Benefit-Cost Analysis Technical Memorandum

Track Improvement Mobility Enhancement-1 (TIME-1): Track Speed Improvement Program Between Bridgeport and Stratford

2022 MEGA Grant Application

Prepared for the Connecticut Department of Transportation (CTDOT) by STV Incorporated

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Executive Summary

This technical memorandum describes the results of a benefit-cost analysis (BCA) that was conducted for the Track Improvement Mobility Enhancement-1 (TIME-1) Project on behalf of the Connecticut Department of Transportation for the USDOT's 2022 MEGA grant program. This analysis was conducted in accordance with the 2022 Benefit-Cost Analysis Guidance for Discretionary Grant Programs[1] and includes estimated benefits and costs based on the best available data at this stage of the planning process. Estimated capital outlays are expected to begin in 2026 and the update infrastructure will begin to be used in 2030. All values are in 2020 dollars discounted at 7 percent and cover a 30-year analysis period.

Table 1 presents the Impact Matrix, which describes the baseline, the Project as a whole, the affected population and the estimated results.

[1] https://www.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

Table 1 - Impact Matrix

Current Status/ Baseline & Problem to Be Addressed	Change to Baseline or Alternatives	Types of Benefits	Affected Population	Economic Benefit (2020$ M, Discounted to 7%)
Capacity and speed are constrained by legacy infrastructure and current operating requirements. As a FRA Class 4 track, the Maximum Authorized Speed (MAS) along the TIME-1 corridor is 70 mph, but in reality rail service along the corridor operates closer to 56 mph. Speed is impacted by the geometry, the state of the infrastructure and the low vertical clearance of bridges, which pose a safety hazard.	TIME-1 replaces seven railroad bridges and improve track geometry by reconstructing the track with wider centers, align catenary over re-centered tracks, and resolve mud spot conditions. These improvements will increase the MAS to 90 mph and result in travel time savings for commuter rail passengers, Amtrak passengers and freight.	**Safety Benefits**		
		Reduced Roadway Fatalities and Crashes from Trip Mode Switch	Roadway users	$10.4
		Less Large Vehicle Collisions with Low Vertical Clearance Bridges	Roadway users	Qualitative
		Catenary Accidents Cost Avoided	Rail riders, Amtrak, commuter rail, freight rail	$0.1
		State of Good Repair		
		Residual Value	Tax payers	$4.1
		Pavement Cost Avoided from Trip Mode Switch	Tax payers	$0.04
		Accelerated Construction	Tax payers	Qualitative
		Economic Impacts, Freight Movement, and Job Creation		
		Travel Time Savings from Existing Riders	Rail riders	$29.5
		Induced Riders (trip not taken)	CT community	$56.3
		Inventory Cost Savings for Rail Freight	Freight rail, CT community	$0.00
		Vehicle Operating Cost Avoided from Trip Mode Switch	Rail riders	$12.5
		Freight Train Operating Cost Savings	Freight rail	$0.7
		O&M Cost Avoided	Tax payers	$35.8
		Congestion Reduction from Trip Mode Switch	Roadway users	$3.4
		Region Competitiveness	CT community	Qualitative
		Better Region Connectivity	CT community	Qualitative
		Climate Change, Resiliency, and the Environment		
		Vehicles Emissions Avoided* from Trip Mode Switch	CT community	$3.5
		Noise Avoided from Trip Mode Switch	CT community	$0.05

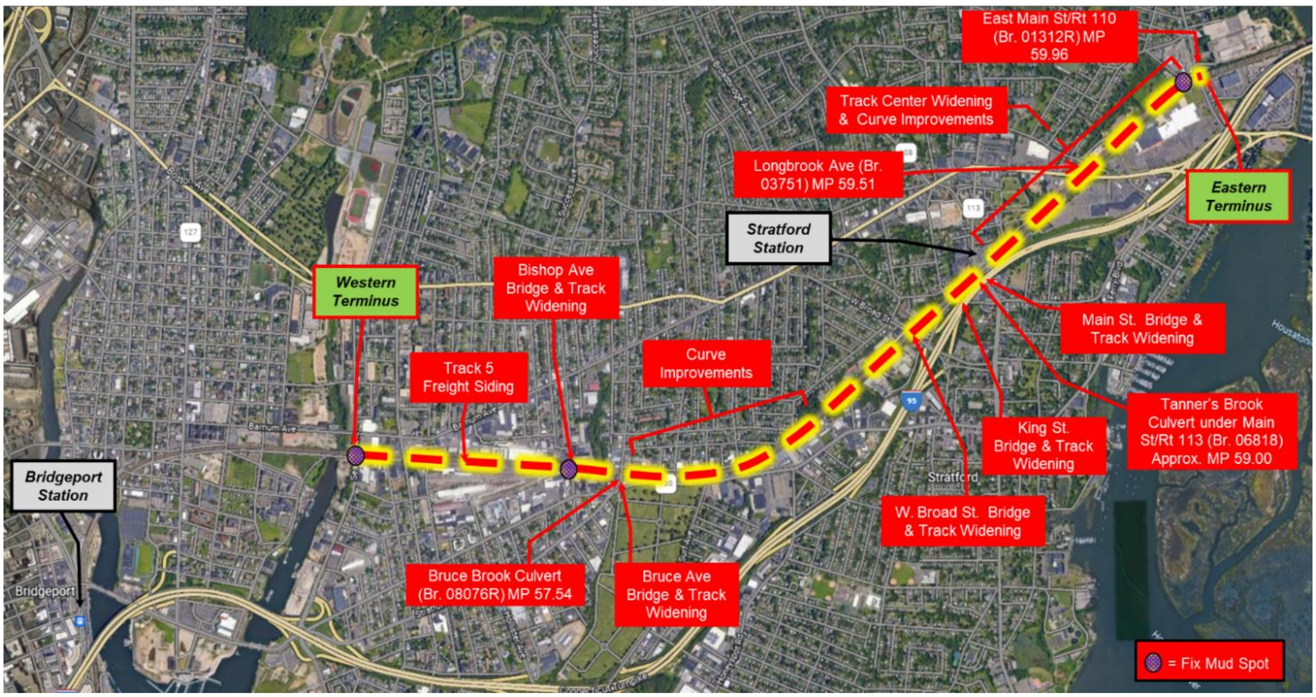
Current Status/ Baseline & Problem to Be Addressed	Change to Baseline or Alternatives	Types of Benefits	Affected Population	Economic Benefit (2020$ M, Discounted to 7%)
		Train Idling Emissions Avoided	CT community	$0.9
		Equity, Multimodal Options, and Quality of Life		
		Health Benefits from Trip Mode Switch	Rail riders	$50.6
		Emergency Response Savings	CT community	$80.0
		Amenities from Trip Mode Switch	Rail riders	$4.4
		Trip Reliability for Existing Riders	Rail riders	$4.6
		Trip Reliability from Trip Mode Switch	Rail riders	$19.3
		Trip Reliability for Trucks on the Road	Roadway users	Qualitative
		Trip Reliability for Rail Freight	Freight rail, CT community	Qualitative

*CO2 is discounted at 3%.

Introduction

Track Improvement Mobility Enhancement for Connecticut[2] (also known as TIME FOR CT) is an actionable plan for safer, faster, and more reliable train service across Connecticut. The initial phase of TIME FOR CT is TIME-1 (the "project"), which is a critical component of the entire program's vision and focuses on reducing backlog bridge replacements and achieving track speed improvement along the approximately 3.3 mile corridor between Bridgeport and Stratford, CT along the New Haven Line (NHL). The NHL is critical to the economic well-being of the region and provides a major link to the core of the New York metropolitan area and the global market. The region's economy relies on this connection and linkage. The TIME-1 phase between Bridgeport and Stratford is shown in Figure 1 below.

Figure 1 - Project Location



The NHL is consistently one of the busiest commuter rail lines in the United States, and the entire system is operating at or near capacity. Ridership throughout the system is expected to increase as both jobs and population are projected to grow. Capacity and speed are constrained by legacy infrastructure and current operating requirements. The project will extend capacity with a new track and increase speed along the project area.

CTDOT must reduce the backlog bridge replacements and achieve track speed improvement between Bridgeport and Stratford, CT to provide safer, faster, and more reliable train service for Metro-North, Amtrak, CSX, and the Providence and Worcester (P&W) Railroad Company. The goals of the project which were used to calculate project costs and benefits include:

- Increase the current Maximum Authorized Speed from 70 mph to 90 mph by upgrading from Class 4 to Class 6 track.

[2] https://portal.ct.gov/DOT/Projects/TIMEFORCT

- Replace six deficient railroad bridges with ballasted decks and two culverts, and address one vertical clearance bridge.
- Re-construct track with wider centers, align catenary over re-centered tracks, and resolve mud spot conditions.
- Improve track geometry allowing increased speeds through the project limits.
- Construct a new track dedicated for freight, increasing the efficiency of freight operations independent of passenger rail.

The project construction schedule is represented in Figure 2.

Figure 2 – Construction Schedule

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Professional Services									
Design									
NEPA									
Right of Way									
Construction									
Opening									

Benefit Analysis Framework

This benefit analysis was conducted using the Benefit-Cost Analysis Guidance for Discretionary Grant Programs document published by the USDOT in February 2022. Where available in the Guidance, rates and monetization factors were used verbatim from the Guidance; however, some benefit methodologies are described in the Guidance with flexibility on how the benefit may be calculated. Additionally, some project-specific values have been substituted in lieu of national averages outlined in the Guidance. For modifications to the methodologies outlined in the BCA Guidance, a source and assumption has been provided in this analysis. As this is a conservative estimate of the benefits on the project, the actual total benefits may be greater than depicted in the results while the project continues to be developed.

In this analysis, the baseline condition assumes that the Project would not be built, and current conditions and operations would continue in the project area, noted throughout the BCA as the no-build scenario. Under the no-build, the purpose of and need for the Project would not be achieved; the existing infrastructure would have to be operated and maintained as it is currently. The condition in which the project is built is referred to the build scenario. This was compared to the baseline to identify benefits and costs of building the project versus not building the project.

The analysis used existing ridership data, freight data, safety incident data, and cost data to calculate the conditions in the no-build scenario and comparing it to the build scenario between the anticipated opening year of 2030 and the future year of 2059, providing a 30-year period of analysis. Per the BCA Guidance, costs are represented at constant 2020 dollars, which avoids forecasting future inflation and escalation. The use of constant dollar values requires that a real discount rate be used discounting to the present value. Per the BCA guidance, a 7 percent discount rate is applied to all values.

Analysis Assumptions

A list of assumptions for the Project is provided in the BCA workbook (see Inputs tab in the file BCA CTDOT TIME 1.xlsx) as well as in Table 2.

Table 2 - BCA Workbook Assumptions

Input	Value	Source
General		
Discount Rate	7%	BCA Guidance for Discretionary Grant Programs - March, 2022
Discount Rate	3%	Sensitivity
Deflator	See "Deflator" Sheet	Table 10.1: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/
Discount Year	2020	BCA Guidance for Discretionary Grant Programs - March, 2022
Dollar Year	2020	BCA Guidance for Discretionary Grant Programs - March, 2022
Analysis Period (years)	30	BCA Guidance for Discretionary Grant Programs - March, 2022
Construction Start	2026	
Analysis Period Begin - Benefits Realized	2030	Assumed January 1st
Analysis Period End	2059	Assumed December 31st
Conversion rate for Metric tons to Short Tons	1.1015	BCA Guidance for Discretionary Grant Programs - March, 2022
Conversion rate for grams per metric ton	1,000,000	https://www.metric-conversions.org/weight/grams-to-metric-tons.htm
Conversion rate for kg per metric ton	1,000	https://www.metric-conversions.org/weight/kilograms-to-metric-tons.htm
Round Trip	2	Trips
Model		
Annualization (Passengers)	312	=52 weeks * 6 days
Annualization (Freight)	365	=52 weeks * 7 days
Passenger Train Corridor Speed, No-Build (MPH)	57.5	See Speed Analysis
Passenger Train Corridor Speed, Build (MPH)	90	CTDOT target
% of TTS NHL on the NEC Passengers Affected by the Project	22%	
Freight Train Corridor Speed, No-Build (MPH)	15	See Speed Analysis
Freight Train Corridor Speed, Build (MPH)	25	CTDOT target

Project Length (Miles)	3.33	M.P. 56.77 to M.P. 60.10
Minutes per Hour	60	
Annual Ridership Growth	1%	Conservative assumption
Annual Freight Growth	1%	Conservative assumption
Mode Switch	2%	Conservative assumption
New riders	2%	Conservative assumption
Period new trip will last to generate econ benefits to the region	4	Hours
Assumed Buffer Time Savings	0.50	Conservative assumption
Economic Competitiveness		
Value of Time - Personal (2020$)	$ 16.20	BCA Guidance for Discretionary Grant Programs - March, 2022
Value of Time - Business (2020$)	$ 29.40	
Value of Time - All Purposes (2020$)	$ 17.80	
Occupancy Rates - passenger vehicles (all travel)	1.67	
VOC light duty vehicle	$ 0.45	
Value per Induced Trip -- Walking (2020$)	$ 7.08	
Marginal Pavement Costs per VMT ($/mile) - Light Duty/Urban (2000$)	$0.00100	FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13, https://www.fhwa.dot.gov/policy/hcas/addendum.cfm (assumes all of the trips are on urban highways)
Marginal Pavement Costs per VMT ($/mile) - Light Duty/Urban (2020$)	$0.00146	Converted using GDP deflator
Marginal Congestion Costs per VMT ($/mile) - Light Duty/Urban (2020$)	$0.124	BCA Guidance for Discretionary Grant Programs - March, 2022
Marginal Noise Costs per VMT ($/mile) - Light Duty/Urban (2020$)	$0.0017	
Safety Improvements		
Property Damage Only (PDO) Crashes (per vehicle)	$4,600	BCA Guidance for Discretionary Grant Programs - March, 2022
Injury Crash	$302,600	
Fatal Crash	$12,837,400	
Environmental Sustainability		
CO2 per passenger mile - Auto (pounds)	0.96	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/PublicTransportationsRoleInRespondingToClimateChange2010.pdf
Pound to grams	453.59	https://www.rapidtables.com/convert/weight/pound-to-gram.html

Gram to Metric Tons	0.000001	https://www.inchcalculator.com/convert/gram-to-metric-ton/
PM2.5 per mile - Auto (grams)	0.0041	https://nepis.epa.gov/Exe/ZyNET.exe/P100EVXP.txt?ZyActionD=ZyDocument&Client=EPA&Index=2006%20Thru%202010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C06THRU10%5CTXT%5C00000033%5CP100EVXP.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=4
VOC per mile - Auto (grams)	1.03	
Nox per mile - Auto (grams)	0.69	
Cost of VOC per Ton	$ 30,000	https://www.epa.gov/sites/default/files/2015-07/documents/mar07_cost_estimation.pdf

Benefits Methods

The methods used to estimate the benefits of the Project are described in the following sections. The benefits are categorized based on the MEGA grant application criteria:

- Safety Benefits
- State of Good Repair
- Economic Impacts, Freight Movement, and Job Creation
- Climate Change, Resiliency, and the Environment
- Equity, Multimodal Options, and Quality of Life
- Innovation Areas: Technology, Project Delivery, and Financing

Safety Benefits

Reduced Roadway Fatalities and Crashes from Trip Mode Switch

The reduction in vehicle miles traveled (VMT) from commuters switching from automobiles to commuter rail will result in less roadway fatalities and crashes, as there will be less drivers on the road. To quantify this benefit, first the reduction in fatalities, injuries, and crashes was calculated by multiplying the annual VMT by the Bureau of Transportation Statistics Motor Vehicle Safety Data rate per 100 million vehicle miles traveled factor for each type of accident. These reductions were then multiplied by the KABCO crash severity level probability distribution, providing a distribution of the reduction in accidents across the likelihood each level of severity would occur. Finally, the accident costs avoided are calculated by multiplying these severity distributions against the value of accident avoided, quantified as a fraction of the value of a statistical life (VSL) which is equal to $12.84million per the BCA Guidance. These values were then discounted at 7 percent.

Table 3 - Motor Vehicle Safety Data

Auto Accidents by Type	Rate	
Fatalities	1.34	per 100,000,000 VMT
Injured persons	79.0	per 100,000,000 VMT
Crashes	181	per 100,000,000 VMT

Source: 2020 BTS Motor Vehicle Safety Data Table 2-17; https://www.bts.gov/content/motor-vehicle-safety-data

Table 4 - KABCO Values for Accident Severity

	Injured - Severity Unknown	O - No injury
AIS 0	0.21538	0.92534
AIS 1	0.62728	0.07257
AIS 2	0.104	0.00198
AIS 3	0.03858	0.00008
AIS 4	0.00442	0
AIS 5	0.01034	0.00003

Note: KABCO/Unknown AIS Data Conversion Matrix, NHTSA July 2011 (updated May 2013) https://safety.fhwa.dot.gov/hsip/spm/fhwasa15067/chap6.cfm

Table 5 – Value of Accident Avoided

Value of Accidents Avoided	Fraction of VSL	2020$ Millions
Value of Statistical Life (VSL)	1.000	$ 12.837
MAIS 5 Critical (0.593) Fraction of VSL	0.593	$ 7.613
MAIS 4 Severe (0.266) Fraction of VSL	0.266	$ 3.415
MAIS 3 Serious (0.105) Fraction of VSL	0.105	$ 1.348
MAIS 2 Moderate (0.047) Fraction of VSL	0.047	$ 0.603
MAIS 1 Minor (0.003) Fraction of VSL	0.003	$ 0.039
PDO		$ 0.005
Source: BCA Guidance for Discretionary Grant Programs - 2022		

The present value of reduced roadway fatalities and crashes from trip mode switch is estimated at $10.35 million at 7 percent discount rate over the 30-year analysis period.

Catenary Accidents Cost Avoided

The current state of repair of the corridor has resulted in collisions between trains and overhead wires or catenary equipment. Over the past ten years, there have been four instances within the study area of these types of accidents occurring with an average of $45,392 cost associated with the incident. The proposed project will adjust the vertical clearances of trains operating on the corridor, avoiding these types of incidents, providing a benefit for catenary accidents cost avoided.

To calculate this benefit, the average cost of the incident was multiplied by the probability that an accident is related to catenary devices, which is 36.4 percent. This value is an annual incident avoided dollar amount, equal to $16,702 per year. These values were then discounted at 7 percent.

The present value of **catenary accident costs avoided is estimated at $112,807** at 7 percent discount rate over the 30-year analysis period.

Less Large Vehicle Collisions with Low Vertical Clearance Bridges

The rail over road bridges along the corridor have a minimum vertical clearance lower than most standard freight trucks. The low vertical clearance at these bridges has resulted in numerous bridge strikes by over height trucks. The bridge replacements in the project will increase the vertical clearances under the bridges thereby reducing or eliminating strikes and improving safety. The two bridges located along state highways (Main Street and East Main Street) will be increased to 13’9” (posted as 13’6”) and the other five bridges located along local roads will be rebuilt at the current height or higher vertical clearance based on coordination with the local municipalities. Current bridge heights along the corridor are shown in Table 6.

Table 6 - Rail over Road Bridge Clearances

State Bridge Number	Mile Post	Town and State	Road Intersection	State/ Local Road	Clearance
08075R	57.46	Bridgeport, CT	Bishop Avenue	Local	10’5”
08077R	57.62	Stratford, CT	Bruce Avenue	Local	9’9”
08078R	58.72	Stratford, CT	West Broad Street	Local	10’9”

State Bridge Number	Mile Post	Town and State	Road Intersection	State/ Local Road	Clearance
08079R	58.88	Stratford, CT	King Street	Local	10’2”
01318R	59.01	Stratford, CT	Main Street	State Hwy.	13’
03751	59.51	Stratford, CT	Longbrook Avenue	Local	N/A (Overpass)
01312R	59.96	Stratford, CT	East Main Street	State Hwy.	11'1"

This **qualitative benefit will result in increased safety** due to increased vertical clearances, allowing for less frequent collisions by over height vehicles.

State of Good Repair

Residual Value

The residual value of a capital investment is the useful service life of that asset which is remaining after the period of analysis has concluded. The period of analysis for this study is 30 years and the capital investments which would have residual value – new track, catenary improvements, and signal improvements – all have a useful service life of 60 years, per the Bureau of Economic Analysis. CTDOT plans for 75 year service life bridges. The remaining value of the track, bridges, catenaries, and signals was summed and discounted from the last year of the 30-year analysis period, 2059.

The residual value of the remaining useful life for these project elements is estimated at $4.1 million at 7 percent discount.

Pavement Cost Avoided from Trip Mode Switch

The reduction in vehicle miles traveled due to switching from automobiles to commuter rail results in less vehicles using the roadways. This will equate to less maintenance costs of roadway pavement, which is quantified by the Federal Highway Administration (FHWA) as $0.00146 per vehicle mile traveled for light duty/urban use. This rate was applied to the annual vehicle miles traveled for each year, and summed and discounted for the 30-year period of analysis.

The pavement cost avoided from mode switch for the project is estimated at $40,643 discounted at 7 percent.

Accelerated Construction

The high density of rail traffic currently operating on the NHL Mainline makes it difficult to take on large scale capital improvements within the project area without impacting service. For the TIME-1 project, reconstructing seven bridges using accelerated construction techniques, under continuous two track outages, will allow the bridges to be replaced one half at a time per stage. In concert with the planned track improvements, the bridges will accommodate increased track spacing.

This innovative technique is beneficial as it reduces project costs from railroad support and overall project administration, causes fewer costly disruptions during construction, reduces the number of utility outages associated with bridge construction, reduces the risk bridge crews must endure while onsite, and allows the railroad operation to resume to normal with a shorter project duration. Figure 3 shows an example of an accelerated bridge construction project.

Figure 3 - Accelerated Bridge Construction Technology

This innovative construction method is a **qualitative benefit which will result in less railroad operation delays during construction** as compared to conventional methodologies.

Economic Impacts, Freight Movement, and Job Creation

Travel Time Savings from Existing Riders

Annual travel time savings estimations for existing riders were derived from growing the 2019 annual boarding data under the no-build condition to 2030 for both the Metro-North Railroad and Amtrak services operating on this portion of the Northeast Corridor, assuming a conservative 1 percent annual growth in ridership. The portion of total ridership on the New Haven Line which boards in the AM southbound to Grand Central Station east of the project area is estimated to be 22 percent, per the Origin-Destination Survey/Onboard Count Report conducted by Resource Systems Group, Inc. in October 2008. This is the portion of the ridership benefitting from the travel time savings of the project, as they will have a shortened trip.

It is assumed that this percentage of total ridership may be applied to the 2019 ridership data for both Metro-North Railroad and Amtrak services, to accurately represent the portion of ridership impacted by the project. Since Amtrak services on the Northeast Corridor operate further north and east of New Haven and include larger cities like Boston, this 22 percent is a conservative estimate for the Amtrak ridership calculation.

Travel time savings per passenger per trip is equal 1.25 minutes per trip. This was calculated by finding the difference in travel time along the project area by traveling 57.5 miles per hour in the no-build scenario to 90 miles per hour in the build scenario (Table 7).

Table 7 – Intercity and Commuter Rail Current Speed by Mile Post

MP Start	MP End	Length	Speed (Mph)
55	55.5	0.5	30
55.5	56.5	1	45
56.5	57	0.5	60
57	59	2	70
Actual Weighted Average			57.5

Source: https://portal.ct.gov/-

/media/DOT/documents/dprojects/TimeForCT/NHL_Capacity_and_Speed_FINAL_Report_062321v2.pdf

The annual boardings is multiplied by this travel time savings per trip and converted to hours, resulting in hours per year saved. The value of time for all trip purposes is equal to $17.80 per hour, according to BCA Guidance. This rate was multiplied by our hours per year saved and discounted by 7 percent.

The travel time savings from existing riders for the project is estimated at $29.5 million discounted at 7 percent.

Induced Riders

While the project's improved travel time savings benefits existing rail users, it also has an impact on riders who will now switch to rail because of its faster, more convenient travel time. Induced riders are calculated based on an assumption that the project will attract 2 percent new riders from the projected 2030 annual ridership along the project segment (i.e., applying the 22 percent to all NHL projections). Once the opening year 2030 annual induced ridership value is established, an annual growth factor of 1 percent is applied, shown as one-way new trips in the BCA workbook.

For this benefit, the FTA Hazard Mitigation Cost Effectiveness (HMCE) Tool provides guidance on only calculating the benefit for one half of a workday, equal to 4 hours. The value of time for all purposes was applied for these induced trips equal to $17.80 per hour. The totals for each year were then discounted at 7 percent and summed.

The value of induced riders for the project is estimated at $1.6 million discounted at 7 percent.

Vehicle Operating Cost Avoided from Trip Mode Switch

When a driver uses their car, there are operating costs associated with that wear and tear from use. A driver who switches to commuter rail will avoid these vehicle operating costs (VOC) because they are no longer putting wear and tear on their car. Total VOC is calculated by multiplying the VMT avoided due to mode switching by the VOC of a light duty vehicle, which is provided in the guidance as $0.45 per mile.

The VMT avoided due to mode switching assumes the 2 percent of ridership for commuters switching modes, a 6.5 mile average one-way trip per Streetlight Data,[3] and an occupancy rate per passenger vehicle of 1.67. A ridership growth rate of 1 percent per year is also assumed in this benefit. These values were discounted at 7 percent and summed per year.

The vehicle operating cost avoided from trip mode switch is estimated at $12.5 million discounted at 7 percent.

Freight Train Operating Cost Savings

To estimate the freight train operating cost savings, it was necessary to estimate the amount of time saved per train in the corridor due to the project. The freight speed is 25 mph west of TIME-1 and is 15 mph in TIME-1 project limit and goes 25 mph after Devon Bridge. After completion of TIME-1, the freight speed will increase to 25 mph after freight train passes Devon Bridge at 15 mph and can run 25 mph up to MP 55.4 and again has to slow down to 15/10 mph due to curve in Bridgeport. Time savings per train is estimated to be 5.33 minutes, based on the length of the corridor and the increase in freight train speed between the no-build and build scenarios. Per a Class I Railroad Annual Report, CSX had a total train operations costs of $1.58 billion in 2020, with 2.64 million train hours in service for the same year. The cost divided by the hours provides the operating cost per train hour, which is $598.19.

[3] https://www.streetlightdata.com/wp-content/uploads/2018/03/Commutes-Across-America_180201.pdf

The analysis assumes that two locomotives are operating per train, with 64 percent of the share of a locomotive's operating cost attributed to non-locomotive-dependent costs; therefore, a factor of 136 percent was applied to the cost per train hour, totaling $813.53 operating cost per train hour. This rate was applied to the annual travel time savings for freight trains in the corridor, then discounted at 7 percent.

The freight train operating cost savings for the project is estimated at $672,613 discounted at 7 percent.

Inventory Cost Savings for Rail Freight

The value of freight, on a per ton and per train basis, is required for estimating inventory savings resulting from reduced travel time. The inventory cost associated with the annual rail cargo and annual hours of delay is based on the commercial discount – the opportunity cost associated with holding assets in inventory rather than using them for another purpose. An avoidance of delays with the delivery of freight contributes to a savings in freight inventory costs. This analysis uses a commercial discount rate of 4.0 percent. Assuming 8,760 hours in a year (365 days * 24 hours), this yields an hourly discount rate of 0.00046 percent. Multiplying this hourly discount rate by value of freight shipped and by the hours of delay avoided yields an annual value of inventory savings.

For this benefit, the following data in Table 8 was used, which provides actual data for the Providence and Worchester Railroad (Class II) and bases the CSX (Class I) data on these values. The benefit is calculated by multiplying the full annual cars, value per ton, and tons per car, then multiplying the product by the hourly commercial discount rate. Finally, this product was multiplied by the annual freight travel time savings to provide inventory cost savings for rail freight, then discounted at 7 percent.

Table 8 - Freight Rail Inventory Assumptions

2019	CSX (Class I)		Providence and Worcester Railroad (Class II)	
	Weekday	Weekend	Weekday	Weekend
Daily Trains	11	1	11	1
Annual Cars	0		22100	
Full Annual Cars	11050		11050	
Value per Ton	$ 0.07		$ 0.07	
Tons per Car	100		70	
Cargo Type	Building supplies, lumber, warehouse distribution material		Construction debris, aggregates, construction materials, lumber, steel, plastics, and chemical	
Notes			Through haulage agreements, the railroad connects with Canadian National Railway, Canadian Pacific Railway, and Norfolk Southern Railway.	

O&M Cost Avoided

The state of repair of the existing infrastructure in the project area requires routine maintenance to allow the corridor to operate at the current capacity. There are four main categories of repair, including replacing ties on bridges, the S Program (structures), the C Program (capital), and annual repairs to catenary or signal infrastructure. Under the no build scenario, the existing infrastructure is kept in place and CTDOT will need to incur in high O&M cost to maintain operations. Table 9 provides detail for the individual costs associated with operating and maintaining the existing infrastructure:

Table 9 - No-Build Scenario O&M Costs

O&M Item	Cost (2022$)	Quantity	Total Each Occurrence	Frequency of Occurrence (years)
Wood Tie	$ 1,500	3334	$ 5,001,000	20
Concrete Tie	$ 1,500	2640	$ 3,960,000	75
Tie on Bridge	$ 1,000	1250	$ 1,250,000	12.5
Bridge Maintenance – S Program	$ 200,000	7	$ 1,400,000	1
Culvert Maintenance – S Program	$ 25,000	2	$ 50,000	1
Major Culvert Repairs – S Program	$ 7,000,000	2	$14,000,000	Once in 2035
Catenary Repairs	$ 15,000	Total	$15,000	1
Signal Repairs	$ 35,000	Total	$35,000	5
Total Replacement – C Program	$30,000,000	Total	$30,000,000	15
Major Maintenance – C Program	$300,000	Total	$300,000	5
Annual Maintenance – C Program	$15,000	Total	$15,000	1

The no-build scenario was totaled for all the required repairs given their frequency, then discounted at 7 percent.

The total operation and maintenance cost avoided in the build scenario is estimated at $35.8 million discounted at 7 percent.

Congestion Reduction from Trip Mode Switch

In the build scenario, car drivers who switch to commuter rail are no longer driving on the roadway, therefore the congestion that those cars caused is now reduced. This benefit uses the vehicle miles traveled avoided in the build scenario and applies a marginal congestion cost per VMT equal to $0.12 per mile for light duty/urban vehicles. The cost of congestion reduced for each year is then discounted at 7 percent and summed.

The congestion reduction from trip mode switch for the project is estimated at $3.4 million discounted at 7 percent.

Region Competitiveness and Better Connectivity

A faster and more reliable intercity, commuter rail and a freight network increase the region competitiveness overall, attracting jobs and business. TIME-1 is the first step to update the whole NHL. TIME-1 increases not only travel speed and reliability, but also increase capacity.

Climate Change, Resiliency, and the Environment

Vehicle Emissions Avoided from Trip Mode Switch

The vehicle miles traveled avoided associated with switching from auto to commuter rail results in less emissions because there are less cars polluting on the roadway. The highway emissions benefits associated with the elimination of vehicles come from the Environmental Protection Agency as well as the USDOT. The vehicle emissions reduction is estimated using emissions rates and monetized using pricing for the impact of volatile organic compounds (VOC), nitrogen oxides (NOx), particulate matter (PM), sulfur dioxide (SO_2), and carbon dioxide (CO_2) on community health, including human and environmental impacts.

Using the EPA and USDOT assumptions on the emission burn rates, the net change in emissions between the Build and No Build are calculated, and the price of emissions per ton were applied. The prices per emission change per year, so these values can best be viewed in the Inputs tab of the workbook.

The VMT for each year was multiplied by the grams of emission per mile traveled, converted to metric tons, then multiplied by a social cost of dollars per metric ton emitted. Finally, these emissions were summed and discounted at 7 percent, with the exception of CO_2 which is discounted at 3 percent per the BCA guidance.

The **vehicle emissions avoided from trip mode switch for the project is estimated at $3.5 million** discounted at 3 percent for CO_2, and 7 percent for the remaining values.

Noise Avoided from Trip Mode Switch

Also related to the reduction of VMT, the less vehicles that are on the road, the less noise pollution there will be in the area. This benefit is calculated by multiplying the annual VMT avoided by the marginal noise cost per VMT, equal to $0.0017 per mile for light duty/urban vehicles, as noted in the BCA Guidance. This calculation was done for each year, then discounted at 7 percent.

The noise avoided from trip mode switch in the project is estimated at $47,276 discounted at 7 percent.

Train Idling Emissions Avoided

Reducing train trip time would lead to a reduction in train emissions. In order to calculate reduced train idling emissions avoided due to the faster train speeds in the build scenario (i.e., from 15 mph to 25 mph), the annual freight locomotive hours saved were calculated using the travel time savings per trip and emission rates in grams per brake horsepower hour were applied. The analysis assumed the horsepower of CSX locomotives to be 6,000, based on the power of GE AC6000CW locomotives. The emissions rates for Tier 3 Line-Haul locomotives are shown in Table 10.

Table 10 - Train Idling Emissions Values

g/bhp-hr	PM10	NOX
Tier 3 Line-Haul Locomotive	**0.10**	**5.50**

The social cost of each emission in dollars per metric ton was applied to calculate the total cost of each emission. These dollar values change each year, so the best way to review these values is in the Inputs tab of the BCA Workbook. These were then summed and discounted at 7 percent.

The train idling emissions avoided for the project is estimated at $924,222 discounted at 7 percent.

Equity, Multimodal Options, and Quality of Life

Health Benefits from Trip Mode Switch

When a person uses transit, they will be healthier because they will be walking to and from the transit mode in lieu of driving, which is predominantly a passive, sitting activity. The BCA Guidance provides the value of an induced walking trip, one way, at $7.08. This rate is applied to the one-way trips avoided by auto calculated previously and discounted at 7 percent.

The health benefits from trip mode switch for the project is estimated at $50.6 million discounted at 7 percent.

Emergency Response Savings

The low bridge clearance in the project area present a safety issue for the citizens as detours to avoid these low bridges can delay emergency response vehicles, from accessing citizens and properties during emergencies. The assumed clearance required for a fire truck[4] is 13’6” per the Fire Apparatus Manufacturers’ Association (FAMA), so any bridge clearance increases which would allow for these vehicles to pass under the rail line would provide an increased benefit to the area.

This benefit was calculated by using a methodology outlined in a FEMA Benefit-Cost Analysis Re-engineering document [5] First, the average distance between firehouses in the area surrounding the project was found, as well as the total population in the area utilizing Census data. The population was assumed to grow at 1 percent annually, so the Census data was adjusted to 2030 with this growth factor, the year the project will begin operations.

Next, an emergency event must be applied to the population. This analysis utilized cardiac arrests, which the American Heart Association estimates that 58.5 cardiac arrests per 100,000 people are treated by EMS personnel. This ratio (58.5/100,000) is multiplied by the population, which is equal to 8.6 cardiac arrests per year in the project area. Using formulae detailed in the referenced FEMA BCA, the response time before a blockage, in this case a low clearance bridge, is calculated and then the response time after a blockage is introduced is calculated. These values may be used to calculate the survival probability and number of deaths per year for both response time scenarios. The increase in deaths per year between the unblocked and the blocked scenarios is the benefit which would be experienced by the project.

Finally, the value of statistical life (VSL) provided in the BCA Guidance equal to $12,837,400 was applied to this increase in number of deaths for each year over the period of analysis, again assuming a 1 percent annual growth rate for population. These emergency services savings were totaled and discounted at 7 percent.

The **emergency response savings for the project is estimated at $80 million** discounted at 7 percent.

Amenities from Trip Mode Switch

New riders switching from auto to trains will enjoy the amenities offered on rail that were not previously accessible by auto. The amenities are listed in the BCA Guidance for switching from a bus service to a train service, detailed in Table 11.

Table 11 - Amenities from Mode Trip Switch

Attribute Type	Bus Stop	Light Rail/Streetcar Stop	Rail Station
Clocks	$0.03	$0.03	$0.06
Electronic Real-Time Information Displays	$0.29	$0.14	$0.82
Information/Emergency Button	$0.22	$0.22	$0.10
PA System	$0.29	$0.05	$0.09

[4] https://www.fama.org/wp-content/uploads/2018/01/TC009-Em-Veh-Weight-Reg-FAMA-IAFC-111122.pdf
[5] FEMA BCAR Resource (hudexchange.info)

Ticket Machines	$0.10	$0.10	$0.06
Car Access Facilities	-	-	$0.11

There is not a value for switching from auto to rail; however, the analysis team submitted a question to MPDG Grants which yielded the result that the rule of half must be applied to the values for switching from bus to rail in order to equate this to an auto user switching to rail, per Section 4.8 of the BCA Guidance on Modal Diversion. The combined benefit for new riders from bus to rail is equal to $1.24 per trip. The rule of the half was applied, which yields a rate of $0.68 per one-way trip. This was applied to the annual one-way trips avoided by auto and discounted at 7 percent.

The amenities benefit from trip mode switch for the project is estimated at $4.4 million discounted at 7 percent.

Trip Reliability from Trip Mode Switch

Travelers who switch from driving their car to riding the train will experience an improvement of trip reliability, which is defined as the value travelers place on the variability in a typical travel time for the same trip from day to day. Riders value a predictable and dependable mode of transportation, which is why there is an economic benefit to switching from a car to a train, as cars are a lot less predictable and dependable than trains.

This benefit was calculated using the travel time savings of riders switching from auto to train for the year and multiplying it by the total unreliability savings, equal to 47.29 hours, The total unreliability savings was calculated by taking the hours per person per year wasted by a driver due to congestion in Bridgeport-Stamford,[6] and subtracting the percentage of travel time savings per person per year where an Amtrak train is unreliable, based on the percentage an Amtrak train is on time, which was found from the Bureau of Transportation Services to be 87 percent.

The annualized unreliability savings were then multiplied by the value of time for all purposes, equal to $17.80 per BCA Guidance, and discounted at 7 percent.

The trip reliability from trip mode switch for the project is estimated at $19.3 million discounted at 7 percent.

Trip Reliability for Existing Riders

NHL existing riders will benefit from a more reliable rail system. For this benefit, it is assumed that the buffer time savings is 0.50 minutes for trips which are not on time. Since Amtrak trains are 87 percent on time along the NHL corridor, the analysis assumes that 13 percent of the trips are not meeting their schedule. Multiplying the boardings affected by TIME-1, the percentage of the trips not meeting the schedule, and the assumed gained buffer time, estimates the number of minutes existing riders will save from a more reliability system. The values were converted to hours, then multiplied by the value of time for all purposes, equal to $17.80 per the BCA Guidance.

The **trip reliability from existing riders in the project is estimated at $4.6 million** discounted at 7 percent.

Trip Reliability for Trucks on the Road

Due to less personal vehicles in the road, trucks benefit from higher trip reliability. The road network will benefit from TIME-1 improvements, leading to less congestion, due to less personal vehicles traveling in

[6] CT_Transportation_by_the_Numbers_TRIP_Report_May_2017.pdf (tripnet.org), https://tripnet.org/wp-content/uploads/2018/08/CT_Transportation_by_the_Numbers_TRIP_Report_May_2017.pdf

the project area. This is a qualitative benefit.

Trip Reliability for Rail Freight

Adding a new track for freight trains increases the reliability of freight cargo since the railroads do not have to share the ROW with the intercity and the commuter services. This is a qualitative benefit.

Costs

The Project has two cost components: the capital costs for the new infrastructure and ongoing operating and maintenance (O&M) costs of that infrastructure. The components used in this analysis are described in this section.

Capital Costs

The project capital costs include the costs track improvements, rehabilitation of railroad bridges, catenary improvements, and signal improvements. At the 10 percent design, there is a 20 percent minor item allowance, a 15 percent contingency, a 40 percent railroad force account, and 15 percent for incidentals. Capital costs were estimated in 2022 dollars and converted to 2020 dollars using the GDP deflator, resulting in a **total cost of $199.2 million** discounted at 7 percent. The detailed capital cost summary is shown in Table 12.

Table 12 - Capital Costs by Year (2020$)

Year	Professional Services Costs	Design Costs	Construction Costs (+ Contingency)	Total Costs	Discounted Total Costs (7%)
2022	$2,299,291	$0	$0	$2,299,291	$2,008,289
2023	$2,299,291	$6,131,442	$0	$8,430,732	$6,881,989
2024	$2,299,291	$6,131,442	$0	$8,430,732	$6,431,765
2025	$2,299,291	$6,131,442	$0	$8,430,732	$6,010,996
2026	$2,299,291	$0	$71,349,108	$73,648,398	$49,075,038
2027	$2,299,291	$0	$71,349,108	$73,648,398	$45,864,521
2028	$2,299,291	$0	$71,349,108	$73,648,398	$42,864,038
2029	$2,299,291	$0	$71,349,108	$73,648,398	$40,059,849
Total	$18,394,325	$18,394,325	$285,396,431	$322,185,080	**$199,196,485**

Annual Operating and Maintenance Costs

The Project would require minimal annual operating and maintenance (O&M) expenditures to maintain the new C program as well as the catenary and signal repairs. It is estimated that these expenditures would amount to a total of $10,000 per year in the build scenario. This analysis estimates that the **O&M costs for the project would equal $67,497** over the period of analysis, discounted at 7 percent.

Benefit-Cost Analysis Results

The analysis measures the benefits created by the project against the costs of the project in two metrics:

the benefit cost ratio (BCR) and net present value (NPV). The BCR is the total benefits divided by the total cost, and seeks to be greater than 1.0 to ensure that for every dollar spent on the project there is a dollar benefitted by the project. The net present value is the total benefits minus the total costs, which seeks to be greater than zero.

The **BCR for the project is 1.6 and the NPV is $117 million**. The detailed benefit cost analysis results are included in Table 13.

Table 13 – TIME-1 Benefit Cost Analysis Results (2020$ M, discounted at 7%, 2030-2059)

Costs	
Capital Costs	***$199.2***
Benefits	
Safety Benefits	
Reduced Roadway Fatalities and Crashes from Trip Mode Switch	*$10.4*
Catenary Accidents Cost Avoided	*$0.1*
Less Large Vehicle Collisions with Low Vertical Clearance Bridges	*Qualitative*
Sub-Total	***$10.5***
State of Good Repair	
Residual Value	*$4.1*
Pavement Cost Avoided from Trip Mode Switch	*$0.04*
Accelerated Construction	*Qualitative*
Sub-Total	***$4.2***
Economic Impacts, Freight Movement, and Job Creation	
Travel Time Savings from Existing Riders	*$29.5*
Induced Riders (trip not taken)	*$56.3*
Inventory Cost Savings for Rail Freight	*$0.0*
Vehicle Operating Cost Avoided from Trip Mode Switch	*$12.5*
Freight Train Operating Cost Savings	*$0.7*
O&M Cost Avoided	*$35.8*
Congestion Reduction from Trip Mode Switch	*$3.4*
Region Competitiveness	*Qualitative*
Better Connectivity	*Qualitative*
Sub-Total	***$138.2***
Climate Change, Resiliency, and the Environment	
Vehicles Emissions Avoided from Trip Mode Switch	*$3.5*
Noise Avoided from Trip Mode Switch	*$0.05*
Train Idling Emissions Avoided	*$0.9*
Sub-Total	***$4.5***
Equity, Multimodal Options, and Quality of Life	
Health Benefits from Trip Mode Switch	*$50.6*
Emergency Response Savings	*$80.0*
Amenities from Trip Mode Switch	*$4.4*
Trip Reliability from Trip Mode Switch	*$19.3*
Trip Reliability for Existing Riders	*$4.6*
Trip Reliability for Trucks on the Road	*Qualitative*
Trip Reliability for Rail Freight	*Qualitative*
Sub-Total	***$155.8***

O&M Costs	***$0.1***
Total Benefits	***$313.2***
Benefit-Cost Ratio	**1.6**
Net Present Value	**$114.0**

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