BUILDing a Better Howard Street

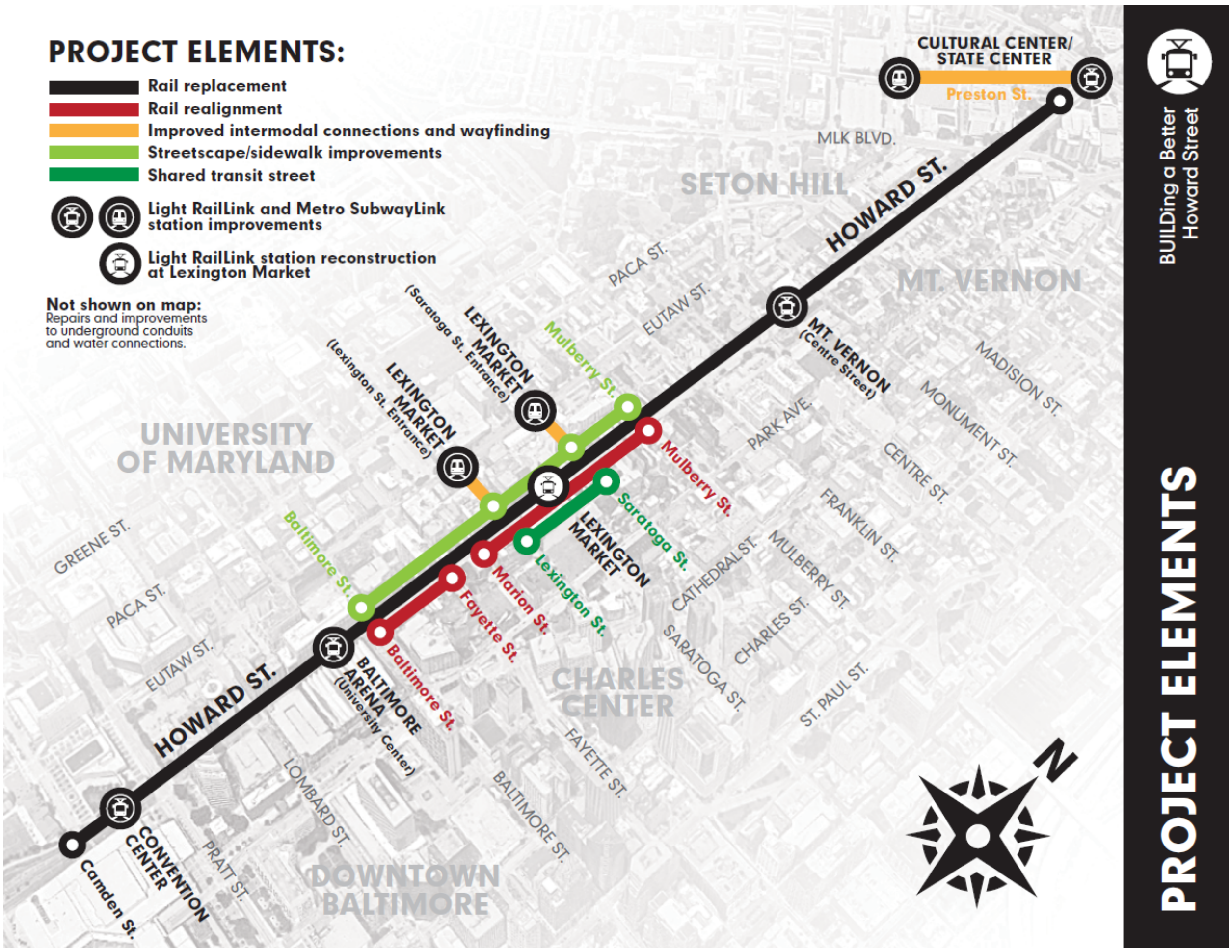
APPENDIX I

APPENDIX I

Benefits Cost Analysis

BUILDING A BETTER HOWARD STREET

BENEFIT-COST ANALYSIS SUPPLEMENTARY DOCUMENTATION



FY2018 BUILD DISCRETIONARY GRANT PROGRAM

PREPARED FOR: MARYLAND DEPARTMENT OF TRANSPORTATION MARYLAND TRANSPORTATION AUTHORITY (MDOT MTA)
JULY 19, 2018

EXECUTIVE SUMMARY

A benefit-cost analysis (BCA) was conducted for the BUILDing a Better Howard Street project ("BBHS," "the project") for submission to the U.S. Department of Transportation (U.S. DOT) as a requirement of a discretionary grant application for the BUILD 2018 program. The analysis was conducted in accordance with the benefit-cost methodology, values, and assumptions specified by U.S. DOT in the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs. The period of analysis corresponds to 34 years and includes 4 years of construction and 30 years of benefits after operations begin in 2022.

Sponsored by the Maryland Department of Transportation Maryland Transit Administration (MDOT MTA), BBHS will leverage much-needed investments in light rail infrastructure to support community-enhancing economic development activity. In so doing, the project will address several needs related to state of good repair, safety, economic and community development, and the environment, all of which will revitalize downtown Baltimore's once premiere shopping district. The project scope includes embedded rail replacement, realignment of curved sections, upgraded water, power and telecommunications lines, streetscape enhancements, updated amenities in stations, wireless communications at traffic signals, a new train detection system, and upgrades to historic properties.

For over 200 years, the Howard Street corridor ("project corridor") has served as a destination shopping district for downtown Baltimore, complementing Charles Street, the primary axis of the City's Central Business District (CBD). The project corridor is anchored by the historic Lexington Market, which was established in 1782 and is one of the longest-running public markets in the world. However, post-World War II suburbanization, a major road project along Howard Street, and the implementation of the Light RailLink created significant and sustained disruptions to businesses that could not be overcome. In the intervening decades, the project corridor has suffered from vacancies and blight.

Changing demographics and market demand for urban living that combines quality places with major transit options position Howard Street to participate in and support the City's economic revitalization and urban renaissance. However, the neighborhood is still hampered by infrastructure repairs needed along the corridor. By transcending historical investment silos and coupling infrastructure improvements with development activity, BBHS elevates the need to repair and replace aging Light RailLink tracks to a generational opportunity to revitalize Baltimore's downtown core.

COSTS

The capital cost for BBHS is expected to be $67.0 million in undiscounted 2017 dollars through 2022. At a 7 percent real discount rate, these costs are $54.1 million. The project is expected to reduce the Light RailLink system's overall operations and maintenance (O&M) costs by ameliorating current substandard rail conditions; these O&M cost savings are projected to average $1.24 million per year in the long term, following a cost savings of $930,000 in the first year following project completion.[1] Over the entire 34-year analysis period, these costs accumulate to $36.9 million in undiscounted 2017 dollars, or $11.5 million when discounted at 7 percent.

The project is expected to be financed by Federal, State, and local funds according to the allocation shown in Table ES-1.

Table ES-1. Project Costs by Funding Source, Year of Expenditure Dollars

Funding Source	Total Project Cost	Percent by Source
Federal (including BUILD)	$25.0 M	35.5%
MDOT Transportation Trust Fund	$31.0 M	43.5%
City of Baltimore	$6.0 M	8.4%
BDC and DPOB	$1.0 M	1.4%
FTA Section 5307	$8.3 M	11.6%
Total	**$71.3 M**	**100.0%**

Source: MDOT MTA

BENEFITS

In 2017 dollars, the project is expected to generate $21.1 million in discounted benefits using a 7 percent discount rate. These benefits consist primarily of travel-time savings for light rail passengers and auto users who transit roadways in the project area, and of safety-related benefits arising from avoided crashes.

The travel-time benefits will be generated in two ways. First, the current deteriorated condition of the existing rail results in persistent degraded service and frequent service suspension. By ameliorating this condition, BBHS will avoid the substantial travel-time delays that would continue to occur in the future without the proposed project. Second, the rail realignment and associated traffic operations changes will increase average running speeds for transit vehicles operating along the corridor, as well as avoid unanticipated service interruptions, particularly

[1] Per USDOT guidance, operations and maintenance costs are grouped with costs, but included in the numerator along with project benefits when calculating the benefit-cost ratio.

during weekend operating periods. In addition to these transit-user travel-time savings, the optimized operating conditions along the corridor will better synchronize transit and automobile traffic, resulting in additional travel-time savings for auto users. All together, these travel-time savings will generate $63.4 million in undiscounted economic benefits, or $18.0 million discounted at 7 percent.

BBHS will also generate economic benefits by reducing the potential for collisions involving pedestrians along the project corridor, as well as crashes involving Light RailLink trains and passenger automobiles along Howard Street. The light rail segments that will be improved by the proposed realignment account for approximately one-half of the total number of reported crashes along the project corridor.

By eliminating curves in the rail that introduce conflicts between transit vehicles and automobiles, it is expected that BBHS will result in the avoidance of approximately 28 percent of these crashes in the future, substantially reducing the number, rate, and severity of crashes within the corridor. Avoided crashes involving pedestrians were quantified and monetized for the BCA, and are expected to generate $9.56 million in undiscounted economic benefits, or $3.02 million discounted at 7 percent. Avoided crashes involving light rail vehicles and autos were not monetized, and are therefore considered as a qualitative benefit.

In addition to these monetized benefits, the project will also result in qualitative economic benefits. As discussed in the application narrative, BBHS will introduce infrastructure improvements to Howard Street that would support economic development efforts along the corridor.

These improvements would allow private developers to capitalize on the significant market demand for new market-rate residential units, and help unlock the development potential of underutilized parcels along the corridor. Below-ground infrastructure improvements will help set the stage for increased investment in this vital corridor, leading to overall gains in productivity, tax revenues, and economic vitality.

RESULTS

Table ES-2 presents the BCA results for BBHS at both a 7 percent and a 3 percent discount rate. Table ES-3 summarizes the magnitude of the project's expected economic benefits, and Table ES-4 provides an overall project benefit matrix.

Table ES-2. Benefit-Cost Analysis Results

Case	Net Present Value (2017$)	Benefit-Cost Ratio
Case A: 7% Discount Rate	-$21.5 million	0.60
Case B: 3% Discount Rate	$1.03 million	1.02

Source: WSP

Table ES-3: Project Impacts, Cumulative 2022-2051

Category	Unit	Quantity	Direction
Person-Hours Traveled	PHT	3,355,895	▼
Injury Crashes	Number	90	▼
Property Damage Only Crashes	Number	180	▼

Source: WSP

Table ES-4. Project Impacts and Benefits Summary, Monetary Values in Present-Value Discounted 2017 Dollars

Current Status/Baseline & Problem to be Addressed	Change to Baseline/ Alternatives	Type of Impact	Population Affected by Impact	Economic Benefit	Summary of Results 7% discount rate	Summary of Results 3% discount rate	Page Reference in BCA
Persistent degraded light rail service and frequent service suspension	Embedded rail replacement and other infrastructure upgrades	Travel time savings resulting from avoided slow orders	Light rail users	29,654 annual PHT savings in 2022, increasing each year through 2051	$18.0 million	$35.1 million	p. 8, p. 15
Suboptimal traffic operations along Howard Street due to light rail alignment and poor coordination with auto traffic	Embedded rail realignment and technology-supported traffic synchronization	Travel time savings for all corridor users	Light rail users, auto users	60,480 annual PHT savings for light rail users in 2022, increasing each year through 2051; 7,352 annual PHT savings for auto users, 2022-2051			p. 8, pp. 15-16
Collisions involving pedestrians	Streetscaping improvements and safety-promoting infrastructure	Avoided pedestrian-involved crashes	Pedestrians along Howard Street	9 avoided crashes per year, including 3 injury crashes	$3.02 million	$5.55 million	p. 9

Source: WSP

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1 INTRODUCTION

A benefit-cost analysis (BCA) was conducted for the BUILDing a Better Howard Street project ("BBHS," "the project") for submission to the U.S. Department of Transportation (U.S. DOT) as a requirement of a discretionary grant application for the BUILD 2018 program submitted by the Maryland Department of Transportation Maryland Transit Administration (MDOT MTA). The following section describes the BCA framework, evaluation metrics, and report contents.

1.1 BCA FRAMEWORK

A BCA is an evaluation framework to assess the economic advantages (benefits) and disadvantages (costs) of an investment alternative. Benefits and costs are broadly defined and are quantified in monetary terms to the extent possible. The overall goal of a BCA is to assess whether the expected benefits of a project justify the costs from a national perspective. A BCA framework attempts to capture the net welfare change created by a project, including cost savings and increases in welfare (benefits), as well as disbenefits where costs can be identified (e.g., project capital costs), and welfare reductions where some groups are expected to be made worse off as a result of the proposed project.

The BCA framework involves defining a Base Case or "No Build" Case, which is compared to the "Build" Case, where the grant request is awarded and the project is built as proposed. The BCA assesses the incremental difference between the Base Case and the Build Case, which represents the net change in welfare. BCAs are forward-looking exercises which seek to assess the incremental change in welfare over a project life-cycle. The importance of future welfare changes is determined through discounting, which is meant to reflect both the opportunity cost of capital as well as the societal preference for the present.

The analysis was conducted in accordance with the benefit-cost methodology as recommended by U.S. DOT in the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs.[2] This methodology includes the following analytical assumptions:

— Assessing benefits with respect to each of the five long-term outcomes defined by U.S. DOT;
— Defining existing and future conditions under a No Build base case as well as under the Build Case (or "Alternatives");
— Assessing the independent utility of each project if the overall application contains multiple separate projects linked together in a common objective;
— Estimating benefits and costs during project construction and operation, including at least 20 years of operations beyond the Project completion when benefits accrue;

[2] U.S. Department of Transportation. 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs. 2018.

— Using U.S. DOT recommended monetized values for reduced fatalities, injuries, property damage, travel time savings, and emissions, while relying on best practices for monetization of other benefits;
— Presenting dollar values in real 2017 dollars. In instances where cost estimates and benefits valuations are expressed in historical dollar years, using an appropriate Consumer Price Index (CPI) to adjust the values;
— Discounting future benefits and costs with real discount rates of 7 percent and 3 percent (sensitivity analysis) consistent with U.S. DOT guidance;

1.2 PRISM

This benefit cost analysis was done using PRISM™, a benefit cost analysis tool that uses a methodology consistent with the most recent guidelines developed by USDOT. The tool quantifies and monetizes benefits according to the following five categories: Quality of Life; Economic Competitiveness; Safety; State of Good Repair; and Environmental Protection.

1.3 REPORT CONTENTS

— Section 2 contains an overview of the project, as well as the general parameters and assumptions used in the BCA.
— Section 3 contains a description of the project's costs and benefits, and how their values were quantified.
— Section 4 contains a description of the methodology and assumptions used to calculate monetized benefits generated by the project.
— Section 5 contains a summary of the overall BCA results.

2 PROJECT OVERVIEW

2.1 BACKGROUND

Baltimore's Howard Street corridor ("project corridor") serves as a crucial north-south transit link between the multimodal connections available at Baltimore-Penn Station to the north, significant employment opportunities within the dense downtown CBD to the east, tourist- and family-oriented destinations along the Inner Harbor to the southeast, major sports venues just to the south, and the University of Maryland at Baltimore (UMB) campus to the west. Three service patterns of MDOT MTA's 29-mile Light RailLink system converge along the 1.1-mile segment of Howard Street between stations at Cultural Center and Convention Center, producing high-frequency transit service (7.5-minute peak and 10-minute off-peak) which connects suburban communities and emerging employment to the north with the Baltimore Washington International Thurgood Marshall Airport (BWI) and its large employment district located 10 miles south.

Owing to their prime accessibility to CBD employment and other significant trip generators (e.g., convention center, ballpark, arena, four medical centers, two universities, the state government complex, six fine arts venues, and Lexington Market), the five Light RailLink stations within the project corridor constitute approximately one-third of the average weekday boardings across the 33-station system, with the Lexington Market (3,175), Baltimore Arena (2,300), and Convention Center (1,050) stations ranking first, second, and fifth, respectively, in ridership. The project corridor also provides walkable connections to two Metro SubwayLink stations, 11 frequent CityLink bus routes, nine LocalLink routes, and six Express BusLink routes, as well as links to non-MDOT MTA services such as the city-owned Charm City Circulator and UMB campus shuttles at University Center and Convention Center stations, four Baltimore Bike Share stations, and four Zipcar pick-up points.

Howard Street features Light RailLink's most closely spaced stations with frequent intersecting streets, including four east-west thoroughfares where dedicated bus lanes were implemented as part of MTA's 2017 BaltimoreLink bus network redesign and rebranding campaign. Maintaining reliable Light RailLink operations along this segment is critical because it features the only two transfer points (Cultural Center and Lexington Market) where passengers can connect to the underground Metro SubwayLink, which runs between Owings Mills to the north and the internationally-renowned Johns Hopkins Hospital located three stations east of Lexington Market. Furthermore, providing predictable service ensures that riders disembarking for long-haul journeys outside of the region make their time-sensitive intercity rail, bus, and air connections at Penn Station (two stops north with Amtrak, MARC commuter rail, and BOLTBUS), Camden Yards Station (one stop south with MARC commuter rail), and BWI.

2.2 PROJECT DESCRIPTION

Despite its central location and myriad operational synergies, Light RailLink service along the project corridor is hindered by a combination of state of good repair (SGR) and safety issues that threaten the long-term viability of reliable transit service. Furthermore, antiquated utilities beneath Howard Street, particularly weak water main connections that prevent compliance with fire code requirement for building-wide sprinkler systems, jeopardize the continued revitalization and transformation of the Howard Street corridor.

To that end, the MDOT MTA has engaged its partners at the Baltimore City Department of Transportation (BCDOT), the Downtown Partnership, and the Bromo, as well as the Market Center Merchants Association, the University of Maryland Medical System (UMMS), the Baltimore Development Corporation (BDC), and other corridor stakeholders, to collaboratively develop a suite of capital enhancements that combines critical Light RailLink SGR activities with transformative changes to the built environment that will unlock the redevelopment potential of the Howard Street corridor. BBHS features the following improvements:

— Replacement of 1.3-miles of embedded rail from Cultural Center to Convention Center, including a new drainage system and a state-of-the-art elastomeric grout system in the realigned sections, to maintain a state of good repair, avoid significant disruptions to the corridor, reduce passenger delays, and ensure reliability;
— Realignment of curved sections and reconstruction of the northbound platform at Lexington Market to increase transit speeds, simplify traffic operations, reduce noise nuisances from car horns and wheel squeal, and extend the useful life of critical assets;
— Upgrade of water, power, and telecommunications lines and connections concurrently at strategically identified locations to remove existing barriers to redevelopment along Howard Street and limit disruptions to abutting businesses;
— Development of a one-block shared transit street at Lexington Market (Saratoga Street to Lexington Street) activated with landscaping, lighting, furniture, and art;
— Implementation of streetscape enhancements from Mulberry Street to Baltimore Street to improve pedestrian and ADA accessibility, safety, passenger comfort, and corridor aesthetics;
— Update of stations with modern amenities (integrated canopies with real-time information and security cameras, new wayfinding) to enhance the passenger experience and improve safety;
— Implementation of new wayfinding systems, ADA elements, and crossing improvements to strengthen the connection between Light RailLink and Metro SubwayLink stations;
— Integration of wireless communications at traffic signals that enable synchronization along the corridor to improve transit and vehicular travel times;
— Installation of a new train detection system at Read Street to enable signal preemption and increase transit speeds; and
— Stabilization, rehabilitation, and upgrades to historic properties along this corridor to reduce vacancy and blight, and strengthen local businesses.

It should be noted that the major elements of the project scope were developed based on recommendations from four separate planning studies in the corridor conducted since 2010, as detailed in Section 4.2 of the application narrative. Furthermore, the rail replacement component of the scope is already programmed in the *MDOT FY 2018-2023 Consolidated Transportation Program (CTP)*.

At its core, BBHS identifies synergies between addressing long-standing state of good repair, safety, and operational needs of the Light RailLink system while establishing a firm built environment foundation upon which high-density transit-oriented development can finally be realized. BBHS will concurrently upgrade utilities, which will effectively increase the development capacity of Howard Street while undertaking transit- and pedestrian-oriented improvements that will maintain a state of good repair, reduce travel times, enhance service reliability and passenger comfort, create a safer travel environment for all users, minimize transportation-related noise, and improve corridor aesthetics.

2.3 GENERAL ASSUMPTIONS

2.3.1 *DISCOUNT RATES AND BASE YEAR*

Costs for the project were provided in year of expenditure (YoE) dollars by MDOT MTA. These costs were adjusted to constant 2017 dollars (2017$) using a historical average derived from the U.S. Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) dating back to 2001.[3] All other values, including estimates for project-generated benefits, are expressed in constant 2017$.

The real discount rates used for this analysis were 3.0 and 7.0 percent, consistent with historic U.S. DOT guidance and OMB Circular A-4.[4]

2.3.2 *EVALUATION PERIOD*

The evaluation period for the project is 34 years, comprising 4 years of construction from 2018 to 2021, and 30 years of operations following project completion in 2022. The analysis period was selected to correspond to the project's useful life, which is estimated to be 30 years.

2.4 BASE CASE AND BUILD CASE

The base case for this analysis assumes that none of the contemplated infrastructure improvements are completed, and that the project corridor remains in its current condition. Though light rail service is likely to continue to degrade in the absence of the project, the BCA does not assume any increases in delay length or frequency, or additional crashes, above and beyond the baseline level. This assumption likely yields a more conservative BCA. The build case assumes that the project will be completed in the sequence described in the application narrative, and that the project is completed in 2022.

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[3] U.S. Bureau of Labor Statistics. Consumer Price Index, All Urban Consumers, U.S. City Average, Series CUSR0000SA0. 1982-1984=100

[4] White House Office of Management and Budget, Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (October 29, 1992). (http://www.whitehouse.gov/omb/circulars_a094).

3 PROJECT COSTS AND BENEFITS

3.1 PROJECT COSTS

3.1.1 *CAPITAL COSTS*

Capital cost estimates were provided by MDOT MTA in YoE dollars; as discussed earlier, these costs were converted to constant 2017$ using a forecast derived from historical CPI-U values.

The capital cost for BBHS is expected to be $67.0 million in undiscounted 2017 dollars through 2022. At a 7 percent real discount rate, these costs are $54.1 million. Capital costs include soft costs (primarily consisting of design and preliminary engineering activities) and construction costs. A breakdown of expected capital costs is presented in Table 3-1.

Table 3-1. Capital Cost Breakdown by Project Element, Year of Expenditure Dollars

Project Element	Cost (YoE$)	Percent of Total
Rail Replacement	$20,600,000	29%
Realignment of Curves	$33,000,000	46%
Utilities Upgrades	$6,400,000	9%
Streetscaping	$4,250,000	6%
Station Wayfinding and Connectivity Improvements	$800,000	1%
Signals & Communications	$850,000	1%
Historic Property Upgrades and Public Art	$1,080,000	2%
Project Management, Design, and Outreach	$4,350,000	6%
Total	$71,330,000	100%

The project is expected to be financed by Federal, State, and local funds according to the allocation shown in Table 3-2.

Table 3-2. Project Costs by Funding Source, Year of Expenditure Dollars

Funding Source	Total Project Cost	Percent by Source
Federal (including BUILD)	$25.0 M	35.0%
MDOT Transportation Trust Fund	$31.0 M	43.5%
City of Baltimore	$6.0 M	8.4%
BDC and DPOB	$1.0 M	1.4%
FTA Section 5307	$8.3 M	11.6%
Total	**$71.3 M**	**100.0%**

Source: MDOT MTA

3.1.2 OPERATIONS AND MAINTENANCE COSTS

The project is expected to reduce the Light RailLink system's overall operations and maintenance (O&M) costs by ameliorating current substandard rail conditions, which cause rail breaks that occur approximately 3.78 times per year, according to 2018 MDOT MTA data. These rail breaks necessitate spending by the agency not only to remedy the rail condition, but also provide bus service that traverses the area of disruption. These costs, which are detailed in Table 3-3, total approximately $328,000 per incident, or $1.24 million per year.

Table 3-3. Rail Break Costs, per Incident

Element	Cost
Repair: Design Cost	$26,000
Repair: Construction Cost	$207,301
Bus Bridge Cost	$95,000
Total	**$328,301**

Source: MDOT MTA

As discussed in Section 2.3, the No Build scenario assumes that the rail infrastructure will remain in its current, degraded condition, though it is in fact likely that the condition will continue to deteriorate further in the future without the project. Consequently, for purposes of a conservative analysis, the BCA assumes that the project will result in annual O&M costs savings that average $1.24 million per year in the long term, following a cost savings of $930,000 in the first year following project completion.[5]

Table 3-4 outlines the anticipated construction schedule and total cost for the project.

Table 3-4: Project Schedule and Costs

Variable	Value
Construction Start	2018
Construction End	2022
Construction Duration	4
Project Opening	2022
Capital Cost (2017$)	$66,996,674
O&M Cost Savings, Annual (2017$)	$1,229,819

[5] Per USDOT guidance, operations and maintenance costs are grouped with costs, but included in the numerator along with project benefits when calculating the benefit-cost ratio.

3.2 PROJECT BENEFITS

The quantifiable economic benefits that will be effectuated by BBHS relate to the amelioration of the current, degraded condition of the embedded rail on Howard Street, as well as to the optimization of service conditions for both transit vehicles and private automobiles along the corridor. For the BCA, two primary categories of benefits have therefore been quantified and monetized: travel-time savings for light rail users and auto users along the project corridor, and safety benefits resulting from avoided pedestrian-involved crashes along Howard Street.

This section outlines these benefit categories and their quantified values. Section 4 provides details related to the methodology and assumptions used to monetize these economic benefits.

3.2.1 *TRAVEL TIME SAVINGS*

Travel-time benefits will be generated by the project in two ways. First, as discussed in Section 4.1 of the application narrative, the current deteriorated condition of the existing 1.3-mile embedded rail segment along the project corridor leaves this critical downtown section of the Light RailLink system susceptible to multi-day service suspensions when broken sections are identified and must be repaired, as well as persistent slow zone orders when routine track inspections reveal degraded segments. In fact, the Light RailLink service was suspended between North Avenue and Camden Yards over an 18-day period in summer 2017 while necessary rail replacement and track maintenance was performed.

Frequent speed restrictions—present during 24 percent of all weekday service and 27 percent of all weekend service over the last year alone—stemming from the poor rail condition generate delays for both weekday and weekend riders, giving weight to the notion that the Light RailLink is only a service for those who lack access to other alternatives. Complete replacement of embedded rail along the corridor will result in the removal of consistent slow orders, thereby increasing transit speeds through the project corridor and significantly increasing the interval between maintenance-related service outages and all-weekend closures of Howard Street. The reduction in transit travel time will increase customer satisfaction and potentially induce new transit trips that are currently completed via passenger vehicles.

Second, the rail realignment and associated traffic operations changes will optimize operating conditions along the corridor, resulting in better-synchronized transit and automobile traffic. These enhancements will generate travel-time savings for transit riders by increasing average running speeds for transit vehicles operating along the corridor. Transit-based signal preemption enabled by the new train detection system at Read Street, as well as preemption and corridor-wide signal synchronization via new wireless communications, will reduce northbound and southbound AM and PM peak transit travel times by a range of approximately 55 to 100 seconds between Mt. Royal and Camden Yards relative to existing un-delayed operations.

These traffic operations enhancements will also allow BBHS to produce substantial delay reductions for motorists. The installation of wireless communications at traffic signals along the project corridor, coupled with retiming the signals, will enable corridor-wide synchronization of both transit and vehicular flows along Howard Street. The rail realignment will result in the removal of southbound traffic between Fayette Street and Baltimore Street, as well as the signal phases associated with the eastbound left turn from Howard Street onto Baltimore Street. these changes are anticipated to reduce northbound automobile travel times during the AM and PM peak hours along the project corridor by almost 60 and 30 seconds, respectively. While southbound drivers are expected to experience a two second increase in PM peak hour travel times, southbound motorists traveling during the AM peak hour are anticipated to save approximately 15 seconds per trip.

Section 4 outlines the assumptions and methodology used to monetize economic benefits resulting from these travel time savings, which amount to $63.4 million in undiscounted economic benefits, or $18.0 million discounted at 7 percent.

3.2.2 *SAFETY BENEFITS*

BBHS is expected to have a substantial impact on pedestrian-involved crashes along Howard Street. According to data provided by MDOT MTA and shown in Table 3-5, from 2014 to 2016 an average of nine pedestrian-involved crashes occurred each year within the project corridor, defined as a 200-foot buffer surrounding intersections within the project corridor. Proposed streetscaping efforts along Howard Street, as well as the east-west facilities that serve to connect the Light RailLink and Metro SubwayLink stations, will include pedestrian crossing improvements to address this unmet pedestrian safety need, and eliminate the potential for similar crashes to occur in the future.

Table 3-5. Pedestrian-Involved Crashes, 2014 to 2016

Crash Type	Total Crashes	Annual Rate (Incidents/Year)
No injury	18	6
Non-incapacitating injury	4	1.33
Possible incapacitating injury	5	1.67
Incapacitating/Disabled injury	0	0
Fatal injury	0	0

Source: MDOT MTA

BBHS will also generate economic benefits by reducing the potential for collisions involving Light RailLink trains and passenger automobiles along Howard Street. From January 2015 to March 2018 a total of 102 collisions involving Light RailLink trains and passenger vehicles were reported along Howard Street within the project limits. Hotspots included the segment between Saratoga Street and Lexington Street where the Lexington Market platforms are located and the intersection of Howard Street at Baltimore Street near the Baltimore Arena platforms

Based on a detailed review of the incident locations, approximately one-half of reported collisions occurred along segments in which the BBHS rail realignment is proposed, as shown in Table 3-6. Crash reports provided by MDOT MTA and the City of Baltimore indicate that approximately 58 percent of those crashes within the realignment area, or 28 percent of all collisions within the project area, could have been avoided if the realignment was in place. By eliminating the three curves that introduce transit-vehicular conflicts at Saratoga, Lexington, and Baltimore Streets, the BBHS project will reduce the number, rate, and severity of train-vehicle crashes within the corridor.

Table 3-6. Light RailLink Train-Vehicle Crashes, January 2015 - March 2018

Location	Total Crashes	Avoidable with BBHS	% Avoidable
Project Corridor	**102**	**29**	**28%**
Rail Realignment Area	**50**	**29**	**58%**
Howard Street at Baltimore Street	21	12	57%
Howard Street at Fayette Street	10	0	0%
Lexington Market Station Area	18	17	94%
Howard Street at Saratoga Street	1	0	0%

Source: MDOT MTA

While it is expected that crashes of this type will be avoided with the project, the available data did not allow for an accurate forecast of the level of severity for crashes that will be avoided in the future. This safety-related benefit is therefore qualitative, and should be considered above and beyond safety benefits quantified in the BCA.

Additionally, changes in traffic operations stemming from the rail realignment will lead to reductions in the number, rate, and severity of traditional vehicle-vehicle crashes. Northbound left turns from Madison Street onto Howard Street, which are currently permitted, will be prohibited. The conversion of Howard Street between Baltimore and Fayette Streets from two-way to one-way northbound traffic will eliminate crashes involving southbound vehicles performing left turns from Howard Street onto Baltimore Street. This benefit is also qualitative, and was not quantified for the BCA.

Section 3 outlines the assumptions and methodology used to monetize economic benefits resulting from these safety benefits, which amount to $9.56 million in undiscounted economic benefits, or $3.02 million discounted at 7 percent.

3.2.3 *RESIDUAL VALUE*

The projected useful life for the rail infrastructure that would be constructed by BBHS is 30 years, which corresponds to the analysis period for the project. As a result, no residual value has been calculated as a project benefit.

3.2.4 *OTHER BENEFITS NOT QUANTIFIED*

In addition to these quantified benefits, the project will also result in qualitative economic benefits. As discussed in the application narrative, BBHS will introduce infrastructure improvements to Howard Street that would support economic development efforts along the corridor. These improvements would allow private developers to capitalize on the significant market demand for new market-rate residential units, and help unlock the development potential of underutilized parcels along the corridor. Below-ground infrastructure improvements will help set the stage for increased investment in this vital corridor, leading to overall gains in productivity, tax revenues, and economic vitality.

Other qualitative benefits that are expected to result from the project include reduced noise pollution at rail/auto conflict points along the project corridor; and improved streetscape and public realm conditions along Howard Street, generating enhanced livability and promoting the overall attractiveness of Baltimore's CBD.

Table 3-7: Project Benefits by Long-Term Outcome Category

Long-Term Outcome	Benefit (Disbenefit) Category	Description	Monetized	Quantified	Qualitative
State of Good Repair	Reduced O&M costs arising from frequent rail breaks Travel-time savings from avoided service disruptions and speed restrictions	Ameliorate current, degraded condition of embedded rail along the project corridor, and deploy new technology (including grouting) to extend the project's useful life	√	√	√
Safety	Reduce number, rate, and severity car/transit vehicle collisions and associated injuries and property damage Allow MDOT MTA to provide enhanced service, potentially mode shifting away trips from private autos	Realign embedded rail along Howard Street to reduce interaction points between autos and transit vehicles Optimize operations along the project corridor, reducing potential for collisions between vehicles	√	√	√
Economic Competitiveness	Travel time savings	Replacement of the embedded rail will eliminate service disruptions and speed restrictions that cause travel-time delays for rail transit passengers	√	√	

Long-Term Outcome	Benefit (Disbenefit) Category	Description	Monetized	Quantified	Qualitative
		Optimized operations along the project corridor will reduce travel times for autos transiting the project corridor			
	Enhanced development potential, increase in property values, and avoidance of significant interruptions to businesses	Concurrent upgrading of water main connections, as well as power and telecommunications conduits, will allow developers to meet fire code requirements for building-wide sprinkler systems and effectively market their properties for high-density development without incurring significant costs without imposing additional non-transportation disruptions to corridor businesses. Streetscaping improvements, historic property upgrades, and public art installations will gradually increase property values along the corridor by creating a unified, marketable aesthetic.			√
Environmental Protection	Reduced noise pollution	Improved or eliminated auto/transit vehicle			√

Long-Term Outcome	Benefit (Disbenefit) Category	Description	Monetized	Quantified	Qualitative
		conflict points will reduce noise pollution produced by light rail operations			
Quality of Life	Enhanced public realm	Public art and other vitality-promoting interventions will enhance the overall attractiveness of the project corridor			√
	ADA Access	ADA-compliant curb ramps, audible pedestrian signals, countdown timers, pushbuttons, and tactile transition surfaces will be installed along the project corridor			√

4 MONETIZED BENEFITS: DATA AND ASSUMPTIONS

4.1 GENERAL INPUTS AND ASSUMPTIONS

In order to convert the quantified inputs discussed in Section 3 and described further in this section, certain key analytical inputs were provided by MDOT MTA based on recent system-wide data and trends.

First, ridership over the analysis period was calculated using the most-recent system boardings and alightings estimates, which include the months from June 2017 to May 2018. Future ridership estimates were forecasted using a 1.0 percent annual growth rate assumption beginning in the year of project opening, 2022; that is, ridership was assumed to remain constant until the opening year. This estimate is likely conservative, given that the enhanced service conditions that BBHS will effectuate are likely to induce ridership gains that exceed 1.0 percent per year.

Average weekday ridership forecasts were annualized using a factor of 310, consistent with MDOT MTA best practices.

4.2 TRAVEL TIME SAVINGS

As discussed in Section 3.2.1, BBHS is expected to generate economic benefits related to travel-time savings in two ways: first, by ameliorating the current deteriorated condition of the embedded rail along the project corridor; and second, by optimizing operating conditions along the corridor, resulting in better-synchronized transit and automobile traffic. These travel-time savings will therefore consist of benefits generated by reduced service disruption, as well as by overall improvements in operating conditions and quality.

4.2.1 *VALUE OF TRAVEL TIME*

As described in the following sections, quantified travel-time savings are calculated and expressed in person-hours traveled (PHT) . These values are converted to monetary units for each year of the analysis period, which includes operating years between 2022 and 2051, using the value of time standards indicated in the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, which are a function of the average national wage rate. The values of time used for the BCA are shown in Table 4-1.

Table 4-1. Value of Time

Variable	Unit	Value	Source
Light Rail Users: Value of Time	2017$	$14.94	U.S. DOT
Auto Users: Value of Time	2017$	$14.94	U.S. DOT
Real Wage Growth Rate	Annual Growth	1.2%	U.S. DOT, 2014

4.2.2 *TRAVEL TIME SAVINGS: REDUCED SERVICE DISRUPTIONS*

Data for service disruptions resulting from deteriorated rail conditions that occurred between May 2017 and April 2018 were provided by MDOT MTA. Because BBHS will remedy the conditions that cause these slow orders, the BCA assumes that the project will generate travel-time savings at a rate equal to that observed in the most-recent available data. Because it is likely that the rail condition will continue to deteriorate, thereby causing additional slow-order-related delays, this assumption is conservative, and likely understates the magnitude of economic benefits that will be generated by the project.

As shown in Table 4-2, the frequency of disruptions and magnitude of travel-time savings those disruptions cause are substantial.

Table 4-2. Projected Travel-Time Savings from Avoided Slow Orders

Segment	Average Weekday Ridership, Northbound	Average Weekday Ridership, Southbound	Travel Time Savings (Seconds), Northbound	Travel Time Savings (Seconds), Southbound	Frequency (Days/Year)	Savings (PHT/Year)
From Mount Royal to Cultural Center	6,464	5,112	122.7	122.7	70	27,625
Between Centre Street & Lexington Market	6,820	4,280	20.5	0.0	5	194
Convention Center	11,303	9,246	0.0	43.6	12	1,345
Between Convention Center & Camden Yards	5,998	4,051	0.0	109.1	4	491
Total						**29,654**

Source: MDOT MTA

In the first year of the project's operations, travel-time savings resulting from avoided slow orders will amount to 29,654 PHT over the analysis period, these savings will accumulate to 1,031,519 PHT.

4.2.3 *TRAVEL-TIME SAVINGS FROM ENHANCED OPERATIONS: RAIL USERS*

Rail replacement and realignment will increase running speeds for transit vehicles, thereby generating travel-time savings for light-rail users. In order to determine the magnitude of these travel-time savings, the microsimulation model VISSIM was used to simulate future traffic conditions following completion of the project. As described earlier and in the application narrative, BBHS improvements are expected to reduce northbound and southbound AM and PM peak transit travel times by a range of approximately 55 to 100 seconds between Mt. Royal and Camden Yards relative to existing, undelayed operations. As shown in Table 4-3, the aggregate value of these travel-time savings is substantial.

Table 4-3. Projected Travel-Time Savings for Light Rail Users

Segment	Length (miles)	Average Weekday Ridership, Northbound	Average Weekday Ridership, Southbound	Travel Time Savings (Seconds), Northbound	Travel Time Savings (Seconds), Southbound	Savings (PHT/Year)
Cultural Center to Centre St	0.47	6,379	4,625	24.0	14.0	18,759
Centre St to Lexington Market	0.44	6,820	4,280	15.0	11.0	12,863
Lexington Market to University Center/Arena	0.09	5,548	4,955	10.0	35.0	19,713
University Center/Arena to Convention Center	0.21	5,755	4,290	11.0	10.0	9,146
Total	**1.21**	**24,502**	**18,150**	**60.0**	**70.0**	**60,480**

Source: MDOT MTA

In the first year of the project's operations, travel-time savings for light rail users resulting from enhanced traffic operations along the project corridor will amount to 60,480 PHT; over the analysis period, these savings will accumulate to 2,103,805 PHT.

4.2.4 *TRAVEL-TIME SAVINGS FROM ENHANCED OPERATIONS: AUTO USERS*

Optimized traffic operations along the project corridor will also reduce travel times for auto users transiting Howard Street. The installation of wireless communications at traffic signals along the project corridor, coupled with retiming the signals, will enable corridor-wide synchronization of both transit and vehicular flows along Howard Street. According to VISSIM modeling performed by MDOT MTA, this optimization will reduce northbound automobile travel times during the AM and PM peak hours along the project corridor by almost 60 and 30 seconds, respectively; while southbound drivers are expected to experience a two second increase in PM peak hour travel times, southbound motorists traveling during the AM peak hour are anticipated to save approximately 15 seconds.

As shown in Table 4-4, the aggregate value of these time savings for auto users is substantial. Because forecasts for auto traffic along the project corridor were not available, no annual growth in the number of users was assumed.

Table 4-4. Projected Travel-Time Savings for Auto Users

Segment	Peak Hour	Savings (PHT/Year)
Conway St at Howard St to John St/Dolphin St at Howard St, including Eutaw Street, Park Ave, & Liberty St.	A.M.	4,311
	P.M.	3,041
	Total	7,352

In the first year of the project's operations, travel-time savings for auto users resulting from enhanced traffic operations along the project corridor will amount to 7,352 PHT; over the analysis period, these savings will accumulate to 220,571 PHT.

4.2.5 *TRAVEL-TIME SAVINGS: MONETIZED RESULTS*

As shown in Table 4-5, the three categories of travel-time savings discussed previously generate substantial monetized economic benefits over the analysis period. In undiscounted 2017$, benefits related to travel-time savings accumulate to $63.4 million, or $18.0 million at a 7 percent discount rate.

Table 4-5. Monetized Travel Time Savings

Travel Time Category	PHT Saved, Opening Year (2022)	PHT Saved, Analysis Period (2022-2051)	Total, Undiscounted	Total, Discounted (7%)
Avoided Slow Orders	29,654	1,031,519	$19,494,148	$5,530,117
Enhanced Operations: Light Rail Users	60,480	2,103,805	$39,758,714	$11,278,786
Enhanced Operations: Auto Users	7,352	220,571	$4,131,793	$1,230,948
Total	97,487	3,355,895	$63,384,656	$18,039,851

4.3 SAFETY BENEFITS

As discussed in Section 3.2.2, BBHS will generate quantifiable, monetizable economic benefits by avoiding pedestrian-involved collisions in the project corridor, defined as a 200-foot buffer surrounding intersections in the project corridor. Project-generated streetscaping efforts along Howard Street, as well as the east-west facilities that serve to connect the Light RailLink and Metro SubwayLink stations, will include pedestrian crossing improvements to address an unmet pedestrian safety need, which has resulted in a substantial number of crashes in recent years.

Because this safety need will be met by the project, the BCA assumes that future crashes will be avoided at rates equal to that observed in recent years. To calculate these rates for a variety of crash severity types, information on recent collisions from MDOT MTA was converted using the KABCO severity-level index contained in that dataset. Table 4-6 indicates the assumed rate of crashes that will be avoided in the future with BBHS.

Table 4-6. Forecasted Crash Reduction Rate

Crash Type (KABCO Scale)	Annual Rate (Incidents/Year)
No Injury (O)	6
Possible Injury (C)	1.33
Non-Incapacitating (B)	1.67

Source: MDOT MTA

These avoided crashes were converted to monetized units using the values provided by U.S. DOT in the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, which are shown in Table 4-7.

Table 4-7. KABCO to Monetized Units Conversion

KABCO Level	Monetized Value
No Injury (O)	$3,200
Possible Injury (C)	$63,900
Non-Incapacitating (B)	$125,000

Source: U.S. DOT

As shown in Table 4-8, economic benefits generated by avoided crashes generate substantial monetized economic benefits over the analysis period. In undiscounted 2017$, benefits related to safety accumulate to $9.56 million in undiscounted 2017 dollars, or $3.02 million discounted at 7 percent.

Table 4-8. Monetized Crash Benefits

Crash Type	Number Avoided, Opening Year (2022)	Number Avoided, Analysis Period (2022-2051)	Total, Undiscounted	Total, Discounted (7%)
No Injury (O)	6	180		
Possible Injury (C)	1.33	50		
Non-Incapacitating (B)	1.67	40		
Total	9	270	$9,562,245	$3,017,461

5 SUMMARY OF RESULTS

5.1 EVALUATION MEASURES

The benefit-cost analysis converts potential gains (benefits) and losses (costs) from the project into monetary units and compares them. The following common benefit-cost evaluation measures are included in this BCA:

— **Net Present Value (NPV)**: NPV compares the net benefits (benefits minus costs) after being discounted to present values using the real discount rate assumption. The NPV provides a perspective on the overall dollar magnitude of cash flows over time in today's dollar terms.

— **Benefit Cost Ratio (BCR):** The evaluation also estimates the benefit-cost ratio; the present value of incremental benefits is divided by the present value of incremental costs to yield the benefit-cost ratio. The BCR expresses the relation of discounted benefits to discounted costs as a measure of the extent to which a project's benefits either exceed or fall short of the costs.

5.2 BCA RESULTS

Table 5-1 presents the evaluation results for the project. Results are presented in undiscounted, discounted at 7 percent and discounted at 3 percent (sensitivity) as prescribed by U.S. DOT. All benefits and costs were estimated in constant 2017 dollars over an evaluation period extending 30 years beyond project completion in 2022.

At a discount rate of 7 percent, the project yields a BCR of 0.60 and an NPV of -$21.5 million; at 3 percent, the project yields a BCR of 1.02 and an NPV of $1.03 million.

Table 5-1: Benefit Cost Analysis Results, 2017 Dollars

BCA Metric	Project Lifecycle		
	Undiscounted	Discounted (7%)	Discounted (3%)
Total Benefits	$72,946,901	$21,057,312	$40,665,237
Total Costs	$30,102,097	$42,556,987	$39,633,162
Net Present Value (NPV)	$42,844,804	-$21,499,675	$1,032,075
Benefit Cost Ratio (BCR)	1.64	0.60	1.02

Source: WSP

The benefits over the project lifecycle are presented in Table 5-2 by U.S. DOT long-term outcome category.

Table 5-2: Benefits by Long-Term Outcome, Millions of 2017 Dollars

Long-Term Outcome	Project Lifecycle		
	Undiscounted	Discounted (7%)	Discounted (3%)
Economic Competitiveness	$63,384,656	$18,039,850	$35,114,436
Safety	$9,562,245	$3,017,461	$5,550,799

Source: WSP

5.3 SENSITIVITY TESTING

A sensitivity analysis is used to help identify which variables have the greatest impact on the BCA results. This analysis can be used to estimate how changes to key variables from their preferred value affect the final results and how sensitive the final results are to these changes. This allows for the assessment of the strength of the BCA, including whether the results reached using the preferred set of input variables are significantly different by reasonable departures from those values. Table 5-3 summarizes the key variable that has been tested for sensitivity and the results of this analysis.

Table 5-3: Benefit Cost Analysis Sensitivity Analysis, Seven Percent Discount Rate

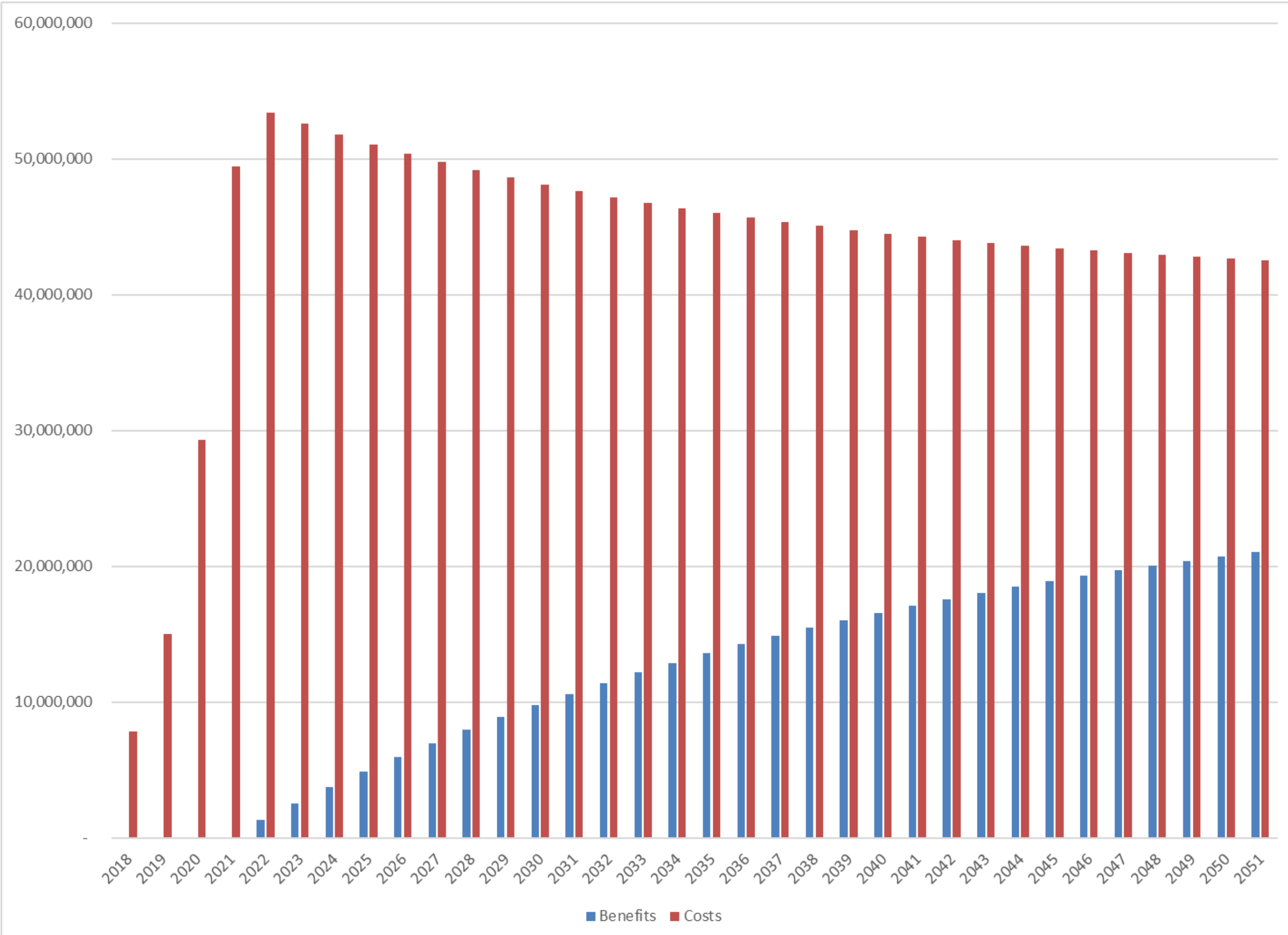
Sensitivity Variable	Sensitivity Value	New BCR	New NPV
Ridership Growth	Low Value (0%, *p.a.*)	0.57	-$23,218,085
	High Value (2%, *p.a.*)	0.64	-$19,480,442

Source: WSP

APPENDIX

A

CUMULATIVE BENEFITS AND COSTS, SEVEN PERCENT DISCOUNT RATE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