**

*All benefits and costs are discounted at 3.1 percent annually, apart from CO_2 emissions, which are discounted at a 2.0% rate. Total capital costs include preliminary engineering and design costs (including environmental costs), final design, and construction costs (including indirect costs).

1 Introduction

This document provides technical information on the benefit-cost analyses (BCA) conducted for the I-69 HOV lane project. This BCA focuses on the monetizable benefits of the project for comparison with the project's total costs. The benefits of the project are based on the expected impacts on both users and non-users of the facility over the entire life cycle of the project. All benefits and costs in future years are discounted to present value terms using a real discount rate established by USDOT. The BCA is implemented using a customized Microsoft Excel model that adheres to the requirements and monetization factors promulgated by the USDOT in its BCA Guidance for Federal discretionary grant programs.[5] In accordance with these guidelines, a 3.1 percent discount rate is used to compute present values for all benefits and costs, except for greenhouse gas emissions benefits, which are discounted at 2 percent. Calculated BCA results include both a benefit-cost ratio (BCR) and net present value (NPV).

2 Project Overview

The existing one-way reversable lane HOV facility operates primarily at-grade in the middle of the I-69 freeway. The direction of the lane is adjusted based on the peak commute flow. From 5am to 11am, the lane runs inbound to downtown Houston (east), and from 1pm to 8pm, the lane runs outbound (west). The HOV lane is open to transit vehicles, vehicles with at least two occupants (i.e., HOVs), and motorcycles. Single occupancy vehicles (SOVs) can access the HOV lane by paying a toll, but only during hours that fall outside the operation hours listed above. It should be noted that this BCA does not account for tolling SOVs in the analysis because the costs of expanding tolling to the additional lane have not yet been developed. Therefore, this analysis assumes that SOVs can use the HOV lane without paying a toll for both the no build and build scenarios.

I-69 is one of the most congested freeways in the state of Texas.[6] By adding additional capacity to the HOV facility and allowing for permanent two-way operations all day, the project will help provide congestion relief and the other associated benefits that follow from improved speed flow, including safety improvements, emission reductions, and others.

2.1 Base Case and Alternatives

The base case (no build scenario) assumes that no improvements will be made to the existing HOV facility. As mentioned above, the BCA models the no build scenario to assume that SOVs are not tolled for using the HOV facility but are restricted in their hours of use.

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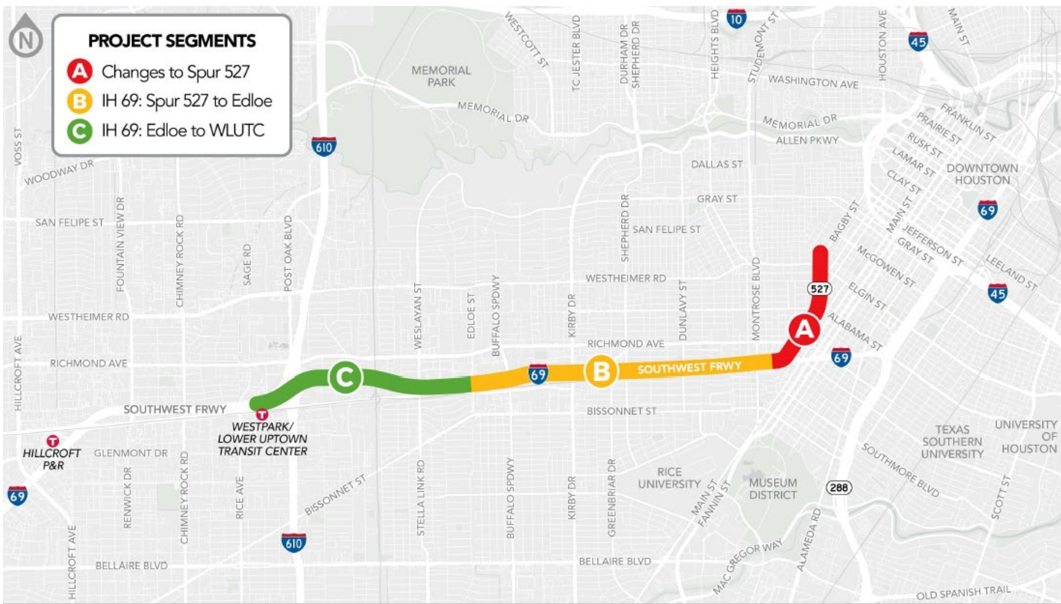
[5] Benefit-Cost Analysis Guidance for Discretionary Grant Programs, USDOT Office of the Secretary, December 2023. Accessed at: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

[6] Transportation Project Questionnaire, developed by METRO, July, 2024.

The alternative (build scenario) will implement the I-69 HOV project. This includes creating an additional lane to provide a two-way HOV facility within the footprint of the existing HOV facility by reducing shoulder widths. The build scenario also does not consider tolls for SOVs using the HOV facility.

Figure 1 includes a map of the planned improvements under the I-69 HOV project, which corresponds to segments A and B (Spur 527 to Edloe). A third segment (segment C) will extend the HOV facility improvements out to Westpark / Lower Uptown Transit Center. Segment C will be implemented in the future and is not considered as part of this BCA. All volumes and flow improvements estimated in this BCA are not contingent on completion of segment C.

Figure 1. Map of Project Segments



2.2 Types of Impacts

The project will directly benefit individuals using transit and passenger vehicles on the improved expanded capacity of I-69 corridor. In particular, transit users will experience travel time savings given improved bus circulation and the added lane in the HOV facility. The improved speed flow of the transit vehicles will also result in emission cost savings. All emission reductions will additionally benefit the larger surrounding communities.

Existing passenger vehicle users of I-69 (prior to the added lane) are not expected to benefit because the travel demand model of this region does not anticipate any change in travel times. Instead, the added capacity on I-69 would be filled be passenger vehicle users that divert from parallel roads.

In addition, the direct beneficiaries of this project (e.g. passenger vehicles that shift to I-69 and transit buses using I-69) would generate benefits for passenger vehicles that remain on the parallel roadways near the I-69 corridor. These other passenger vehicles would benefit from reduced congestion, improved safety, reduced emissions, and reduced noise levels.

Finally, some operating cost savings are expected to accrue to METRO. By avoiding the daily conversion of the reversible lane to a permanent two-way facility, this will require fewer gate operations and is expected to result in some avoided gate repair costs.

2.3 Project Cost and Schedule

Spending on project preliminary design and engineering (including environmental costs) started in 2023 and will be completed in 2024. Final design costs are expected to be incurred from 2025 to 2026. Construction is expected to last from 2027 through 2034. The total capital costs of the project are approximately $86.3 million (in undiscounted 2022 dollars). Discounted with a 3.1 percent real discount rate, these project costs become $68.4 million in discounted 2022 dollars. Table 1 presents the estimated costs in both undiscounted and discounted 2022 dollars.

In addition, METRO projects cost savings from avoided gate repairs. The conversion of a reversable lane to a permanent two-way facility will lead to fewer entrance gate operations, which in turn will result in avoided gate repair costs. An annual cost savings estimate was developed by METRO and applied in the BCA for each year after opening through the benefits period. The savings are estimated to be $100,000 in $2023 and $94,709 in $2022. The total present value of these cost reductions is about $1.0 million.

Table 1: Project Cost Summary, in Millions of 2022 Dollars

Cost Type	Undiscounted	Discounted at 3.1%
Preliminary Engineering and Design / Environmental	$3.2	$3.1
Final Design	$9.0	$8.1
Construction / Indirect Costs	$74.1	$57.3
Total Capital Costs	**$86.3**	**$68.4**
Total O&M Cost Savings	**-$1.9**	**-$1.0**

3 General Assumptions

After the 12 years of project spending, the BCA includes benefits over a 20-year period of operations. As described earlier, all future monetized values have been discounted to 2022 dollars using a real discount rate of 3.1 percent (apart from carbon dioxide emissions, which are discounted at 2.0 percent) as per USDOT BCA Guidance. All dollar values have been converted to constant 2022 dollars also per USDOT BCA Guidance.

The BCA methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are expressed in 2022 dollars;
- The model period of analysis begins in 2023 and ends in 2054;
- Project spending is assumed to occur over a 12-year period, 2023 through 2034; This includes two years of preliminary engineering and design and environmental studies, two years of final design, and eight years of construction (2027-2034); and
- Change in travel demand is assumed to be realized in the first year of operations.

4 Demand Projections

HDR used the Houston-Galveston Area Council (HGAC) Regional Travel Demand Model (TDM) to analyze traffic impacts from the project improvement. The model produces traffic forecasts for the no build scenario and the build scenario, for years 2030 and 2045, assuming a project opening year of 2030. Values for interim years were interpolated based on the average annual growth rate. Because the project is expected to open in 2035, the BCA uses the build scenario forecast starting in year 2035. The model produces travel data for both vehicles and transit.

Vehicle traffic forecasts were produced by the TDM for the AM peak period, PM peak period, and daily volumes, by direction (eastbound versus westbound), and for the HOV and general purpose (GP) lanes. The peak period modeled by the TDM accounts for an average peak period of 3.5 hours in the AM and PM periods, respectively. Thus, some of the traffic using the HOV facility traveling inbound from 5am to 11am may be captured in the off-peak volumes from the TDM. Similarly for the outbound traffic using the HOV facility from 1pm to 8pm may be captured in the off-peak volumes. This means that the results attributed to peak traffic in this BCA may be slightly underestimating the benefits. These TDM outputs are summarized in Table 2.

Table 2: Travel Demand Outputs—Vehicle Volumes

Variable Name	HOV 2030	HOV 2045	Average Annual Growth, %	GP 2030	GP 2045	Average Annual Growth, %
No Build	16,400	17,600	0.5%	354,600	364,400	0.18%
EB AM Peak Period	3,900	3,900	0.0%	31,200	32,400	0.3%
EB PM Peak Period	0	0	0.0%	34,200	35,100	0.2%
EB Off Peak Period	7,100	7,700	0.5%	115,200	117,200	0.1%
WB AM Peak Period	0	0	0.0%	30,600	31,200	0.1%
WB PM Peak Period	2,700	3,300	1.3%	33,900	35,100	0.2%
WB Off Peak Period	2,700	2,700	0.0%	109,500	113,400	0.2%
Build	29,600	26,300	-0.8%	346,600	359,200	0.24%
EB AM Peak Period	4,200	4,200	0.0%	30,900	32,100	0.3%
EB PM Peak Period	3,600	3,000	-1.2%	32,700	33,600	0.2%
EB Off Peak Period	10,500	8,900	-1.1%	112,500	116,600	0.2%
WB AM Peak Period	900	600	-2.7%	30,000	30,600	0.1%
WB PM Peak Period	3,900	4,200	0.5%	33,300	34,500	0.2%
WB Off Peak Period	6,500	5,400	-1.2%	107,200	111,800	0.3%

As shown in the table, the build condition is expected to significantly increase vehicles in the HOV lanes but also reduce vehicles in the GP lanes. The reduction in traffic in the GP lanes could be caused by a shift by some GP vehicles to the improved HOV facility. Overall, the model predicts a total increase in vehicle volumes in the build scenario when combining volumes in both HOV and GP lanes. The total increase in vehicle volumes on I-69 is assumed to be diverted from nearby arterials in the study area because the added capacity improves travel speeds compared to the arterials. Diverted vehicles from parallel routes will in turn reduce congestion for the remaining vehicles on these alternative routes.

Note that, within the HOV lanes, the TDM predicts negative growth in the build scenario between years 2030 and 2045, and very low growth in the no build scenario. The TDM accounts for several major planned roadway and transit projects (including University BRT project, the I-10 expansion, and the North Houston Highway Improvement Project (HNNIP) which are included in the 2045 forecast but not the 2030 forecast. These projects may be intercepting some demand from the HOV transit trips. Regardless, the build HOV volumes are still much greater than those in the no build scenario.

The TDM estimated an average daily vehicle speed for all vehicles using both HOV and GP lanes for years 2030 and 2045. These speeds are shown in Table 3.

Table 3: Travel Demand Outputs – Average Daily Vehicle Speeds

Average Daily Speed, mph	2030	2045
No Build	29.1	26.5
Build	29.1	26.5

As shown in the table, average speeds were found to be the same for the no build and build scenarios. While there may be a speed improvement on the GP lanes given the reduced volumes, this data indicates that on average, the change in speeds for vehicles using both the HOV and GP lanes will result in no net speed improvement. Therefore, no travel time savings were modeled for vehicles remaining on the I-69 facility. However, vehicles diverting to the I-69 facility from alternative routes must be receiving a speed improvement in order to justify the diversion. Therefore, travel time savings have been captured for these diverted vehicles as part of this BCA.

The TDM was also used to produce forecasts of transit ridership for the total peak period and off-peak period, by direction (inbound versus outbound), for years 2030 and 2045. See Table 4.

Table 4: Travel Demand Outputs –Transit Ridership Volumes

Variable Name	2030	2045	Average Annual Growth, %
No Build	24,232	29,738	1.4%
EB Peak Period	12,249	8,938	-2.1%
EB Off Peak Period	1,952	4,819	6.2%
WB Peak Period	7,596	9,352	1.4%
WB Off Peak Period	2,435	6,629	6.9%
Build	24,024	30,026	1.5%
EB Peak Period	12,050	8,911	-2.0%
EB Off Peak Period	2,040	4,824	5.9%
WB Peak Period	7,573	9,644	1.6%
WB Off Peak Period	2,361	6,647	7.1%

As shown in the table, there is an initial decline in ridership expected in the build compared to the no build, but by 2045 more ridership overall is predicted in the build scenario. It should be noted that the TDM only considered METRO buses, not other transit vehicles. Transit trips were considered for all METRO buses in the system that would be affected by the I-69 HOV lane. Because transit vehicles weave in and out of the HOV lane, the trips shown account for a combination of HOV and GP lane use.

Average transit speeds were produced by the TDM for the HOV facility in the AM peak hour and PM peak hour, by direction (inbound versus outbound), by year (2030 and 2045), for the build and no build scenarios. No speed improvements are expected for the off-peak period for transit. These speeds are shown below in Table 5.

Table 5: Travel Demand Outputs –Transit Peak Speeds in HOV

Variable Name	2030	2045
No Build		
EB AM Peak Hour	32	34
EB PM Peak Hour	n/a	n/a
WB AM Peak Hour	n/a	n/a
WB PM Peak Hour	32	34
Build		
EB AM Peak Hour	35	44
EB PM Peak Hour	29	44
WB AM Peak Hour	29	44
WB PM Peak Hour	35	44

As shown in the table, passengers riding transit vehicles using the HOV lane will experience speed improvements of up to 10 mph by 2045, depending on the time of day. Note that no speeds are provided for the eastbound PM peak hour and westbound AM peak hour in the no build scenario. This is because the one-way reversable HOV lane runs eastbound (inbound to downtown) during the AM peak and westbound during the PM peak.

5 Estimation of Economic Benefits

This section describes the measurement approach used for each benefit category as outlined in **Error! Reference source not found.** and described in Section 2.2: Types of Impacts. An overview of the methods, assumptions, and estimates are provided.

5.1 Benefits and Estimation Methods

The methodology used for estimating each of the benefits is presented below. All benefits are based on the demand projections and speeds described in Section 4.

- **Travel Time Savings for Transit Passengers:** The additional capacity in the HOV facility, plus the creation of a permanent two-way facility, will result in travel time savings to transit users. The TDM estimates this impact for all METRO transit buses that are affected by the I-69 HOV facility. To model these savings, first the BCA converts transit passenger trips from the TDM to vehicle trips by using an average vehicle occupancy (AVO) rate of 35 for the peak period and 10 for the off peak period, as shown below in Table 6. The BCA then uses the speeds modeled by the TDM for the AM and PM peak hours to calculate the change in vehicle hours per trip between the build and no build. This savings per trip is applied to the existing transit volumes, and the rule-of-half is applied for the new transit volumes. Total hours saved are monetized using an hourly value of time parameter. Value of time parameters are sourced from the USDOT BCA guidance for passengers and bus drivers, as shown below in Table 6. Daily benefits are annualized using a factor of 312 days per year, which represents 260 workdays plus one weekend day per week (52). Volumes produced by the TDM are for an average weekday. However, given that I-69 is one of the most congested corridors in the state, it was assumed that some congestion exists on the weekends as well.

- **Emission Reduction due to Transit Speed Improvements:** Emission rates are larger per mile traveled at congested speeds versus non-congested speeds. Therefore, the transit speed improvements also translate to reduced emissions. EPA's MOVES tool was run for Harris County, TX for transit vehicles for years 2025, 2035, and 2045. It was assumed that transit vehicles use a combination of both compressed natural gas and diesel fuel types. The MOVES model was used to produce emission rates (grams per mile) by speed bin for seven different emission types: CO_2, CO, NO_X, PM_{10}, $PM_{2.5}$, SO_2, and VOC. Based on the different average transit speeds in the no build versus build, per-mile emission rates were looked up for years 2030 and 2045 by emission type. Emission rates for interim years were interpolated using an average annual growth rate. Transit vehicle volumes in the no build and build were multiplied by the project improved segment length (3.5 miles) and by the per-mile emission rates to calculate total emissions in the no build and build. Avoided emissions were monetized based on parameters in the USDOT BCA Guidance (see Table 6). Because the BCA Guidance only includes monetization factors for CO_2, NO_X, $PM_{2.5}$, and SO_2, these were the only emission types monetized. However, avoided emissions were still quantified for all emission types (as shown in Table ES-2).

- **Travel Time Savings for Vehicles Shifting to I-69:** As shown in Table 2, **t**he TDM outputs predict an increase in total vehicle traffic due to the added HOV capacity. These vehicles are diverting from nearby parallel routes due to the improved HOV facility on I-69. While the TDM did not produce data on the travel costs of these vehicles prior to diversion, it follows that these new vehicles on I-69 shifted routes due to improved speeds and therefore will experience travel time savings. An average speed of 20mph was assumed for no build travel speeds for arterial roads, the assumed type of roadway that would use the expanded I-69 corridor. This speed was compared to the average daily speeds for vehicles (as shown in Table 3) to calculate the change in vehicle hours per trip between the build and no build. The vehicle hours saved per trip was multiplied by the volume of traffic that shifted to I-69. Because these are new vehicle trips, the rule of half is used to calculate the benefits of these travel time savings. The percent truck traffic was used to split out time savings for passenger vehicles versus trucks, and separate average vehicle occupancy factors and value of time parameters were used per vehicle type as recommended by the USDOT BCA Guidance (see Table 6). Daily benefits are annualized using a factor of 312 days per year, given that the volumes produced by the TDM are for an average weekday.

- **External Cost Savings from Traffic Diverting Off Alternative Routes:** the added capacity on I-69 will attract vehicles to divert to I-69 from other parallel routes. Vehicles remaining on those parallel routes. In turn, the vehicle users on the parallel routes would experience corresponding benefits because of the fewer vehicles on those roads. These benefits include:

    - **Congestion Reduction Benefits:** The USDOT BCA Guidance provides a marginal external cost of congestion parameter which captures the values of reduced congestion given a reduction in traffic. The benefit is calculated in the BCA based on the change in numbers of vehicles from a roadway and these benefits accrue to vehicle users that remain on the facility. The dollar-per-mile congestion parameter was selected for light duty vehicles and trucks in urban areas. These parameters were multiplied by the traffic volume diverting to I-69. Traffic was broken out by autos versus trucks based on a percent truck parameter and converted to vehicle miles traveled (VMT) based on the improved length of the I-69 facility (see Table 6). Benefits were annualized using a factor of 312 days per year.

    - **Safety Benefits:** Similar to the congestion relief benefit, the reduced vehicle traffic on parallel roads generates reduced accident risks for vehicles that remain on those roads. Dollar-per-mile external safety cost parameters were taken from the USDOT BCA Guidance for light duty vehicles and trucks in urban areas (see Table 6). These parameters were multiplied by the traffic volume diverting to I-69, split out by passenger vehicles versus trucks and multiplied by the improved segment length. Benefits were annualized using a factor of 312 days per year.

- **Emission Reduction Benefits:** Reduced traffic volumes and congestion on the parallel facilities will lead to lower emission rates. Dollar-per-mile parameters were taken from the USDOT BCA Guidance for light duty vehicles and trucks in urban areas (see Table 6). Different parameters were included for CO2 versus other emission types. These parameters were multiplied by the traffic volume diverting to I-69, split out by passenger vehicles versus trucks and multiplied by the improved segment length. Benefits were annualized using a factor of 312 days per year.
- **Noise Reduction Benefits:** Reduced congestion also results in lower noise levels. Noise pollution can be an annoyance or even cause harm at certain levels. Dollar-per-mile parameters were taken from the USDOT BCA Guidance for light duty vehicles and trucks in urban areas (see Table 6). These parameters were multiplied by the traffic volume diverting to I-69, split out by passenger vehicles versus trucks and multiplied by the improved segment length. Benefits were annualized using a factor of 312 days per year.

5.2 Assumptions

The assumptions used in the estimation of economic benefits are summarized in Table 6.

Table 6: Assumptions used in the Estimation of Economic Benefits

Benefit Categories	Variable Name	Unit	Value	Source / Notes
Modeling Parameters	Base Year (for discounting)	year	2022	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs - December 2023
	Analysis Start Year	year	2023	METRO; first year of project spending
	Project Open Year	year	2035	METRO. Based on project schedule
	Project Segment Length	miles	3.5	Project plans and google maps
	Annualization Factor (Weekdays)	days/year	312	Used to annualize; considers all weekdays per year (260) plus one weekend day (52). TDM data is based on a typical weekday but since I-69 is one of the most congested freeways in TX it is likely that some congestion exists on weekend days as well.
	Benefits Period	years	20	Per USDOT BCA Guidance, capacity expansion projects should use a period of 20 years
	Last Year of Analysis	year	2054	Calculated
	General Discount Rate	percent	3.1%	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs - December 2023
	Environmental Discount Rate (CO2)	percent	2.0%	

Benefit Categories	Variable Name	Unit	Value	Source / Notes
Travel Time Savings	Value of Time (All Purpose)	2022 $/person-hour	$19.60	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs - December 2023
	Value of Time (Bus Driver)	2022 $/driver-hour	$36.50	
	Value of Time (Truck)	2022 $/driver-hour	$33.50	
	Percent Truck Traffic in HOV Lanes	%	0.0%	Based on project description
	Percent Truck Traffic in GP Lanes - Peak	%	8.0%	Based on data from TDM
	Percent Truck Traffic in GP Lanes - Off Peak	%	11.5%	Based on data from TDM
	Passenger Vehicle AVO	persons / veh	1.48	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs - December 2023
	Truck AVO	persons / veh	1	Assumption
	Bus AVO- Peak Period	persons / veh	35	Assumption based on data from HGAC TDM
	Bus AVO- Off Peak Period	persons / veh	10	Assumption based on data from HGAC TDM
	Average Speed on Alt. Routes	mph	20	Assumption. We don't have data on travel conditions of diverting vehicles, but speeds must be lower than those on I69 given that vehicles are diverting. Most primary arterials which have multiple intersections average speeds of 20 to 25mph
External Costs	Cost of Congestion- Autos- Urban	2022 $ /mile	$0.14	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs - December 2023
	Cost of Congestion- Trucks- Urban	2022 $ /mile	$0.35	
	Cost of Noise- Autos- Urban	2022 $ /mile	$0.00	
	Cost of Noise- Trucks- Urban	2022 $ /mile	$0.04	
	Cost of Safety- Autos- Urban	2022 $ /mile	$0.02	
	Cost of Safety- Trucks- Urban	2022 $ /mile	$0.02	
	Cost of CO2 Emissions- Autos- Urban	2022 $ /mile	$0.11	
	Cost of CO2 Emissions- Trucks- Urban	2022 $ /mile	$0.30	
	Cost of Non-CO2 Emissions- Autos- Urban	2022 $ /mile	$0.01	
	Cost of Non-CO2 Emissions- Trucks- Urban	2022 $ /mile	$0.04	

5.3 Aggregation of Benefit Estimates

The results indicated that at a 3.1 percent real discount rate, a $68.4 million investment would result in $80.4 million in total benefits and a benefit-cost ratio of approximately 1.18. Table 7 presents the benefit estimates by category over the project lifecycle. Total external cost savings for vehicles remaining on the parallel facilities (due to vehicles diverting to I-69) represents the largest benefit category ($28.51 million in discounted 2022 dollars). The next two largest benefits are travel time savings to vehicle diverting to I-69 from parallel routes ($25.31 million in discounted 2022 dollars) followed by total travel time savings to transit users ($24.99 million in discounted 2022 dollars). All benefits monetized in this BCA are driven by the traffic and speed forecasts from the HGAC TDM.

Table 7: Estimates of Economic Benefits, Millions of 2022 Dollars*

Cost Type	Over 20-year Benefits Period	
	Undiscounted	Discounted
Travel Time Savings to Transit Users	$51.59	$24.99
Travel Time Savings for Vehicles Diverting to I69	$48.40	$25.31
External Cost Savings from Diverted Traffic from Alt Routes	$54.20	$28.51
Emission Cost Savings from Transit Speed Improvement	$1.02	$0.63
Total Benefits	**$155.21**	**$79.44**

*Total may not sum up due to rounding

6 BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a number of assumptions and long-term projections, both of which are subject to considerable uncertainty.

The primary purpose of the sensitivity analysis is to help identify the variables and model parameters whose variations have the greatest impact on the BCA outcomes: the “critical variables.”

The sensitivity analysis can also be used to:

- Evaluate the impact of changes in individual critical variables, i.e. how much the final results would vary with reasonable departures from the “preferred” or most likely value for the variable; and
- Assess the robustness of the BCA and evaluate, in particular, whether the conclusions reached under the “preferred” set of input values are significantly altered by reasonable departures from those values.

The outcomes of the quantitative sensitivity analysis report the benefit-cost ratio and discounted NPV over the 20-year benefits period assuming the following sensitivity scenarios:

- **Average speed on alternative parallel route**: the default value used in the BCA is 20mph to reflect typical travel speeds on arterial routes. If this speed were adjusted higher by 10%, this would produce an average speed of 22mph, which would result in lower travel time savings for vehicles and produce an NPV of $4.64 million and BCR of 1.07. If the speed were adjusted 10% lower than the base scenario, this would increase travel time savings for vehicles and produce an NPV of $20.99 million and a BCR of 1.31.
- **Average passenger vehicle occupancy rate**: the default passenger vehicle AVO in the BCA is 1.48 per USDOT BCA Guidance for a weekday peak period. If the AVO were 10% higher (i.e., 1.63), this would result in more persons per vehicle benefitting from travel time savings for diverted vehicles to I-69. The BCA NPV would increase to $14.52, resulting in a BCR of 1.21. If the passenger vehicle AVO were 10% lower (i.e., 1.33), this would result in an NPV of $9.47 and a BCR of 1.14.

To summarize, none of the sensitivity scenarios tested drives the BCR below 1.0.

Table 8: Sensitivity Test Results

Scenario	Change in Parameter Value	NPV, $ millions of discounted 2022 dollars	BCR
Base Scenario	N/A (no change)	$12.00	1.18
Average Speed on Alt. Routes- high	10% higher average speed on alternative route (i.e., 22mph)	$4.64	1.07
Average Speed on Alt. Routes- low	10% lower average speed on alternative route (i.e., 18mph)	$20.99	1.31
Passenger Vehicle AVO-high	10% higher passenger vehicle AVO (i.e., 1.63)	$14.52	1.21
Passenger Vehicle AVO-low	10% lower passenger vehicle AVO (i.e., 1.33)	$9.47	1.14