Benefit-Cost & Social Equity Value Analysis Narrative

Houston METRO Missouri City Park & Ride Project

Houston METRO

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Executive Summary

The Benefit-Cost Analysis (BCA) conducted for the Houston Metro Missouri City Park & Ride (MC P&R) project compares the costs associated with the proposed investment to its monetized benefits. To the extent possible, benefits have been monetized. Houston METRO is pursuing Houston-Galveston Area Council (HGAC) funding to develop a replacement for the temporary park and ride facility serving express commuters who travel from Missouri City to the Texas Medical Center. Due to rapid population growth and development in Missouri City, METRO determined the need for a permanent site that would accommodate more riders and provide an improved passenger experience. These improvements will provide a number of amenities to users absent from the current facility. The facility will be constructed by a developer via a capitalized lease.

The MO City P&R project is anticipated to have significant impacts, including:

- Add significant capacity for park and ride transit users to the Texas Medical Center;
- Install transit amenities at the new facility;
- Attract additional transit users, reducing net personal vehicle travel and therefore positively impacting growing congestion and travel times.
- Improve safety for facility and road users; and
  Reduce overall carbon emissions.

Table ES-1 summarizes the changes expected from the project and the associated benefits. Monetized and non-monetized benefits are provided.

The Project is estimated to cost $55.9 million (in current dollars) for construction, with a start date of construction in 2024 and completion in 2025; as such, benefits are expected to begin in 2026. The discounted cost of the project, using a 3.1% discount rate is $53.3 million (in $2022), inclusive of the construction costs as well as an added $1.5 million (in current dollars) in lifecycle added amenity maintenance costs.

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

Current Status or Baseline & Problems to be Addressed	Changes to Baseline/Alternatives	Benefits	Summary of Results (Discounted)
Overburdened transit route with long and growing travel times	Induce some auto users to switch to transit, reducing the number of vehicles using the route during peak periods	Travel Time Savings	-$6.0[1]
High total auto operating costs	Vehicle cost savings due to shifting from auto to bus	Travel Cost Savings	$30.6
Limited parking spaces and lack of amenities at the temporary facility, resulting in reduced ridership	Increase available parking and transit amenities, allowing additional bus users to park and ride and attracting additional riders	Facility Amenity Benefits	$8.8
Limited safety-oriented amenities at the current facility reducing overall user safety	Improve safety at the new facility	Safety Benefits	$0.9
High congestion and auto demand leading to high levels of carbon emissions	Induce some auto users to switch to transit during peak periods, reducing the number of vehicles using the route leading to a reduction in carbon emissions	Emission Benefits	$3.8
Overburdened travel route	Reduction of vehicle miles travelled along the route causes improvements for remaining vehicles (congestion, noise, safety and emissions)	External Travel Cost Savings	$11.8
Total Benefits			**$49.9**

The period of analysis includes 20 years of operations after the construction is completed. The BCA discussed below reveals that the project is expected to generate $49.9 million in discounted benefits, which means that the Net Present Value is -$3.4 million and the Benefit-Cost Ratio (BCR) is 0.94.

A component of the BCA is the benefit of reduced emissions resulting from reduced travel times and reduced overall vehicle miles traveled. These are estimated from the HGAC travel demand model and USDOT's MOVES model of emissions factors. The monetary value of these emissions reductions are described in Table ES-1, above. Table ES-2 describes the estimated

[1] Note that the BCA estimates a net travel time loss. This is because the travel demand model anticipates significant mode shifting from quicker auto to slower bus travel. These users switch because other elements of travel (cost, experience) are deemed more attracted in the build scenario. These benefits are accounted for in other benefit categories resulting in a net benefit for mode shifting users.

emissions reductions, by emission type, in volume terms for the first year of project operation and for the BCA forecast lifecycle.

Table ES-2: Emissions Reductions Estimates, 2028 and 20-Year Lifecycle[2]

Emissions Type	Reduction in 2028 (kg/day)	20-Year Reduction Forecast (total tons)
CO_2	785.594	17,406.4
NO_x	0.168	0.674
$PM_{2.5}$	0.004	0.069
SO_2	0.004	0.096

In addition to the monetized benefits presented in Table ES-5, the project would generate other benefits that are difficult to monetize. Among these, the project improves local access and condition of transportation infrastructure in the downtown and surrounding areas. This will further enable and encourage local business investment and tourism in the area and improve local and visitor experience, which will produce economic development benefits. These benefits (economic development benefits, complete journey quality benefits, and travel time savings from avoided road closures), if they could be expressed in monetary terms, would increase the overall benefit- cost ratio. Additionally, the project will improve short-term employment by creating local construction jobs and supporting local construction material suppliers.

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

Project Evaluation Metric	Constant Dollars	Present Value, 3.1% Discount Rate
Total Benefits	$77.9	$49.9
Total Costs	$58.2	$53.3
Net Present Value	N/A	-$3.4
Benefit-Cost Ratio	N/A	0.94

A summary of the relevant data and calculations used to derive the total monetized benefits and costs of the project are shown in Table ES-5.

In addition to the Benefit-Cost Analysis, a Social Equity Value Analysis (SEVA) has also been implemented to determine the societal value of the project by *weighting* the distribution of benefits and costs by income group. SEVA is a relatively new form of analysis that captures the higher values of time and cost savings, along with other benefits, for people with lower incomes. The SEVA results take income equity considerations into account based on both local and National priorities. The results of this analysis indicates that the MO City Park & Ride project is likely to generate substantial level of net benefits for the community (Table ES-4).

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[2] Emissions volume reductions include net change in emissions from both passenger and transit vehicles.

The SEVA analysis indicates that the majority of transit and passenger vehicle users are in the lower two area income groups. These are the users that will experience the greatest share of benefits from the project, indicating a high level of social equity from the project. Overall, these two income groups are expected to experience over 90% of total project benefits.[3] Almost 85% of project benefits accrue to the lowest income residents.

Table ES- 4: BCA and SEVA Results in Present Value Terms ($ millions)

Types and Measures	BCA Results	SEVA Results
Benefits		
Travel Time Savings[4]	($6.0)	(W$8.4)
Travel Cost Savings	$30.6	W$68.6
Safety Benefits	$0.9	W$0.9
Facility Amenity Benefits	$8.8	W$8.7
Emission Benefits	$3.8	W$3.5
External Travel Cost Savings	$11.8	W$10.6
TOTAL[5] PV Benefits	**$49.9**	**W$83.8**
TOTAL PV Costs	**$53.3**	**W$53.3**
NPV	**($3.4)**	**W$30.5**
BCR	**0.94**	**1.6**

[3] Income-weighted analysis of project benefits.

[4] See footnote 1

[5] Totals may not sum due to rounding.

Table ES-5: Summary of Discounted Benefits and Costs ($2022, Millions)*

CY	Travel Time Savings	Travel Cost Savings	Safety Benefits	Facility Amenity Benefits	Emission Reduction Benefits	External Travel Cost	Total Benefits	Total Capital Costs	Total Annual Maintenance Costs	Net Present Value
2024	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$26.27	$0.00	-$26.27
2025	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$25.48	$0.00	-$25.48
2026	-$0.15	$0.91	$0.03	$0.47	$0.07	$0.25	$1.57	$0.00	$0.08	$1.49
2027	-$0.17	$1.01	$0.03	$0.46	$0.08	$0.30	$1.72	$0.00	$0.08	$1.64
2028	-$0.19	$1.10	$0.03	$0.46	$0.10	$0.35	$1.86	$0.00	$0.08	$1.78
2029	-$0.21	$1.19	$0.04	$0.46	$0.11	$0.40	$1.99	$0.00	$0.08	$1.90
2030	-$0.22	$1.27	$0.04	$0.46	$0.12	$0.44	$2.10	$0.00	$0.08	$2.02
2031	-$0.24	$1.34	$0.04	$0.46	$0.14	$0.48	$2.22	$0.00	$0.08	$2.14
2032	-$0.26	$1.41	$0.04	$0.46	$0.15	$0.52	$2.32	$0.00	$0.08	$2.24
2033	-$0.27	$1.47	$0.04	$0.45	$0.16	$0.55	$2.41	$0.00	$0.08	$2.33
2034	-$0.29	$1.53	$0.05	$0.45	$0.17	$0.58	$2.49	$0.00	$0.08	$2.42
2035	-$0.30	$1.58	$0.05	$0.45	$0.18	$0.61	$2.57	$0.00	$0.08	$2.49
2036	-$0.32	$1.63	$0.05	$0.44	$0.20	$0.64	$2.64	$0.00	$0.08	$2.57
2037	-$0.33	$1.67	$0.05	$0.44	$0.21	$0.67	$2.71	$0.00	$0.08	$2.63
2038	-$0.34	$1.71	$0.05	$0.44	$0.22	$0.69	$2.77	$0.00	$0.08	$2.69
2039	-$0.35	$1.75	$0.05	$0.43	$0.23	$0.71	$2.82	$0.00	$0.07	$2.75
2040	-$0.36	$1.78	$0.05	$0.43	$0.24	$0.73	$2.87	$0.00	$0.07	$2.80
2041	-$0.38	$1.81	$0.05	$0.42	$0.25	$0.75	$2.91	$0.00	$0.07	$2.84
2042	-$0.39	$1.83	$0.06	$0.42	$0.26	$0.76	$2.95	$0.00	$0.07	$2.88
2043	-$0.40	$1.86	$0.06	$0.41	$0.27	$0.78	$2.98	$0.00	$0.07	$2.91
2044	-$0.41	$1.88	$0.06	$0.41	$0.28	$0.79	$3.01	$0.00	$0.07	$2.94
2045	-$0.41	$1.89	$0.06	$0.41	$0.29	$0.80	$3.03	$0.00	$0.07	$2.96
Total	**-$5.97**	**$30.60**	**$0.92**	**$8.83**	**$3.75**	**$11.80**	**$49.93**	**$51.75**	**$1.53**	**-$3.35**

*All benefits and costs are discounted at 3.1 percent annually. Total costs include preliminary engineering costs, management costs, and construction costs. Annual maintenance costs include maintenance of added amenities only.

1 Introduction

This document provides technical information on the benefit-cost analysis (BCA) conducted for the *Missouri City P&R* 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 grant programs. 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.[6] BCA results include both a benefit-cost ratio (BCR) and net present value (NPV).

2 Project Overview

The Missouri City Park & Ride will serve the residents of Missouri City, Texas. Missouri City is defined as one of the fastest growing areas in the Galveston-Houston Metropolitan Statistical Area. Missouri City has added 6,901 residents between 2010 and 2020, growing by 10.25 percent. Strategically located at the intersection of the Fort Bend Parkway and State Highway (SH) 6, this facility will also serve fast growing areas in Northern Brazoria and Southern Fort Bend Counties. The Missouri City Park & Ride will provide transit opportunities for passengers traveling to the Texas Medical Center as well as improved transit access to jobs located within easy reach of connecting METRO rail and bus services. Many Missouri City residents are employed in the Texas Medical Center and will benefit from reliable transit service to this highly dense and congested employment center.

METRO currently provides P&R services from Missouri City to the Texas Medical Center on route 270 (recently redesignated from route 170) from a temporary location near the proposed development. Route 270 provides just over 34 hours of revenue service per weekday on six peak buses. In 2019, annual boardings were 225,120. The current, temporary park & ride facility can accommodate approximately 220 vehicles. Prior to the Covid19 pandemic, the temporary facility was fully occupied on an average weekday. Facility usage and overall transit ridership fell during the pandemic but has slowly returned to pre-pandemic status. An analysis of population and use trends indicates that the facility will return to fully occupied status this year. The forecast indicates that in 2030, demand will be between 480 and 620 spaces on the average weekday.

[6] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs. December 2023.

The permanent Park & Ride facility would constitute significant improvements over the current situation:

- Expand capacity for route 270, van pool and carpool users.
- Improve overall customer experience and comfort, including service reliability and passenger amenities.
- Reduce VMT and improve speed and reliability in the corridor to and from activity centers in an area of high growth.
- Provide attractive transit service that achieves even higher ridership.

2.1 Base Case and Alternatives

The base case (no build scenario) assumes that no improvements or replacements will be made to the existing temporary park and ride facility, continuing to operate it “as is”, discouraging potential riders. The alternative (build scenario) will implement the full MC P&R project. This includes increasing available parking from 220 spaces to 2,000. Improvements to bus stations will include installing:

- Clocks,
- Electronic real-time displays,
- Information/emergency buttons,
- Stop seating availability,
- Step-free access to stop,
- Step-free access to vehicles,
- Bike facilities,
- Car Access Facilities; and
- Elevator(s).

The types of impacts expected from the project and corresponding benefits and beneficiaries are described in the next section.

2.2 Types of Impacts

The project will benefit individuals using both transit and personal vehicle modes along the Missouri City – Texas Medical Center corridor in their daily personal or business travel. These individuals will experience more efficient traveling conditions, resulting in reduced travel time and fewer transit fatalities, injuries, and property damage only (PDO) accidents. They will also enjoy transit amenity benefits at the new MC P&R facility. Both users and non-users will also experience emissions benefits from an increased mode shift from auto to transit vehicles.

2.3 Project Cost and Schedule

Project development (preliminary engineering) and right-of-way costs will be incurred between 2024 and 2025. The total capital costs of the project are approximately $55.9 million (in 2022 dollars). Total additional maintenance costs for added transit amenities are approximately $2.3 million (in 2022 dollars). Discounted with a 3.1 percent real discount rate, these project costs becomes $53.3 million discounted 2022 dollars. Total costs include construction costs, project management, and added amenity maintenance. The breakdown of costs are provided in Table 1.

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

Cost Type	Constant Cost, Undiscounted	Cost $2022, millions (3.1% Discount Rate)
Estimated Capital Cost	$55.9	$51.8
Estimated Amenity Maintenance Costs	$2.3	$1.5
Total Costs[7]	**$58.2**	**$53.3**

3 General Assumptions

The BCA measures benefits and costs for a 20-year period of operations. The monetized benefits and costs are estimated in 2022 dollars with future dollars discounted in compliance with USDOT BCA methodology requirements using a 3.1 percent real rate. The 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 period of analysis begins in 2022 and ends in 2045. It includes two construction years (2024 to 2025) and 20 years of operations (2026 to 2045);
- A constant 3.1 percent real discount rate is assumed throughout the period of analysis except for greenhouse gas emissions, which applies a 2 percent real discount rate, consistent with USDOT Guidance;
- Change in travel demand is assumed to be fully realized in the first year of operations; and
- Unless specified otherwise, the results shown in this document correspond to the effects of the build scenario.

4 Demand Projections

HDR developed travel demand estimates based on the HGAC regional Travel Demand Model (TDM) for the build and no build scenarios. The model estimates current ridership, travel time, and trip length. It also provides forecasts for these variables in the build and no build scenarios. Finally, the model provides injury and fatality reduction factors in the build scenario and provides information for carbon reduction benefits.

The majority of the project benefits are related to transit transportation trips. To monetize these benefits, HDR uses the results of the Travel Demand Model to forecast annual ridership in the build and no build scenarios. The project is expected to benefit existing and new transit users

[7] Totals may not sum due to rounding.

along the Missouri City – Texas Medical Center corridor. The project will affect travel demand from riders, travel times, and the number of personal vehicle trips. Table 2 summarizes the ridership results of the Travel Demand Model.

Table 2: Assumptions used in the Estimation of Travel Demand

Variable Name	2019	2045 (No Build)	2045 (Build)
Total Ridership (persons)	226,060	317,500	566,420
Reduced Car Trips	n.a.	n.a.	226,291
Diverted Riders	0	0	35,560
Average Passenger Travel Time, Transit (minutes)	42	52.5	52.5
Average Travel Time, Auto (minutes)	27	30	30

5 Estimation of Economic Benefits

This section describes the measurement approach used for each benefit or impact category identified in *Section 2.2: Types of Impacts*, and provides an overview of the associated methodology, assumptions, and estimates.

5.1 Benefits and Estimation Methods

The methodology used for estimating each of the benefits listed is presented below. Consistent with USDOT guidance, full benefits for travel time savings, facility amenity benefits:, and travel cost savings are assigned to existing transit users. New users are assigned half the full benefits in these categories.[8] For all other categories of benefits, the BCA assigns benefits to the relevant population.

- **Travel Time Savings:** The project will strive to optimize travel time along the Missouri City transit route. Travel time savings, as a benefit category, generally represents the decrease in travel time in the Build scenario compared to the No Build. However, for this project, the mode shift from passenger car to bus passenger will result in an *increase* in travel time for the new users of the Route 270 bus service. These users are anticipated to nonetheless shift modes to transit due to other elements of travel cost (vehicle operating costs, parking costs, transportation experience). The BCA model calculates the user decision to now take the bus because of the potential cost savings in travel costs as well as a value for traveling without the burden of driving. The model assigns full value of these benefits to existing riders and, consistent with USDOT guidance regarding induced ridership, half the value of those benefits to new riders. The difference in total value of travel time spent in-vehicle between passenger vehicle driver and bus passenger is monetized per USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).

[8] USDOT, Benefit-Cost Analysis Guidance for Discretionary Grant Programs. December 2023, Section 5.8.

- **External Cost Savings from Traffic Diverting from Passenger Vehicles to Transit:** The mode shift from passenger vehicles to transit will reduce the amount of vehicles along the route to the Texas Medical Center. In turn, the vehicle users on the route would experience the corresponding benefits because of the fewer vehicles on the road. The model assigns full value of these benefits to existing riders and, consistent with USDOT guidance regarding induced ridership, half the value of those benefits to new riders. 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 reduction in vehicle miles travelled in the Build scenario. The dollar-per-mile congestion parameter was selected for all urban vehicles (see Table 3). These parameters were multiplied by the annual vehicle miles traveled (VMT) reduction throughout the period of analysis.
    - **Safety Benefits:** Similar to the congestion relief benefit, the reduced vehicle traffic along the route generates reduced accident risks for the vehicles that remain on those roads. Dollar-per-mile external safety cost parameters were taken from the USDOT BCA Guidance for all urban vehicles (see Table 3). These parameters were multiplied by the annual reduction in VMT in the Build scenario.
    - **Emission Reduction Benefits:** Reduced traffic volumes and congestion along the route to the Texas Medical Center will lead to lower emissions rates. Dollar-per-mile parameters were taken from the USDOT BCA Guidance for all urban vehicles (see Table 3). These parameters were multiplied by the annual reduction in VMT in the Build scenario.
    - **Noise Reduction Benefits:** Reduced congestion also results in lower noise levels along the corridor. 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 all urban vehicles (see Table 3). These parameters were multiplied by the annual reduction in VMT in the Build scenario.
- **Congestion Reduction Benefits:** The Missouri City Park & Ride will influence more passenger vehicle drivers to now switch to transit services. The Travel Demand model estimates the projected total of vehicle miles reduced in the Build scenario. The value for congestion costs per vehicle mile travelled is monetized in the USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).
- **Travel Cost Savings:** The choice of using transit services to travel to the Texas Medical Center rather than drive will significantly reduce total travel costs for the average passenger. Existing and induced bus passengers will also avoid parking costs at the Texas Medical Center. Total travel costs are calculated using the differences between a passenger vehicle commute and a bus passenger commute. Bus passenger costs are based on the bus fares of the route 270, which services the MC P&R. Passenger vehicle costs are based on the vehicle operating costs for light duty vehicles and is monetized in the USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).

- **Avoided Crash Benefits:** Crash and injury rates were calculated using the TxDot annual motor vehicle crash statistics for years 2017-2021. An equal weight of travel for the two counties (Harris and Fort Bend) was used to produce a route average for the MO City Park & Ride. Crash and injury reductions were defined with the reduced passenger vehicle volume in a Build scenario. The reduction in projected injuries and fatalities are monetized per USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).

- **Facility Amenity Benefits:** The project will install a number of facility benefits at the MO City Park & Ride. These amenities include clocks, electronic real-time displays, information/emergency buttons, stop seating availability, step-free access to stop, step-free access to vehicles, bike facilities, car access facilities, and elevators. The model assigns full value of these benefits to existing riders and, consistent with USDOT guidance regarding induced ridership, half the value of those benefits to new riders.

- **Emission Reduction Benefits**: The reduction in passenger vehicle miles travelled will reduce vehicle-related emissions. However, there will be an increase in bus vehicle miles travelled in the Build scenario which is taken into account as a dis-benefit. The Travel Demand Model estimates the reduction in VMT for both buses and automobiles in the Build scenario. The BCA model uses emissions rates provided with inputs from MOVES3. Total damage costs per emissions are monetized per USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).

5.2 Assumptions

The assumptions used in the estimation of economic benefits are summarized in Table 3.

Table 3: Assumptions used in the Estimation of Economic Benefits

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 (Not Driving)	2022 $/person-hour	$19.60	
External Travel Costs Savings	Congestion (All Vehicles Urban)	2022 $/vehicle-mile	$0.154	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Safety (All Vehicles Urban)	2022 $/vehicle-mile	$0.02	
	Emissions (All Vehicles Urban)	2022 $/vehicle-mile	$0.12	
	Noise (All Vehicles Urban)	2022 $/vehicle-mile	$0.01	
Travel Cost Savings	Light Duty Vehicles	2022 $/value per mile	$0.52	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Passenger Vehicle Parking at Texas Medical Center	2022 $	$17.00	https://www.tmc.edu/wp-content/uploads/2024/01/TMC_Visitor_Parking_Brochure_2024_ONLINE.pdf
	Bus Fare	2022 $	$3.25	271 Missouri City - SH6 | METRO Park & Ride Bus | Accessible

Benefit Categories	Variable Name	Unit	Value	Source / Notes
				Public Transit | Houston, Texas (ridemetro.org)
Avoided Crash Benefits	Fatality (K)	Crash rate	1.41	[Annual Texas motor vehicle crash statistics (txdot.gov)]
	Incapacitating Injury (A)	Crash rate	7.41	
	Non-Incapacitating Injury (B)	Crash rate	35.65	
	Possible Injury (C)	Crash rate	86.63	
	Non-Injuries (O)	Crash rate	713.19	
	Property Damage Only (PDO)	Crash rate	331.98	
Facility Amenity Benefits	Clocks	2022 $ / user trip	$0.03	See Table A-10 in USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs. December 2023.
	Electronic Real-Time Information Displays	2022 $ / user trip	$0.32	
	Information/Emergency Button	2022 $ / user trip	$0.25	
	Platform/Stop Seating Availability	2022 $ / user trip	$0.20	
	Step-Free Access to Station/Stop	2022 $ / user trip	$0.33	
	Step-Free Access to Vehicle	2022 $ / user trip	$0.43	
	Bike Facilities	2022 $ / user trip	$0.10	
	Car Access Facilities	2022 $ / user trip	$0.12	
	Elevator	2022 $ / user trip	$0.07	
Emissions Reduction Benefits	Metric ton per Year to Kilograms per Day	Conversion	2.74	Conversion
	Carbon Dioxide (CO2)	Gram per mile	var.	EPA, MOVES3
	Nitrogen Oxides (NOX)	Gram per mile	var.	EPA, MOVES3
	Particulate Matter (PM2.5)	Gram per mile	var.	EPA, MOVES3
	Sulfur Oxides (SOX)	Gram per mile	var.	EPA, MOVES3

5.3 Aggregation of Benefit Estimates

The results indicated that at a 3.1 percent real discount rate, a $53.3 million investment would result in $49.9 million in total benefits and a benefit-cost ratio of approximately 0.94. Table 4 presents the benefit estimates by benefit categories over the project's lifecycle. Travel cost savings represent the largest contributor to total discounted benefits ($30.6 million) followed by external travel cost savings ($11.8 million) and facility amenity benefits ($8.8 million). Total benefits are mainly driven by the large ridership demand along the MO City Park & Ride routes.

Table 4: Estimates of Economic Benefits, Millions of 2022 Dollars*

Benefit Category	Over the Project Lifecycle	
	Undiscounted	Discounted at 3.1%
Travel Time Savings	($9.6)	($6.0)
Travel Cost Savings	$48.5	$30.6
Avoided Crash Benefits	$1.5	$0.9
Facility Amenity Benefits	$13.4	$8.8
Emission Reduction Benefits	$5.1	$3.8
External Travel Cost Savings	$19.0	$11.8
Total Benefits	**$77.9**	**$49.9**

*Total may not sum up due to rounding

6 BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on a large 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 for the project using a 3.1 percent discount rate are summarized below.

- Increasing the parking cost at the Texas Medical Center to $20 results in a BCR of 0.99.
- A 50 percent increase in project costs results in a BCR of 0.9

To summarize, none of the sensitivity scenarios tested above drives the BCR above 1.0. Under reasonable assumptions, and with more comprehensive active transportation trip forecasts, the project would likely result in a BCR of greater than 1.0.

Table 5: Sensitivity Test Results, Millions of 2022 Dollars

Parameters	Change in Parameter Value	NPV	B/C Ratio
Current Scenario	n.a.	($3.35)	0.94
Parking Cost	Parking Cost increases to $20	($0.63)	0.99
Project Cost	Increasing the total project cost by 50%	($12.43)	0.85

7 Social Equity Value Analysis

7.1 Overview

In addition to a standard BCA, a Social Equity Value Analysis (SEVA) is performed to evaluate the distributional effects of the Houston Metro MO City P&R project. SEVA is HDR's approach to implementing the weighted BCA (wBCA) concept and was performed to represent an alternative value of the Project to society – one that considers how the resulting benefits are distributed among different income groups. The distributional aspects involved in a wBCA include:

- the distribution of benefits (relative to incomes of affected persons);
- the magnitude and type of benefits and costs (as estimated by a BCA); and,
- the value of such benefits and costs (relative to individuals' marginal utilities of income).

A wBCA uses data on the income distribution of beneficiaries to determine the shares of total benefits and costs that would be gained and incurred, respectively, by different income groups. Then, weights are applied to those shares of total benefits and costs (as shown in **EQ. 1**) to determine a new measure of the Project's value. Weights are computed following economic theory and using economic evidence that captures the value of changes in monetized outcomes relative to the incomes of beneficiaries. The results of a wBCA can be viewed alongside a BCA and according to the Office of Management and Budget (OMB, 2023), either can be used as a rationale for the Project investment. Additional information on computation and application of weights is discussed in an appendix to this report.

A wBCA produces a new measure of societal value - a weighted Net Present Value (wNPV) in the form of:

EQ. 1

$$wNPV = \sum_{i}^{I} \left[\sum_{j}^{J} w_i^{\alpha} \cdot B_{ij} - \sum_{k}^{K} w_i^{\alpha} \cdot C_{ik} \right]$$

Income weights, $w_i^{\alpha} = (y_{\alpha}/y_i)^{\varepsilon}$, for each income group i are composed of reference incomes y_i, a benchmark income (y_{α}), and the elasticity of marginal utility of income (ε), and these weights are multiplied with the shares of benefits B_{ij}, by benefit category j, for each income group and the shares of cost contributions C_{ik}, by funding source k, for each income group. The results of a wBCA are measured in different units from a BCA. It is reasonable to define results of a wBCA in terms of "weighted dollars" to distinguish its quantitative results from those of a BCA, which is estimated in actual dollars. Weighted dollars refer to the value of the project relative to someone who earns an income at the benchmark level in the study area.

7.2 Weighted Benefits and Costs Results

The results of the wBCA are presented in Table 6 in the forms of unweighted and weighted benefits and costs, net benefits and BC ratio. Only in the weighted analyses are the net benefits greater than zero and the BC ratio greater than 1. These results indicate that from an income-weighted perspective, the weighted benefits and weighted NPV are significantly higher relative to the same magnitude in cost. The weighted NPV provides significant net benefits compared to the standard BCA. These results clearly indicate how the project generates significantly higher benefits for low-income persons.

Table 6: Comparisons of weighted and unweighted BCAs

BCA Metric	BCA	Weighted-BCA
Benefits ($M)	$49.93	w$83.83
Costs ($M)	$53.29	w$53.29
NPV ($M)	($3.35)	w$30.54
BC Ratio	0.94	1.57

Table 7 presents the results of monetized BCA-based benefits and weighted benefits by category. This view of weighted BCA shows how the utility value of each benefit category is scaled up as weighted benefits. For instance, the weighted value of safety benefits for passenger vehicles is significantly higher than the magnitude of standard benefits.[9] Similarly, impacts on travel cost savings for bus passengers are about more than two times higher in magnitude compared to a standard BCA.

Table 7: Estimated Unweighted and Weighted Benefits (2022 $M, Discounted at 3.1%)

Category	Standard Benefits	Weighted Benefits
Travel Time Savings	-$5.97	-W$8.43
External Cost	$11.80	W$10.59
Travel Cost Savings	$30.60	W$69.48
Safety Benefits	$0.92	W$8.69
Transit Amenity Benefits	$8.83	W$3.49
Emission Benefits	$3.75	W$0.00
Total	**$49.93**	**W$83.83**

In summary, the BCR is higher than in the standard BCA. This further emphasizes the importance of benefits to users and local populations, especially lower income populations that value benefits and costs on a differently than higher income groups.

[9] A comparison of magnitudes is only reasonable here since the magnitudes of costs between weighted and standard BCAs is the same.

8 Appendix – Social Equity Value Analysis

8.1 Overview

The key process of a wBCA involves estimating weights, based on the marginal utilities of income MU_i, for individual "i" (or income group). These weights are computed for each individual or group from $w_i^{\alpha} = (y_{\alpha}/y_i)^{\varepsilon}$, relative on income levels y_i. The elasticity of utility of income ε reflects the amount by which utility changes from a change in income. Another constant, the benchmark income level y_{α}, is included to support the interpretation of results (van der Pol, Bos, & Romijn, 2017). That is, the benchmark income "normalizes" the utility value of monetized benefits and costs by defining a unit of utility to be equal to the utility of income at the benchmark. With normalized weights, the results of a wBCA are measured in "weighted dollars" to distinguish results from actual money. Formally, weighted dollars represent societal utility relative to the marginal utility of income of a person at the benchmark income.

The marginal utility of income has been shown, in various research studies, that a person's utility in ("or value for") an additional dollar declines as a person's income increases. For instance, if a project generates out-of-pocket cost savings for transit users, those savings would be valued more by a lower income person than one earning more. Across a population, this research suggests that persons with lower incomes would value improvements more than those with higher incomes. Key inputs to a wBCA include: (a) formation of income groups; (b) estimation of weights; (c) estimation of share of benefits and costs per income group; and (d) computation of weighted benefits and costs. Additional information is contained at the end of this section.

8.2 Theoretical Foundation of Weighted-BCA

An alternative to BCA draws from concepts related to Social Welfare Functions (SWF) which recognize differences in the value of benefits and costs for individuals (Adler M. , 2019). SWFs draw from decades of academic economic research that has focused on the impact of policies and projects on social welfare. A weighted-BCA is derived from a particular form of SWF – the utilitarian SWF ("USWF") – since it has appealing properties for project valuation. The principal difference between BCA and weighted BCA entails the representation of economic utility, or "satisfaction," from an alternative (e.g., a decision, action or event). A weighted BCA recognizes a more complete value of individuals' utilities in both the *consumptive value* of a good or service (as determined by a WTP) and the *value of a change in consumption (or income)* associated with a person's income. Adapting this concept to a project, the value is based on monetized net benefits and the value of net benefits differs for individuals at different income levels.

The utility value of a project outcome to an individual is captured mathematically as a marginal utility of income for an individual i, "MU_i". MU_i for different income levels indicate how the utility of each additional dollar declines as a person's income increases (Cowell & Gardiner, 1999). At the same time, the value of an additional dollar generates more utility for a lower-income person than a wealthier one. In project evaluations, it is assumed that MU_i relates to the monetized values of project outcomes and costs.

The MU_i enters a weighted-BCA equation as a "utility weight." Utility weights are multiplied with BCA-estimated benefits and costs (Fleurbaey & Rossi, 2016) to determine the societal utility of a project. Utility weights are computed for different levels of income of persons affected by a project. Higher weights are estimated for lower income persons, and vice versa. The magnitude of a weight is also determined by an elasticity of utility of income that determines how much additional utility is gained at different levels of income. Research studies, using a variety of methods, have estimated elasticity parameters that can be used in actual project evaluations (Acland & Greenberg, 2023).

Utility weights "w_i" are computed from the utility of income by taking the utility function's first derivative $\delta U/\delta y_i$ to reveal the amount by which utility changes relative to a change in income. In economic terms, this derivative is the marginal utility of income MU_i and is assumed to differ for each individual "i" who has a different level of income. EQ. 2 shows that MU_i, from an isoelastic utility function depends on the elasticity of income utility ε, and income level y_i:

EQ. 2:

$$w_i = MU_i = \left(\frac{1}{y_i}\right)^{\varepsilon}$$

This function is consistent with analytical findings which indicate that as income increases, MU_i declines (for any value of ε). The value of ε captures the degree to which an increase in income provides additional utility (Adler M. , 2016). Note that when $\varepsilon = 0$, all weights equal 1 and USWF reduces to a standard BCA approach. Values of ε have been estimated in a variety of economics studies and the choice of which value to apply in models is an important policy decision or evaluated through sensitivity analyses.

Most literature discusses "normalizing" weights with an income level, y_α , before multiplying them with benefits and costs (van der Pol, Bos, & Romijn, 2017). A normalizing income, or "benchmark income of a reference person", entails defining this income level equal to a unit of utility. The benchmark income is therefore a reference point for considering changes in utility for all beneficiaries relative to their incomes. By normalizing weights, the utilities at all levels of income are evaluated relative to the MU at that level of income.[10] The income weights of a y_α benchmark income are:

EQ. 3

$$w_i^{\alpha} = \left(\frac{y_\alpha}{y_i}\right)^{\varepsilon}$$

The results of a weighted-BCA are in units of "weighted dollars" that are not the same as the real currency dollars with value in a market. "Weighted dollars" measure utility from the

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[10] A commonly discussed benchmark income in the literature is a population's median income, and its corresponding MU is based on y_{Med}^{ε}.

perspective of persons who earn a benchmark level of income. A weighted-BCA involves a sum of individual utilities from changes in project outcomes. For a project with J benefit categories and K sources of funding (and cost burdens at an individual level), it is necessary to determine the shares of benefits and costs that are attributable to each individual. As shown in EQ. 4, the weighted net present value "$wNPV$" equals the difference in weighted benefits and costs.

EQ. 4

$$wNPV = \sum_{i}^{I} \left[\sum_{j}^{J} w_i^{\alpha} \cdot B_{ij} - \sum_{k}^{K} w_i^{\alpha} \cdot C_{ik} \right]$$

Computing $wNPV$ is straightforward since weights can be applied to already estimated benefits and costs from a BCA. Of course, applying weights to benefits and costs in present value form requires the assumption that relative incomes do not change much over time. In addition, it is assumed that individuals in each income groups have the same characteristics of project use or impact and thus, the portions of benefits and costs can be estimated as the percentage of beneficiaries per group. Also, since utility weights are derived from the utility of a change in income, *monetized values* of benefits would have to be similarly interpretable as a change in income, as noted above.

8.3 Formation of income groups ($\mathbf{y_i}$)

A first step in conducting a wBCA entails compiling and analyzing income data for the project area. All income measures are estimated after accounting for taxes and transfers using data from the U.S. Census and U.S. Treasury (US Dept. of Treasury, 2022). This step forms income groups based on US Census data[11] on household income for the wider MSA. The income groups specific to this project are presented in Figure 1. Income groups are determined for quintiles – five income bands, each of which is approximately 20% of the population. The income levels shown in Figure 1 are 'reference incomes'.

The results in Figure 1 are estimated after accounting for taxes and transfers using data from the U.S. Census and U.S. Treasury (US Dept. of Treasury, 2022). This step forms income groups that are used in establishing weights and estimating benefits and costs to individuals. US Census data on household income for the wider MSA is presented in Figure 2.[12] Income groups are determined for quintiles – five income bands, each of which is approximately 20% of the population. Specifically, a simple log-log linear model can be used to estimate LN(Income cutoff) as a function of LN(Cumulative Percentiles).[13] With estimated parameters, it is straightforward to determine income levels for quintiles, as well as other percentile groupings. Reference incomes of each quintile are the same way, by statistically estimating income cutoffs

[11] These data are defined a gross household income (i.e. pre-tax and transfer).
[12] These data are defined a gross household income (i.e. pre-tax and transfer).
[13] The log-log models produce high r-squared statistics and provide good fits for incomes between the 5th and 95th percentiles.

and mid-points with a log-log function of cumulative percentiles. The results of the statistical analysis generate reference incomes for each quintile that are in turn used as values of y_i in computed weights.

Figure 1: Reference Incomes (in thousands of $2022), Adjusted - Equivalized, Post-tax & Transfer

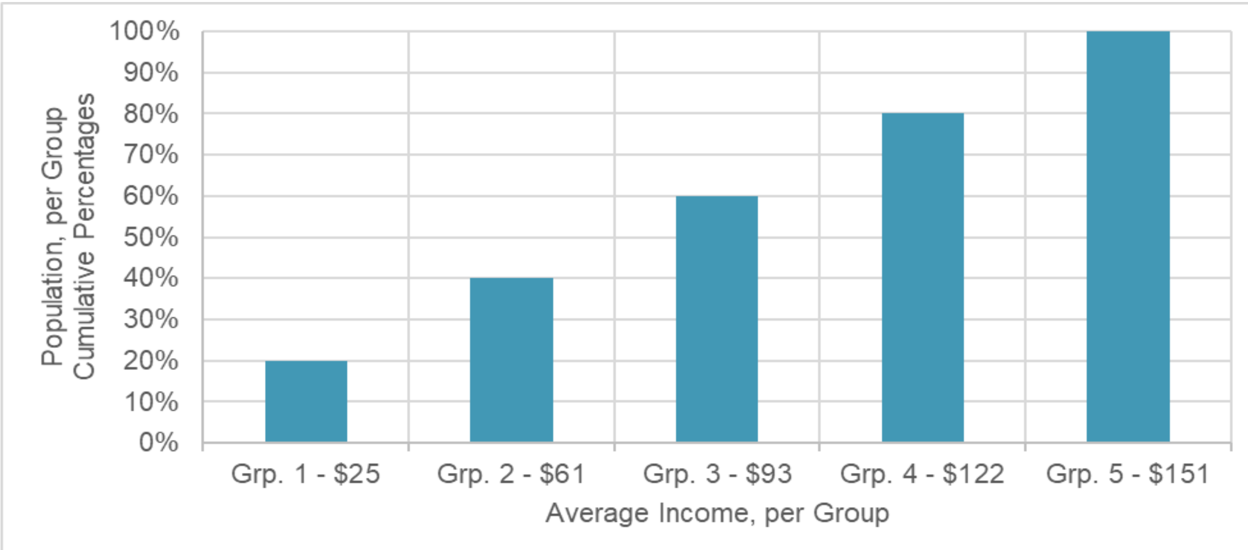
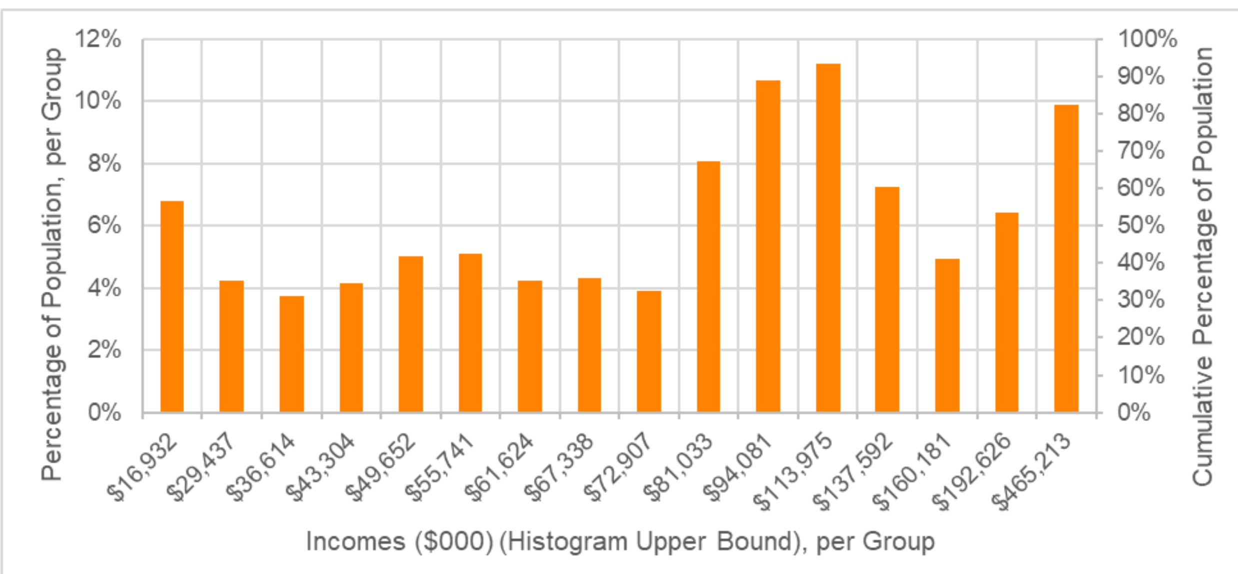


Figure 2: Regional Income Distribution, Houston-The Woodlands-Sugar Land, TX Metro Area ($2022)



8.4 Estimation of Weights

As noted above, income weights $w_i^\alpha = (y_\alpha / y_i)^\varepsilon$ require data for each income group i on the reference income y_i (computed above), a benchmark income (y_α), and the elasticity of marginal utility of income ($\boldsymbol{\varepsilon}$). The value of elasticity is set to 1.4, following OMB (OMB, 2023).[14]

For the benchmark income, economic theory does not provide guidance. The benchmark income is a way of normalizing the marginal utility of income so that results can be measured in more familiar units.[15] The specification of a benchmark income is important when considering the results of a wBCA in terms of the WNPV (EQ. 1) because weighted net benefits are directly proportional to the benchmark.[16] Most academic and applied wBCA, including the OMB (2023), reference the median income to be an appropriate benchmark income. [17] This specification though is set without accounting for how projects are funded.

8.4.1 Analysis of Benchmark Income ($\boldsymbol{y_\alpha}$)

This analysis sets the benchmark income to enable direct comparisons between the weighted and unweighted results for this specific project. Here, the benchmark income is computed to *normalize* weighted costs so that they equal the magnitude of unweighted costs. A *cost-normalizing* benchmark income relies on data on individuals' cost contributions (i.e. their taxes and fees) to governmental discretionary funds that could be used for this project, as discussed above in Step 2. This benchmark income produces weighted costs equal in magnitude to unweighted costs and in turn enables comparisons of weighted and unweighted costs and benefits even though they are in different units. The benchmark income is estimated by combining the shares of cost contributions by quintile via a weighted average with the marginal utility of income per reference income. The computation process begins with solving the weighted cost part of EQ. 1 in this equation,

EQ. 5

$$\sum_i \left(\frac{y_\alpha}{y_i}\right)^\varepsilon C_i = C$$

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[14] Other elasticity values from the literature range from 1.0 to over 2.0 (Acland & Greenberg, 2023).
[15] Without normalizing weights with a benchmark income, the results of a weighted BCA are in units of utility. With a benchmark income, the results are interpretable relative to the utility of someone who earns the benchmark income.
[16] The benchmark income is a constant and can be moved outside the summations in EQ. 1. In contrast, the benchmark does not affect the weighted benefit-cost ratio because it divides by itself and accordingly can provide an unbiased comparison with standard BC ratio results.
[17] Many other academic approaches assume the median income is a reasonable benchmark income. In such cases, neither the magnitudes of weighted and unweighted benefits or costs are likely to be comparable. In the approach developed here, the magnitudes of costs are set equal so that comparisons of benefit magnitudes are possible.

where C_i is the cost contribution (via taxes and fees) for group i and y_i is the reference income for group i and ε is the elasticity of marginal utility of income.[18]

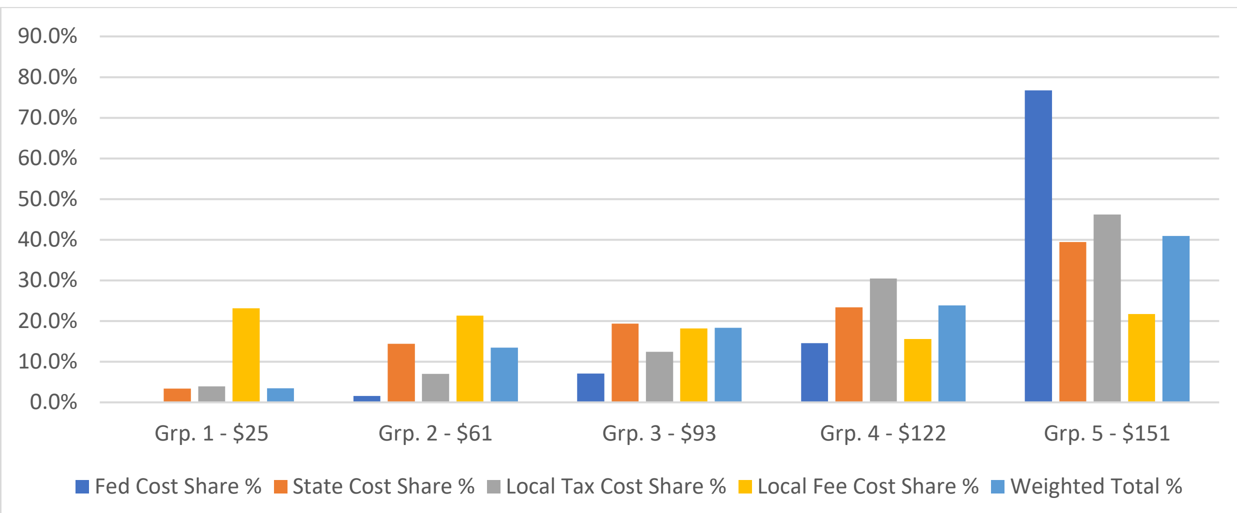
The proportions of cost burden, p_i, which indicate the percentage shares of total cost for a given funding source are defined such that $\sum_i p_i = 1$ and $p_i C = C_i$. Substituting this equality into:

EQ. 6

$$\sum_i \left(\frac{y_\alpha}{y_i}\right)^\varepsilon p_i C = C \;\rightarrow\; \left(\sum_i p_i {y_i}^{-\varepsilon}\right)^{-1} = {y_\alpha}^\varepsilon$$

The normalizing constant y_α is equivalent to a cost burden-weighted harmonic mean of incomes, for a given elasticity. Equivalently, this equation indicates that y_α is the income representing the weighted average of marginal utilities, where this weight is based on the shares of cost burdens.[19] Using the equation above and the data in **Figure** 3, the benchmark income is estimated to be about $91.6 thousand.

Figure 3: Cost Share by Income and Funding Source



Data Sources: (US Dept. of Treasury, 2022), (ITEP, 2018)

8.4.2 Adjusted Weights

For benefit categories in transportation projects that are monetized with a population average (or median) income, such as value of travel time savings, and safety (reduced accident risk), weights need to be adjusted. These adjusted weights reflect an equivalent measure of individualized benefits per income groups. Adjusted weights implicitly replace a population

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[18] This equation is applicable for one funding source, once the weighted cost burden is computed based on the overall sources of funding for different shares of total costs.

[19] A similar approach is explored by Van der Pol, Bos, & Romijn (2017).

valuation parameter with an individualized one since benefits are a function of income. For instance, the benefits of timing savings are directly proportional to the wage rates (i.e. in units of $ / hour) which are used to monetize the change in time (i.e. in minutes, say). Different adjustment weights are computed for different population value parameters (e.g. median or average incomes). The BCA categories that require adjusted weights are shown in Table 8.

Table 8: Adjusted Weights per Benefit Category

Benefit Category	Mode	Type of Weight Applied
Travel Time Savings	PV	Adjusted Weights (Average income)
Congestion Reduction	PV	Adjusted Weights (Average income)
Travel Cost Savings	Transit	Adjusted Weights (Median Weights)
Safety Benefits	PV	Adjusted Weights (Median income)
Transit Amenity Benefits	Transit	Adjusted Weights (Average income)
Emission Benefits	Local	Adjusted Weights (Average income)

The approach to adjusting weights involves combining weighted benefits with an additional ratio of incomes that includes the population-valued parameter. Standard benefits of travel time savings are computed by combining a function of the median wage rate, $f(\tilde{v})$[20], with average travel time savings $\bar{t}$. Standard benefits for individual i are $B_i^{\tilde{v}} = \bar{t} \cdot f(\tilde{v})$, but individualized benefits on a person's actual value of time v_i are $B_i^{v_i} = \bar{t} \cdot f(v_i)$. Since benefits are proportional to the valuation parameter, individualized time savings benefits can be estimated from a population-valued benefit by multiplying it with the ratio of travel time savings values, $B_i^{v_i} = \left(f(v_i)/f(\tilde{v})\right) \cdot B_i^{\tilde{v}}$.

Income-weighted benefits for travel time savings are equal to: $\hat{B}_i^{v_i} = w_i^n \cdot B_i^{v_i}$, assuming the incomes used to compute weights are proportional to wage rates $f(v)$, then weights can be computed as a ratio of wages, $w_i^n = \left(f(v_i)/f(\tilde{v})\right)^{\varepsilon}$. This assumption is reasonable if wages are the primary contributor to incomes, and this is certainly the case for most people. When benefits are estimated with a median income parameter, the ratio of the value of time savings can be combined so that $\hat{B}_i^{v_i} = w_i^n \cdot \left(f(v_i)/f(\tilde{v})\right)^{\varepsilon} \cdot B_i^{\tilde{v}}$, which simplifies to find weighted benefits per individual as $\hat{B}^{v_i} = (w_i^n)^{\varepsilon-1} \cdot B_i^{\tilde{v}}$. The smaller elasticity value on weights, $\varepsilon - 1$, captures the remaining level of weighted dollars per income level i that be necessary to equal the total weighted benefits if the benefits were instead originally estimated at an affected persons' actual wage rate (their WTP for time savings).[21]

[20] The value of travel time savings is typically defined as a function of median wages. For instance, non-business travel time is generally valued at one-half the median wage, as discussed in (U.S.-DOT 2020).
[21] This also means that a population parameter, such as a median wage rate, implicitly captures equity aspects of the project at an elasticity value of $\varepsilon = 1$.

A general form for adjusting weights is $\widetilde{w}_i^{\alpha} = \left(y_{\alpha}/y_{Pop}\right) \cdot (y_{\alpha}/y_i)^{\varepsilon-1}$ where y_{α} is the benchmark income, y_i is the individualized valuation parameter for a benefit category, and y_{Pop} is the population value parameter with which benefits are estimated. Table 9 presents normal weights and adjusted income weights based on benefits categories that are monetized with median and average incomes, respectively.

Table 9: Estimated Income Weights

Income Group	Average Ann. Adjusted HH Income ($000)	Normal Income Weights	Adjusted Weights (median income)	Adjusted Weights (average income)
1	$24.52	6.32	2.09	1.46
2	$60.88	1.77	1.45	1.01
3	$92.76	0.98	1.23	0.86
4	$122.47	0.67	1.10	0.77
5	$150.77	0.50	1.01	0.71

Data Source: (Replica, 2023), U.S. Census.

8.5 Estimation of Benefits and Costs by Income Group

8.5.1 Project Beneficiaries and Shares of Total Benefits

The next step in conducting a wBCA entails identifying individual project beneficiaries and their shares of total benefits. Specification of affected persons is important because each sub-group of affected persons may have a different distribution of income. These distributions of income are used to determine the shares of total benefits that would accrue to different income groups. The benefits and beneficiaries include:

- Travel time savings: These benefits are assumed to accrue to users and affect their income directly.
- Passenger vehicle safety benefits: These benefits also accrue to passenger vehicle users and have been estimated with USDOT guidance on the value of statistical life, which is ultimately a function of average incomes in the U.S.
- Emissions reductions of air contaminant (CAC): These benefits are assumed to affect local residents as defined by those households in the city.
- Emissions reductions of greenhouse gases (GHG): It is assumed that these benefits are spread equally among the population in the MSA.
- Transit amenity user benefits: These benefits accrue to active transportation users. Benefits are estimated according to USDOT guidance, which is assumed to be a function of average U.S. income.

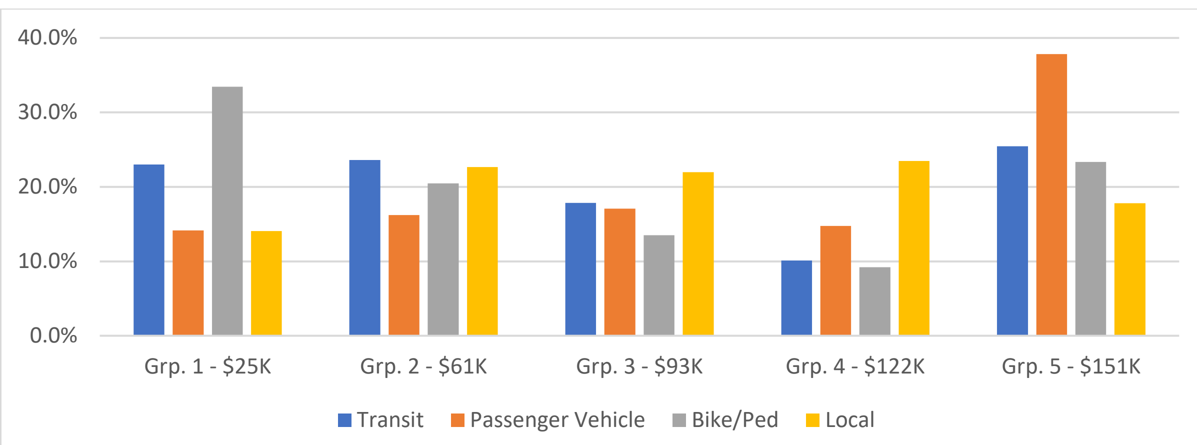
Table 10: Overview of Benefits and Beneficiaries

Benefit Category	PV Benefits (2022 $M)	Affected Persons, for Income Distribution
Travel Time Savings	(w$8.43)	PV
External Cost	w$10.59	PV
Travel Cost Savings	w$68.57	Transit
Safety Benefits	w$0.91	PV
Transit Amenity Benefits	w$8.69	Transit
Emission Benefits	w$3.49	Local

Note: Present Value benefits are estimated with a 3.1% discount rate, except for GHG benefits which is estimated with a 2% discount rate.

Figure 4 presents the percentages of affected persons per income group. Income data for passenger vehicle, bike/ped users, and local households in the city are obtained from Replica and U.S. Census, respectively. These percentages are used to determine the shares of total benefits that would be gained per income group, for a given benefit category and set of affected persons. As shown, the shares of bike/ped users are highest in the lowest quintile. In addition, no one in the local city population group makes an income in the highest quintile, as defined by the MSA.

Figure 4: Percentages of Users per Income Group, by Mode



Data Source: (Replica, 2023), U.S. Census.

8.5.2 Sources of Project Costs and Shares of Total Cost Burdens by Quintile

Recall from EQ. 1 that project costs must also be apportioned across income groups before weights can be applied. Estimating the shares of costs contributed by people in each quintile involves analyzing the taxes and fees that contribute to discretionary funds (i.e. their 'cost burden'). It is assumed that any governmental revenues that are not dedicated to fund a specific activity would contribute to discretionary funds for use to fund projects like this.[22] In this analysis, costs are spread out among federal, state, and local sources. Thus, the cost burdens per quintile are obtained from US Treasury (US Dept. of Treasury, 2022) analysis of tax burdens by income groups for federal sources, and state and local sources, since METRO receives a combination of these sources for its capital and operating expenses. The shares of these sources of funding for METRO are obtained from its recent financial report. The allocation of costs to sources is determined by the Project and shown below in Table 11.

Table 11: Adjusted Capital Cost Burden Percentages

Cost Item and Source of Costs	Present Value Cost ($ million)	% of Funding by Source
Total Capital Cost*	$51.75	100%
HGAC	$46.58	90%
METRO	$5.18	10%
Operations & Maintenance Costs*	$1.53	100%
METRO	$1.53	100%

[22] For instance, federal payroll taxes would not be used for infrastructure projects because they would be fully directed to social security and medicare programs.

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