TEAM KENTUCKY
TRANSPORTATION CABINET

FY 2024 Reconnecting Communities Pilot Grant Program

KIPDA

Reconnecting Central Portland to the Riverfront

Appendix F – BCA Narrative

Benefit-Cost & Social Equity Value Analysis Narrative

Reconnecting Central Portland to the Riverfront

KYTC Grant Application

September 29, 2024

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Executive Summary

The Benefit-Cost Analysis (BCA) conducted for the Kentuckiana Regional Planning and Development Agency (KIPDA) Reconnecting Central Portland to the Riverfront project (The Project) compares the costs associated with the proposed investment to its monetized benefits. To the extent possible, benefits have been monetized. KIPDA is pursuing grant funding to reconnect Portland, the riverfront community that helped put Louisville on the map, with improved accessibility and pedestrian enhancements. These improvements will provide upgraded connections for the community and reconfiguration of existing infrastructure.

The Reconnecting Central Portland to the Riverfront project is anticipated to have significant impacts, including:

- Improving pedestrian and vehicle safety throughout the riverfront community
- Adding sidewalks and other roadway connections for pedestrians and cyclists to coexist along traffic routes
- Improving accessibility and connection routes

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 $29.7 million (in year of expenditure dollars) for construction[1], with a start date of construction in 2027 and completion in 2029; as such, benefits are expected to begin in 2030. The total discounted cost of the project, using a 3.1% discount rate is $22.2 million (in 2022 dollars).

[1] This value includes construction, utility relocation, inspection & DSDC, and final design. Right of way cost is estimated to be zero. Escalation rate is assumed to be 4 percent per year. Planning study cost, NEPA, and preliminary engineering estimated at $2.0 million in 2024 dollars are considered prior costs for the purposes of this BCA: these are not included in the $29.7 million but included in the capital cost category in the BCA to properly account for all costs of the project.

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

Changes to Baseline/Alternatives	Benefits	Summary of Results, $M (Discounted at 3.1%)
Reduction in expected annual crashes along the project corridor	Safety Benefits	$28.5
Decreased traffic speeds in the Build scenario	Travel Time Savings	-$2.6
Improved pedestrian corridor with the installation of sidewalks	Healthy and Amenity Benefits	$7.2
Increased vehicle hours travelled resulting in additional emissions	Emission Benefits	-$0.5
Annual expected maintenance costs	Maintenance Costs	-$0.8
Additional value of individual projects past the period of analysis	Residual Value	$2.7

The period of analysis includes 20 years of operations after the construction is completed. The BCA reveals that the project is expected to generate $34.6 million in discounted benefits, which means that the Net Present Value is $12.4 million and the **Benefit-Cost Ratio (BCR) is 1.56**. A summary of the total monetized benefits and costs of the project are shown in Table ES- 2. Table ES- 4 presents the cost and benefits by year.

Table ES- 2: Overall Results of the Benefit Cost Analysis, Millions of 2022 Dollars

Project Evaluation Metric	Present Value, 3.1% Discount Rate
Total Benefits	$34.6
Total Costs	$22.2
Net Present Value	$12.4
Benefit-Cost Ratio	1.56

In addition to the monetized benefits presented in Table ES- 1 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.

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 (Table ES- 3) indicate that the Reconnecting Central Portland to the Riverfront project is likely to generate substantial level of net benefits for the community. The SEVA analysis indicates that the majority of transit users, bikers, and pedestrians 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 almost 70% of total project benefits.[2] Almost 40% of project benefits accrue to the lowest income residents.

Table ES- 3: BCA and SEVA Results in Present Value Terms ($ millions)

Project Evaluation Metric	BCA Results	SEVA Results
Benefits		
Safety Benefits	$28.5	$65.0
Travel Time Savings	-$2.6	-$5.8
Healthy and Amenity Benefits	$7.2	$18.7
Emission Benefits	-$0.5	-$1.0
Maintenance Costs	-$0.8	-$0.8
Residual Value	$2.7	$2.7
Total PV Benefits	**$34.6**	**$78.8**
Total PV Costs	**$22.2**	**$22.2**
NPV	**$12.4**	**$56.7**
BCR	**1.56**	**3.56**

Source: HDR inc, Economic and Social Value Analysis of the Reconnecting Central Portland to the Riverfront Proposal. Totals may not sum due to rounding.

[2] Income-weighted analysis of project benefits.

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

CY	Safety Benefits	Travel Time Savings	Health and Amenity Benefits	Emission Benefits	Maintenance Cost Savings	Residual Value	Total Benefits	Total Costs	NPV
Pre-Benefits Period	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$22.15	-$22.15
2030	$1.80	-$0.16	$0.45	-$0.03	-$0.05	$0.00	$2.01		$2.01
2031	$1.75	-$0.16	$0.44	-$0.03	-$0.05	$0.00	$1.96		$1.96
2032	$1.71	-$0.15	$0.43	-$0.03	-$0.05	$0.00	$1.91		$1.91
2033	$1.67	-$0.15	$0.42	-$0.03	-$0.05	$0.00	$1.86		$1.86
2034	$1.62	-$0.15	$0.41	-$0.03	-$0.05	$0.00	$1.81		$1.81
2035	$1.58	-$0.14	$0.40	-$0.03	-$0.04	$0.00	$1.77		$1.77
2036	$1.54	-$0.14	$0.39	-$0.03	-$0.04	$0.00	$1.72		$1.72
2037	$1.51	-$0.13	$0.38	-$0.03	-$0.04	$0.00	$1.68		$1.68
2038	$1.47	-$0.13	$0.37	-$0.03	-$0.04	$0.00	$1.64		$1.64
2039	$1.43	-$0.13	$0.36	-$0.03	-$0.04	$0.00	$1.60		$1.60
2040	$1.39	-$0.12	$0.35	-$0.02	-$0.04	$0.00	$1.56		$1.56
2041	$1.36	-$0.12	$0.34	-$0.02	-$0.04	$0.00	$1.52		$1.52
2042	$1.32	-$0.12	$0.33	-$0.02	-$0.04	$0.00	$1.48		$1.48
2043	$1.29	-$0.12	$0.33	-$0.02	-$0.03	$0.00	$1.45		$1.45
2044	$1.26	-$0.11	$0.32	-$0.02	-$0.03	$0.00	$1.41		$1.41
2045	$1.23	-$0.11	$0.31	-$0.02	-$0.03	$0.00	$1.37		$1.37
2046	$1.20	-$0.11	$0.30	-$0.02	-$0.03	$0.00	$1.34		$1.34
2047	$1.17	-$0.10	$0.29	-$0.02	-$0.03	$0.00	$1.30		$1.30
2048	$1.14	-$0.10	$0.29	-$0.02	-$0.03	$0.00	$1.27		$1.27
2049	$1.11	-$0.10	$0.28	-$0.02	-$0.03	$2.69	$3.92		$3.92
Total	**$28.54**	**-$2.56**	**$7.17**	**-$0.47**	**-$0.78**	**$2.69**	**$34.58**	**$22.15**	**$12.43**

*All benefits and costs are discounted at 3.1 percent annually (except for CO2 emissions, discounted at 2 percent). Total capital costs include all project cost, including “prior” costs. Totals may not sum due to rounding.

1 Introduction

This document provides technical information on the benefit-cost analyses (BCA) conducted for the Reconnecting Central Portland to the Riverfront 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 an augmented Bridge Investment Program (BIP) Benefit-Cost Analysis Tool 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.[3] BCA results include both a benefit-cost ratio (BCR) and net present value (NPV).

2 Project Overview

This application is respectfully submitted by the Kentuckiana Regional Planning and Development Agency (KIPDA), the regional Metropolitan Planning Organization (MPO) for the project area, with the support and full endorsement of the Kentucky Transportation Cabinet (KYTC) and Louisville Metro Government (LMG). The total cost for the Reconnecting Central Portland to the Riverfront Project (The Project) is $29.7 million. KIPDA is requesting a $14.94 million RCP grant to advance this important project to construction.

The Project is located west of downtown Louisville, Kentucky on the southern edge of the Ohio River in the Portland Neighborhood, an area rich in river history. Portland was originally the largest of the major settlements in Kentucky and Indiana at the Falls of the Ohio River and was a significant port in this area. However, over the years it has been negatively impacted by regional and national infrastructure projects including the construction of Interstate 64 (I-64) in the mid-1970s.

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

Figure 1: Reconnecting Central Portland to the Riverfront Project

The Project, intended to mitigate the harm caused by these past projects, is made up of seven components (Figure 1). Consistent with the Reconnecting Communities Pilot (RCP) Program, these components will reconnect the community across I-64 and better integrate the highway right-of-way with the surrounding land use character and context. The Project will significantly benefit the Portland neighborhood, which is an “Area of Persistent Poverty” as defined by the Bipartisan Infrastructure Law and a “Historically Disadvantaged Community” as defined by the Federal Justice40 Interim Guidance.

The Project is located within the study area of the Northwest Louisville Community Connectivity Study, which is being conducted by KYTC to examine transportation barriers in the I-64 corridor between 13th Street (east of the project area and near downtown) and the I-64 bridge over the Ohio River (west of the project area). Many studies have been completed in this area over the years; however, little action has occurred to address the needs that have been identified. The Project will directly address the most critical connectivity and safety needs identified by the current study and previous related studies.

2.1 Base Case and Alternatives

The base case (no build scenario) assumes that no improvements will be made to the existing project area, discouraging tourism and accessibility. The alternative (build scenario) will implement the full Reconnecting Central Portland to the Riverfront project. This includes openingup the project area to reconnect the surrounding community by installing crosswalks at major intersections along the route. Improvements in the build scenario include:

- Project 1 - 22nd Street Complete Street Upgrades (Bank Street to Lannan Park)
- Project 2 - I-64 Off-Ramp to 22nd Street
- Project 3 - I-64 On-Ramp from 22nd Street
- Project 4 - Replace Pedestrian Bridge to Lannan Park
- Project 5 - Replace Pedestrian Bridge at 19th Street
- Project 6 - I-64 Community Edge Upgrades
- Project 7 - McAlpine Lock and Lannan Park Existing Access Upgrades

The project will also implement multimodal access upgrades. 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 along the project corridor in their daily personal or business travel. These individuals will experience safer travel conditions, resulting in fewer fatalities, injuries, and property damage only (PDO) accidents. A reduction in speeds along the corridor also supports better safety standards however adds to the time of travel for users. Pedestrians and bike riders will also enjoy improved amenities in the project area with the installation of sidewalks and reduced traffic speeds. An increase in total vehicle hours travelled will produce more emissions but is expected to be the least of all benefit categories. Replacing old pedestrian bridges in the project corridor will guarantee a residual value for the infrastructure resulting in the bridge, as an asset, having value beyond the period of analysis.

2.3 Project Cost and Schedule

Project development (preliminary engineering) will be incurred between 2027 and 2029[4]. The total capital costs of the project are approximately $29.7 million (in year of expenditure dollars), plus $2.0 million of 2024 dollars planned for 2024 and 2025, which adds up to $26.1 million of 2022 dollars (undiscounted).[5] Discounted using a 3.1 percent real discount rate, these project costs in 2022 dollars become $22.2 million. The breakdown of costs among the 7 project is provided in Table 1.

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[4] The more detailed schedule can be found in the Project Schedule worksheet of the accompanying BCA model.

[5] The year of expenditure estimate, 2024 dollar estimate, as well as the converted 2022 dollar estimate and calculations are in the Cost Summary worksheet of the accompanying BCA model. The “prior cost” (which includes planning study and NEPA and preliminary engineering) was estimated for the entire project and then was assigned to individual project proportionally based on construction cost estimate.

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

Project Segment	Construction Costs, Undiscounted	Construction Costs, Discounted at 3.1%
Project 1	$4.3	$3.6
Project 2	$1.3	$1.1
Project 3	$1.6	$1.4
Project 4	$6.0	$5.1
Project 5	$5.2	$4.4
Project 6	$3.3	$2.8
Project 7	$4.3	$3.6
Total Costs[6]	**$26.1**	**$22.2**

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 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 2025 and ends in 2049. It includes five project development and construction years (2025 to 2029) and 20 years of operations (2030 to 2049);
- 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.
- The augmented BIP BCA Tool was used to develop the BCA. Although only two of the 7 projects are bridge projects, this tool was selected as it provides a built-in functionality to analyze the 7 projects separately and summarize the overall results in an efficient way.

4 Demand Projections

Traffic volumes were taken from the traffic forecast for the Northwest Louisville Community Connectivity Study. A 0.5% annual growth rate was used in the traffic forecast for the Northwest

[6] Totals may not sum due to rounding.

Louisville Community Connectivity Study. The proposed safety improvements are expected to result in lower speeds in the study area, which would result in increased travel times. The change in travel time for the 22nd Street corridor from Northwestern Parkway to Bank Street (Project 1) in the BCA is based on the changes in speed due to the project. Table 2 presents the volumes and vehicle speeds for Project 1.[7]

Table 2: Project 1 Vehicular Volumes and Speeds

Scenario and Vehicle Type	Project open year (2030)	Last year of analysis (2049)
No Build - Passenger AADT	10,621	11,677
No Build - Truck AADT	855	940
No Build - Bus AADT	0	0
No Build - Speed	29.4 mph	29.4 mph
No Build - Speed (rounded up)	30.0 mph	30.0 mph
Build - Passenger AADT	10,621	11,677
Build - Truck AADT	855	940
Build - Bus AADT	0	0
Build - Speed	25.0 mph	25.0 mph
Build - Speed (rounded down)	20.0 mph	20.0 mph

The existing travel times along segments were determined by dividing the length of the segment by the 85th percentile speed on the segment, as reported by the Kentucky Transportation Cabinet. Design travel times were developed by assuming that the safety improvements would reduce speeds to 25 mph along all segments. Table 2 shows the exact speeds for No Build and Build scenarios, as well as rounded speeds that are used for determining the emissions impact of the reduction in speeds due to the project.[8]

Based on proposed improvements, HDR used the approach from FDOT Multimodal Quality / Level of Service Handbook[9] to estimate pedestrian and cyclist volumes for No Build and Build scenarios. Table 3 presents these daily volumes.[10]

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[7] For simplicity, volumes for all other projects (Project 2 through Project 7) is set to 1 in 2030 and grows using the 0.5 percent per year growth rate mentioned above.

[8] To avoid potential underestimation of environmental impact of the project, this BCA explicitly overestimates this negative impact. As BIP BCA Tool's emissions data is in 10 mph increments, it was decided to estimate the impact of decreasing the speed by 10 mph instead of about 5 mph, because in the latter case the tool would show no environmental impact.

[9] The Handbook can be accessed online using the link: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/planning/systems/systems-management/document-repository/qlos/fdot_qlos_handbook_v6-0_clean.pdf?sfvrsn=f9f1759d_4

[10] For further detail on level of service (LOS) improvements and volumes for individual projects, see BikePedVolumes worksheet of the accompanying BCA model. The worksheet also contains segment lengths by project (starting at cell C24).

Table 3: Active Transportation Volumes

Scenario and Active Transportation Type	2028	2048
No Build - Daily Pedestrian Volume	190	209
No Build - Daily Cyclist Volume	26	28
Build - Daily Pedestrian Volume	455	501
Build - Daily Cyclist Volume	100	110

5 Estimation of Economic Benefits

This section describes the measurement approach used for each benefit or impact category identified in Section 2.2 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. The economic analysis used the Federal Highway Administration's (FHWA) Bridge Investment Program (BIP) Benefit-Cost Analysis Tool to produce the estimation of benefits. The flexibility of the BIP tool provided a sensible option when considering the uniqueness of each project "segment". Please see the attached benefit-cost analysis model.

- **Pedestrian Amenity Benefits:** The project includes plans to install or extend sidewalks at multiple locations throughout the project corridor. A reduction in traffic speeds along one of the corridors will also improve the safety of pedestrians traveling through the area. These combined effects will improve pedestrian safety and journey quality and will make overall trip experience safer for all pedestrians and bike riders. For current and future user counts, observed traffic counts were used and grown to account for the period of analysis. Total pedestrian amenity benefits are monetized using USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).[11]

- **Travel Time Savings:** The project will strive to optimize travel time throughout the Portland area. All but one of the project segments are expected to remain at current traffic speeds. However, one project segment will experience a reduction in traffic speeds, resulting in an increase in total travel time. The BCA model uses traffic speeds from the Build and No-Build scenarios to estimate the total increase in travel time for passengers in the one project segment. Light vehicles and trucks were assumed to be travelling at the same speed along the corridor. The total increase in travel time was

[11] Amenity benefits for pedestrians and cyclists were estimated for projects 1, 4, 5, 6, and 7. Tables 46 through 49 in worksheets Project1A ("A" because the benefit applies only for a portion of Project 1's length), Project4, Project5, Project6, and Project7 of the accompanying BCA model. Table 57 of Project1 worksheet was modified to include the Amenity benefits calculated in Project 1A worksheet.

monetized per USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).[12]

- **Safety Benefits:** The economic analysis uses crash data from the Kentucky State Police database to estimate average annual crash rates.[13] Existing crash rates from a five-year period (2018-2022) were multiplied by crash modification factors to calculate projected crash rates for each project segment.[14] The reduction in crash rates used the difference in existing crash rates and projected crash rates. The reduction in projected injuries, fatalities, and property damage only (PDO) crashes were then monetized per USDOT's Guidance for Discretionary Grant Programs.[15]

- **Emission Reduction Benefits:** The increase in total vehicle travel time (described Travel Time Savings, above) will lead to an increase in both CO2 and non-CO2 emissions for vehicles travelling along the individual corridor.[16] All other project segments are expected to have zero increase in total vehicle emissions. Total damage costs per emission type are monetized per USDOT's BCA Guidance for Discretionary Grant Programs (December 2023).

- **Residual Value:** More than one of the segments in this project involve the construction of new pedestrian bridges. General maintenance and repair over time can prove to be more costly than constructing a new bridge. Bridges themselves have an expected useful life of 75 years. Therefore, the bridges will have a remaining value beyond the period of analysis. Economic analysis uses the years after the period of analysis to calculate the discounted value of the bridge after 20 years. Total residual value is monetized using a percentage of the project segment costs and the remaining life cycle of the bridge[17].

5.2 Assumptions

The assumptions used in the estimation of economic benefits are summarized in Table 4.

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[12] Tables 41 through 43 in Project1 worksheet were edited to calculate this benefit category.
[13] Crash data is included in the CrashData worksheet of the BCA model.
[14] Crash modification factors are included in the CrashSummary worksheet of the BCA model.
[15] Safety was calculated for Projects 1, 2, and 3 only. Tables 35 through 39 in worksheets Project1, Project2, and Project3 provide the inputs to calculate Safety benefit.
[16] To estimate this disbenefit and to exaggerate it, the two worksheets were created in the model, using the built-in structure (Project1_emissNB and Project1_emissB) – the speeds for No Build is rounded up to 30 mph, while the Build speed is rounded down to 20 mph. The final benefits resulting calculated as emissions costs difference between these two scenarios are included in Table 57 of Project1 worksheet.
[17] Table 13 of Project4 and Project5 worksheets includes inputs needed to calculate this benefit category using standard BIP BCA Tool's methodology.

Table 4: Assumptions used in the Estimation of Economic Benefits

Benefit Categories	Variable Name	Unit	Value	Source / Notes
Pedestrian Benefits	Expand Sidewalk (per foot of added Width) (2)	2022 $	$0.11	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs – December 2023
	Reducing Traffic Speed by 1 mph (for speeds ≤ 45 mph)	2022 $	$0.09	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs – December 2023
	Reducing Traffic Volume by 1 Vehicle per Hour (for ADT ≤ 55,000)	2022 $	$0.001	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs – December 2023
	Install Marked- Crosswalk on Roadway with Volumes ≥ 10,000 Vehicles per Day	2022 $	$0.19	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs – December 2023
	Install Signal for Pedestrian Crossing on Roadway with Volumes ≥ 13,000 Vehicles per Day	2022 $	$0.51	USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs – December 2023
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	
Safety Benefits	Cost of Injury	2022 $ / injury	$313,000	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Cost of Fatality	2022 $ / fatality	$14,022,900	
Emission Benefits	Carbon dioxide (CO_2)	Costs per metric ton	varies	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Nitrogen Oxides (NO_X)	Costs per metric ton	varies	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Particulate Matter ($PM_{2.5}$)	Costs per metric ton	varies	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.
	Sulfur Oxides (SO_X)	Costs per metric ton	varies	USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs.* December 2023.

5.3 Aggregation of Benefit Estimates

The results indicated that at a 3.1 percent real discount rate, a $21.0 million capital investment would result in $34.6 million in total benefits and a benefit-cost ratio of approximately 1.65. Table 5 presents the benefit estimates by benefit categories over the project's lifecycle. Safety benefits represent the largest contributor to total benefits.

Table 5: Estimated of Economic Benefits, Millions of 2022 Dollars*

Benefits	Summary of Benefits, $M (Discounted at 3.1%)
Safety Benefits	$28.5
Travel Time Savings	-$2.6
Healthy and Amenity Benefits	$7.2
Emission Benefits	-$0.5
Maintenance Costs	-$0.8
Residual Value	$2.7
Total Benefits	**$34.6**

*Total may not sum up due to rounding

6 BCA Sensitivity Analysis

The BCA outcomes presented in the previous sections rely on 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 to determine how much the final results 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.

- Decrease capital cost by 20%[18]
- Increase capital cost by 20%[19]
- Zero growth rate in traffic[20]
- No maintenance cost increase due to project[21]
- Double the maintenance cost increase due to project[22]

Table 6: Sensitivity Test Results, Millions of 2022 Dollars

Parameters	Change in Parameter Value	NPV	B/C Ratio
Base Scenario	**n.a.**	$12.4	1.56
Scenario 1	Decrease capital cost by 20%	$16.3	1.92
Scenario 2	Increase capital cost by 20%	$8.5	1.32
Scenario 3	Zero growth rate in traffic	$11.4	1.52
Scenario 4	No maintenance cost increase due to project	$13.2	1.60
Scenario 5	Double the maintenance cost increase due to project	$11.6	1.53

To summarize, none of the sensitivity scenarios tested above drives the BCR below 1.0. Under reasonable assumptions the project would likely result in a BCR of greater than 1.0.

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 Reconnecting Central Portland to the Riverfront 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).

[18] In the accompanying BCA model, changing the value in cell D27 of Cost Summary worksheet from 100% to 80%.
[19] Changing the value in cell D27 of Cost Summary worksheet from 100% to 120%.
[20] Changing the value in cell B15 of Assumptions worksheet from 0.5% to 0%.
[21] Changing the value in cell C15 of Maintenance Costs worksheet from 100% to 0%.
[22] Changing the value in cell C15 of Maintenance Costs worksheet from 100% to 200%.

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 Regional and User Income Analysis

The first step in conducting a wBCA consists of collecting household level income data for the desired project area. Income data is obtained from the U.S. Census and is estimated after accounting for both taxes and transfers (US Dept. of Treasury, 2022). Figure 2 shows the income distributions for selected geographical regions, provided by the Census Reporter. The graphed data in Figure 2 represents an individual's "money income (MI)," or the amount an individual earns <u>before</u> any tax deductions. Although a formidable depiction of an individual's income, it does not fully take into consideration the number of people living in the household and how these people share resources and take advantage of economies of scale. To more accurately capture the money an individual available to spend, the SEVA model uses "equivalized, post-tax, and transfer income (EDI)", or an equivalized disposable income. EDI income is estimated from US Census data reported as MI for each of the sixteen income bins. The new EDI values are then converted into quintiles – five income bands, each of which represents approximately 20% of the population. Each region (national, state, local) would have new, equivalized-adjusted income bands. Table 7 shows the reference incomes of the new income bands for Jefferson County, Kentucky.

Figure 2: Income Distributions, in Selected Regions

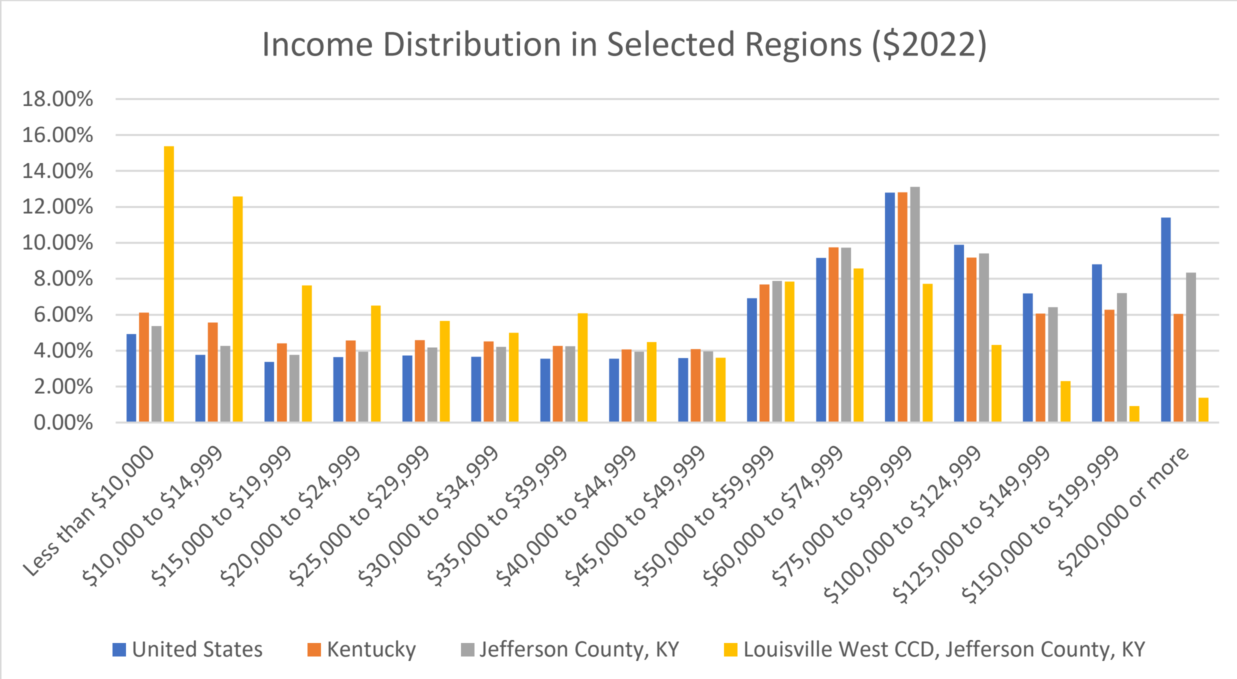
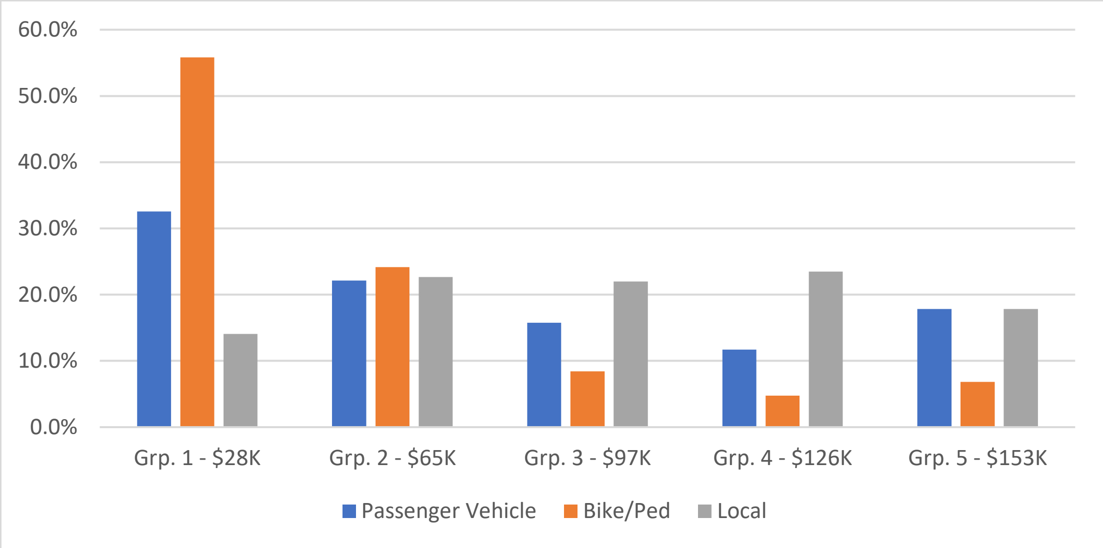


Table 7: Reference Incomes (in $2022, thou.), Adjusted – Equivalized, Post-tax &Transfer

Income Quintiles	Average Ann. Adjusted HH Income ($000)
1	$27.72
2	$65.43
3	$97.10
4	$125.99
5	$153.09

Next, user data are analyzed to determine the proportion of people (by regional income groups) who would benefit from the project. User income data are retrieved from Replica, a commercial data source that estimates characteristics of users for each person-trip in the selected area by mode. Data on an individual's household income are extracted for each trip taker. An analysis is conducted then to determine the proportion of users whose incomes, defined as "trip taker household income", that fall within the income quintiles that are defined for the region. The results indicate that a much higher proportion of low-income users walk or cycle compared to using a passenger vehicle in Jefferson County, Kentucky (as shown in Figure 3). User data pulled for Jefferson County also indicates that the incomes of trip-takers for either mode are lower than the national average. The "local" percentages in Figure 3 are included as reference and refer to the incomes in the Louisville West CCD.

Figure 3: Percentages of Users per Income Group, by Mode



7.3 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).

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.[23] The specification of a benchmark income is important when considering the results of a wBCA in terms of the WNPV. Most academic and applied wBCA, including the OMB (2023), reference the median income to be an appropriate benchmark income. An alternative approach is discussed in the appendix that defines a benchmark so that the weighted and unweighted costs have the same magnitude. In this project, the benchmark income is computed to be $126.32 thousand.

Table 8 presents normal weights and adjusted income weights based on benefits categories that are monetized with median incomes, respectively. For benefit categories in transportation projects that are monetized with a population 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 valuation parameter with an individualized one since benefits are a function of income. The approach to adjusting weights is developed in the appendix. A general formula for adjusting weights is

[23] 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.

EQ. 2

$$\widetilde{w}_i^{\alpha} = \left(y_\alpha / y_{Pop}\right) \cdot \left(y_\alpha / y_i\right)^{\varepsilon - 1}$$

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 8: Estimated Income Weights

Income Group	Average Ann. Adjusted HH Income ($000)	Normal Income Weights	Adjusted Weights (median income)
1	$27.72	8.37	3.11
2	$65.43	2.51	2.21
3	$97.10	1.45	1.88
4	$125.99	1.00	1.70
5	$153.09	0.76	1.57

7.4 Weighted Benefits and Costs Results

The results of the wBCA are presented in Table 9 in the forms of unweighted and weighted benefits and costs, net benefits and BC ratio. In both standard and weighted analyses, net benefits are greater than zero and BC ratios are 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 and the weighted BCR are more than 200% higher than in the standard BCA. These results clearly indicate how the project generates significantly higher benefits for low-income persons.

Table 9: Comparisons of weighted and unweighted BCAs

BCA Metric	BCA	Weighted-BCA
Benefits ($M)	$34.6	W$78.8
Costs ($M)	$22.2	W$22.2
NPV ($M)	$12.4	W$56.7
BC Ratio	1.56	3.56

Table 10 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 are more than 50% higher than the magnitude of standard benefits.[24]

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

Similarly, impacts on journey quality for pedestrians are significantly greater in magnitude compared to a standard BCA. 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.

Table 10: Estimated Unweighted and Weighted Benefits (2022 $M, Discounted at 3.1%)

Category	Standard Benefits	Weighted Benefits
Safety Benefits	$28.5	W$65.0
Travel Time Savings	-$2.6	-W$5.8
Health and Amenity Benefits	$7.2	W$18.7
Emission Benefits	-$0.5	-W$1.0
Maintenance Costs	-$0.8	-W$0.8
Residual Value	$2.7	W$2.7
Total	$34.6	W$78.8

Technical Appendix: Social Equity Value Analysis

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.

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, 2016). 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. 3** shows that MU_i, from an isoelastic utility function depends on the elasticity of income utility ε, and income level y_i:

EQ. 3

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

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.[25] The income weights of a y_α benchmark income are:

EQ. 4

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

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 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. 5, the weighted net present value "$wNPV$" equals the difference in weighted benefits and costs.

EQ. 5

$$wNPV = \sum_i^I \left[\sum_j^J w_i^\alpha \cdot B_{ij} - \sum_k^K w_i^\alpha \cdot C_{ik}\right]$$

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.

Formation of income groups and reference incomes (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[26] on household income for the wider MSA. Income groups are determined for quintiles – five income bands, each of which is approximately 20% of the population, and the midpoints in each income band are called 'reference incomes'. Specifically,

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

[26] These data are defined a gross household income (i.e. pre-tax and transfer).

a simple log-log linear model can be used to estimate LN(Income cutoff) as a function of LN(Cumulative Percentiles).[27] 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 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.

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)).[28]

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.[29] 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.[30] Most academic and applied wBCA, including the OMB (2023), reference the median income to be an appropriate benchmark income. [31] This specification though is set without accounting for how projects are funded.

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

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[27] The log-log models produce high r-squared statistics and provide good fits for incomes between the 5th and 95th percentiles.

[28] Other elasticity values from the literature range from 1.0 to over 2.0 (Acland & Greenberg, 2023).

[29] 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.

[30] The benchmark income is a constant and can be moved outside the summations in **Error! Reference source not found.**. 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.

[31] 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.

utility of income per reference income. The computation process begins with solving the weighted cost part of EQ. 1 in this equation,

EQ. 6

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

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.[32]

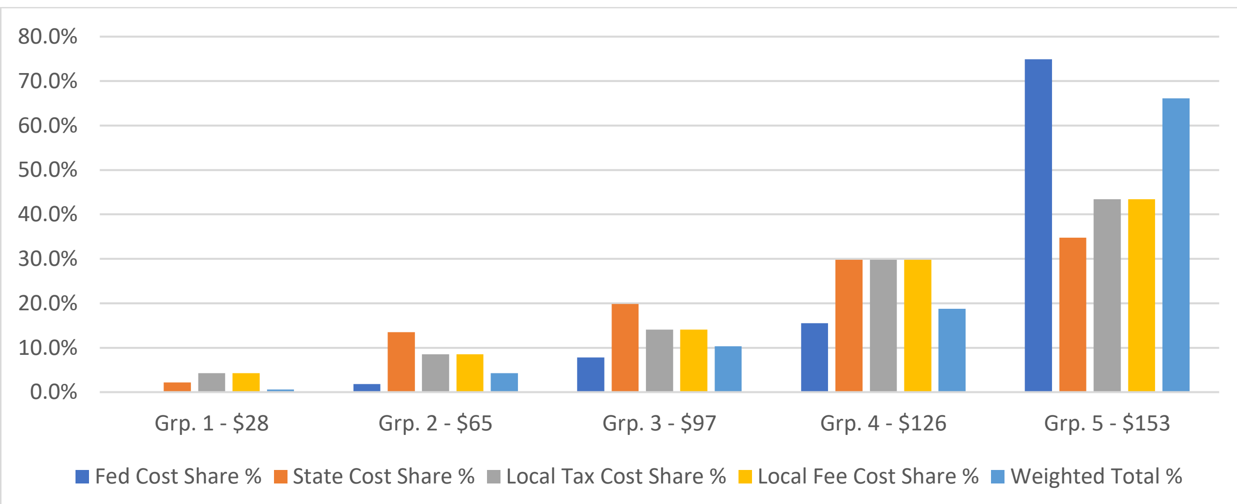
The proportions of cost burden, p_i, which indicate the percentage shares of total cost for a given funding source are defined such that $\sum_i p_i = 1$ and $p_i C = C_i$. Substituting this equality into:

EQ. 7

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

The normalizing constant $\mathbf{y_\alpha}$ is equivalent to a cost burden-weighted harmonic mean of incomes, for a given elasticity. Equivalently, this equation indicates that $\mathbf{y_\alpha}$ is the income representing the weighted average of marginal utilities, where this weight is based on the shares of cost burdens**.**[33]

Figure 4: Cost Share by Income and Funding Source



Data Sources: (US Dept. of Treasury, 2022)2022), (ITEP, 2018), Replica (2023)

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[32] 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.
[33] A similar approach is explored by Van der Pol, Bos, & Romijn (2017).

Adjusted Weights

For benefit categories in transportation projects that are monetized with a population 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 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 11.

Table 11: Adjusted Weights per Benefit Category

Benefit Category	Mode	Type of Weight Applied
Safety Benefits	Passenger Vehicle Users	Adjusted Weights (Median income)
Travel Time Savings	Passenger Vehicle Users	Adjusted Weights (Median income)
Health and Amenity Benefits	Bike/Ped	Adjusted Weights (Median income)
Emission Benefits	Local Population (Louis. West CCD)	Adjusted Weights (Median 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, $f(\tilde{v})$[34], 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

[34] 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.

weighted benefits if the benefits were instead originally estimated at an affected persons' actual wage rate (their WTP for time savings).[35]

A general form for adjusting weights is

EQ. 8

$$\widetilde{w}_i^{\alpha} = \left(y_{\alpha}/y_{Pop}\right) \cdot \left(y_{\alpha}/y_i\right)^{\varepsilon-1}$$

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.

Estimation of Benefits and Costs by Income Group

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.
- 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 median 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. These are monetized largely with the median U.S. income. Emissions reductions of greenhouse gases (GHG): It is assumed that these benefits are spread equally among the population in the MSA.
- Bike and pedestrian journey quality and health benefits: These benefits accrue to active transportation users. Benefits are estimated according to USDOT guidance, which is assumed to be a function of median U.S. income.

Table 12: Overview of Benefits and Beneficiaries

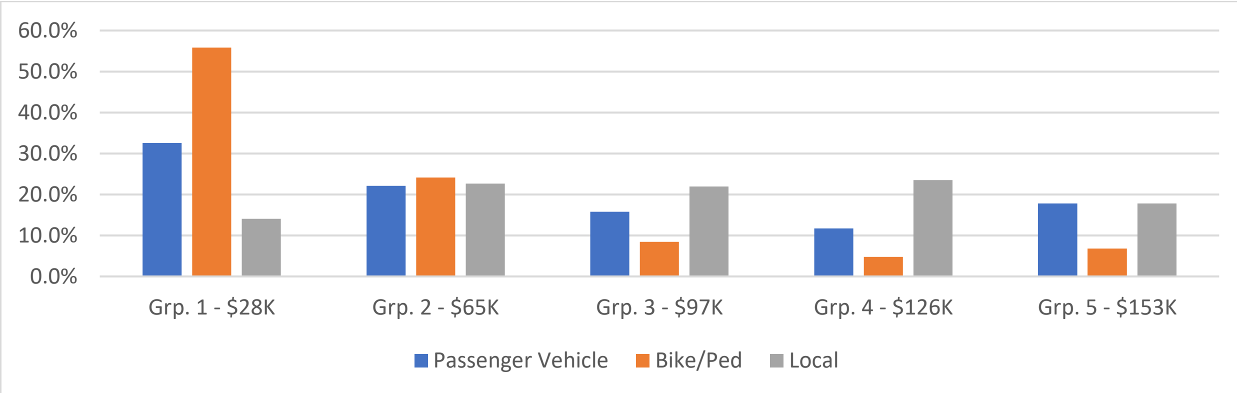
Benefit Category	PV Benefits (2022 $M)	Affected Persons, for Income Distribution
Safety Benefits	$65.0	Passenger Vehicle Users
Travel Time Savings	-$5.8	Passenger Vehicle Users
Health and Amenity Benefits	$18.7	Bike/Ped
Emission Benefits	-$1.0	Local Population (Louis. West CCD)

[35] 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 $\varepsilon = 1$.

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 5 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.

Figure 5: Percentages of Users per Income Group, by Mode



Data Source: (Replica, 2023), U.S. Census 2022)

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.[36] 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 KYTC receives a combination of these sources for its capital and operating expenses. The shares of these sources of funding for KYTC are obtained from its recent financial report. The allocation of costs to sources is determined by the Project and shown below in Table 13. Note that the distributional analysis incorporates residual value as a cost factor and then includes it with other benefits for the benefit-cost ratio and net present values.

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

Table 13: Adjusted Capital Cost Burden Percentages

Cost Item and Source of Costs	Present Value Cost ($ million)	% of Funding by Source
Capital Cost (includes Residual Value)	**$19.47**	100.0%
Federal	$15.57	80.0%
KYTC	$3.84	19.7%
Local Louisville Metro	$0.06	0.3%
O&M Cost	**$0.78**	100.0%
Local Louisville Metro	$0.78	100.0%
Total Cost	**$20.25**	

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