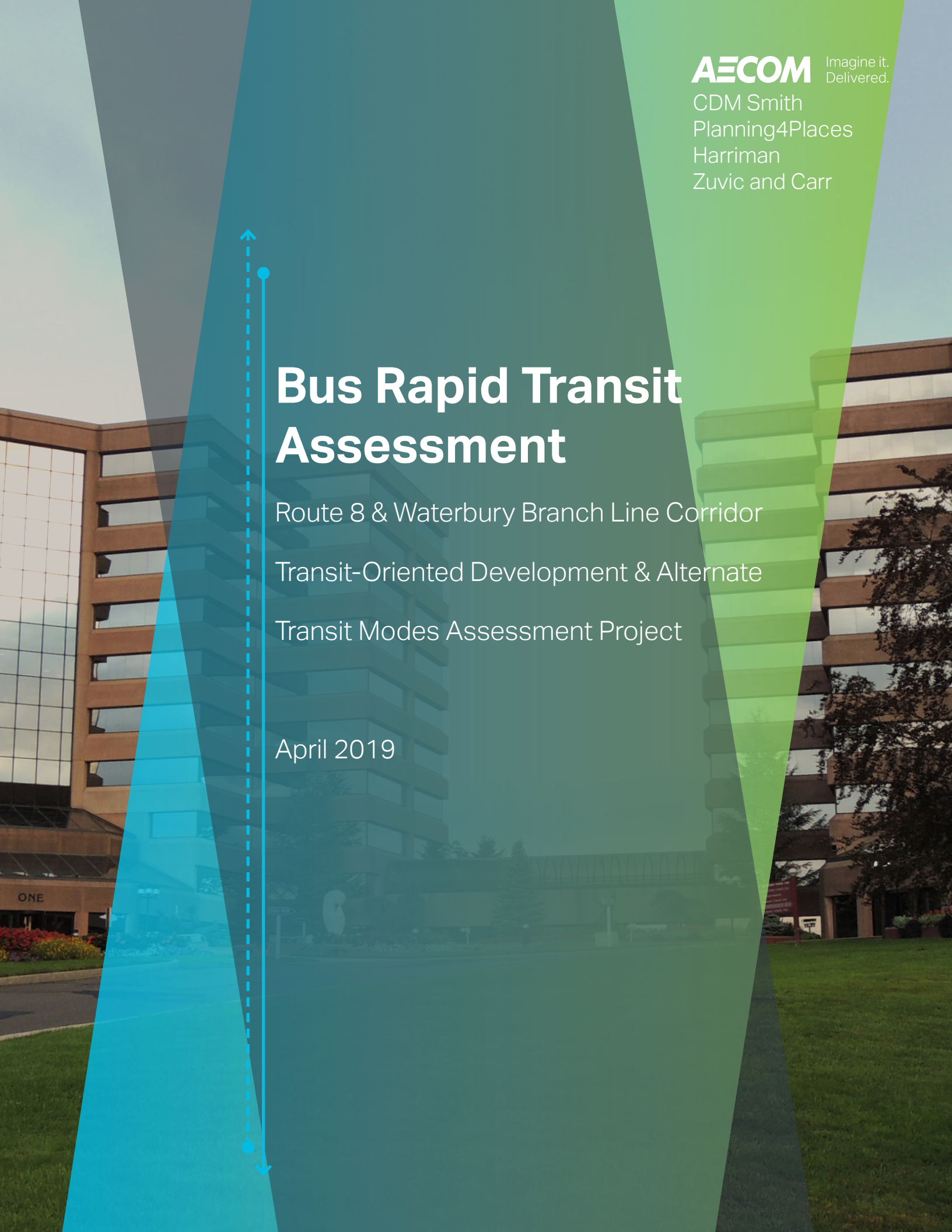

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Bus Rapid Transit Assessment

Route 8 & Waterbury Branch Line Corridor

Transit-Oriented Development & Alternate Transit Modes Assessment Project

April 2019

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EXECUTIVE SUMMARY

When looking at alternate transportation modes to connect the Naugatuck Valley to coastal Connecticut centers of employment and services and regional centers beyond, both commuter rail service on the Waterbury Branch Line and transit service along the Route 8 corridor are viable options. However, today neither system offers the level of service that would be attractive to and convenient for commuters. With targeted investment, they have the potential to effectively serve two different markets and provide alternatives to driving.

Enhanced and expanded service on the WBL will better serve those travelling from the Naugatuck Valley region to Stamford and New York City areas, but the WBL cannot serve commuters travelling to, from and along the Route 8 corridor between Derby and Bridgeport. The possibility of developing a Bus Rapid Transit System (BRT) in the corridor is being considered to fill the void of transit services. The intent is to provide high quality and attractive service to an area underserved by transit. The proposed BRT would complement commuter rail service, not compete or replace it.

Some benefits of a Route 8 corridor BRT include the following:

- Provides more direct service from the Naugatuck Valley planning region and the Derby-Shelton rail station and to the Bridgeport Transportation Center and New Haven main line.
- Can provide more frequent service within the corridor.
- Fills the 'void' in transit service for the corporate and office centers located within the Bridgeport Avenue and Route 8 corridor.

Bus Rapid Transit (BRT) is a cost-effective approach to transit service that blends the positive features of rail with the flexibility of bus transit, to make riding the bus a higher-end service alternative. Implementing BRT service along the Route 8 corridor could reduce traffic delays, improve connectivity to alternative modes, and support economic development.

BRT Alternatives

Five BRT alternatives were explored for the Route 8 corridor based on the following criteria:

- Availability of land/lanes to operate in a dedicated right-of-way.
- Ability to provide express service where land availability for a dedicated right-of-way is limited.
- Ability to serve the Derby /Shelton train station and the corporate office parks located in the corridor.
- Potential to add signal priority where possible.
- Ability to serve the west side of the Naugatuck River where there is limited express transit service.

A summary of the alternatives is presented in Table 0-1. Alternatives 1, 2, 3 and 5 connect the Derby/Shelton Train Station to the Bridgeport Transportation Center (BTC), while Alternative 4 connects Waterbury to the BTC. Options 1,2, and 5 have dedicated rights-of-way where Alternatives 3 and 4 would operate in general traffic lanes.

BRT Elements

There are seven main elements to BRT systems, depicted in the following illustration. The main element that differentiates BRT alternatives is the by type of running way:

- Shoulder running
- Median running
- Mixed traffic in general purpose lanes

All other elements can be applied regardless of the type of running way selected.

Table 0-1. BRT Alternatives Summary

Alternative	Description	Termini	Dedicated ROW	Pros	Cons
Alternative 1 Median Running on Route 8	Wholly separated facility, built within the center right-of-way of Route 8	Derby/Shelton Train Station & Bridgeport Transportation Center	Yes	• Limited right-of-way acquisition • Dedicated lane on over half of the route	• High capital costs • Deviations required to connect to corporate centers or new feeder routes to connect BRT stations to the office parks • Requires internal corporate center circulation system • Requires bridge reconstruction • The section of the route with dedicated ROW is the section with the least congestion currently
Alternative 2 Shoulder Running on Route 8	Operates within the outside shoulder of Route 8	Derby/Shelton Train Station & Bridgeport Transportation Center	Yes	• Limited right-of-way acquisition • Dedicated lane while on Route 8	• Conflicts with exit ramps • Deviations required to connect to corporate centers or new feeder routes to connect BRT stations to the office parks • Requires internal corporate center circulation system • Requires bridge reconstruction • Insufficient shoulder width in many locations
Alternative 3 Enhanced GBT Route 22X along Bridgeport Avenue	Extension of Route 22X to the Derby/Shelton Train Station	Derby/Shelton Train Station & Bridgeport Transportation Center	No	• No right-of-way acquisition • No infrastructure requirements • Minimal capital cost	• No dedicated right-of-way • Increased operating costs
Alternative 4 Express Bus on Route 8	Express bus in mixed traffic along Route 8	Waterbury; Bridgeport Transportation Center	No	• No right-of-way acquisition • No infrastructure requirements • Minimal cost • Supplements Metro North Waterbury Branch Line Service and offers service to additional destinations	• No dedicated right-of-way • Deviations required to serve the Shelton Business Park and other corporate office parks along the corridor

Alternative 5 Full BRT on Bridgeport Avenue	BRT running way on Bridgeport Avenue	Derby/Shelton Train Station & Bridgeport Transportation Center or Future Barnum Station	Yes	• Dedicated lane on over half of the route • Potential to serve Trumbull Corporate Park and Lake Success Business Park • Augments GBT Route 22X service	• High capital cost • High right-of-way acquisition cost • Insufficient shoulder width in many locations • Duplicates part of existing GBT Route 22X

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1.ELEMENTS OF BRT

Bus Rapid Transit (BRT) characteristics, practices and standards have been studied extensively in the U.S. and internationally. Examples include the U.S. DOT Federal Transit Administration (FTA), which established BRT guidelines in its document, Characteristics of Bus Rapid Transit for Decision Makers. In addition, the American Public Transportation Association (APTA), through its APTA Standards Development Program, provided guidance on the design of running ways, service, stations, ITS, and branding for BRT services. At the international level, the Institute for Transportation and Development Policy (ITDP) published the first Bus Rapid Transit Standards document.

The following seven elements shown in Figure 1-1 are considered part of the standard set of BRT features and each is described in further detail. The standard BRT features, with the exception of the running way, could be included as part of all the potential alternatives discussed in this memo. A uniting thread of these six features is that they do not require any alteration to the current right-of-way configuration, such as travel lane/parking reduction or property acquisition. Therefore, the two defining factors in each of the alternatives presented are the origin/destination of the service (i.e. purpose of the route, population served) and type of running way (or lack thereof), which is discussed in the next section.

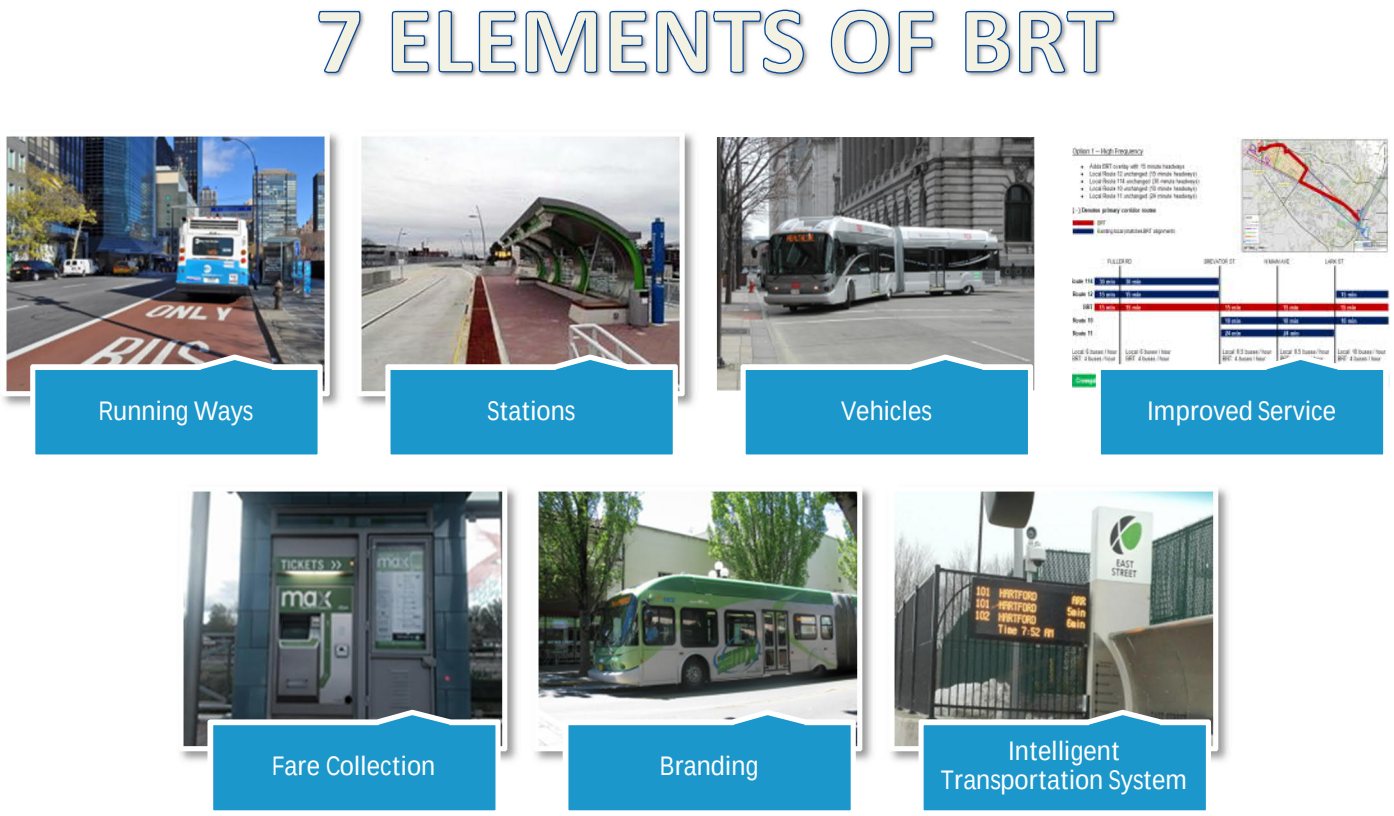


Figure 1-1. BRT Elements

1.1 Running Ways

The running way dictates where the vehicle travels, and how it is configured has a significant impact on the speed, reliability and cost of a BRT system. The three primary BRT running way characteristics are the degree of separation from other traffic (type of lane), lane markings, and vehicle guidance. The running way type is defined by how the vehicle operates with respect to other traffic, and can be any of the following: dedicated busways with physical barriers from other traffic lanes, exclusive on-street lanes, non-exclusive lanes but intersection bypass lanes such as queue jumps, shoulder lanes, or shared high-occupancy vehicle lanes. A single BRT can use multiple types of lanes and can operate in general/mixed traffic.

The markings on a running way communicate to other motorists and to passengers that a BRT running way is present. Markings can include signage, raised delineators, pavement markers, or unique pavement coloring, all of which greatly increase the visibility of lane restrictions. Pavement markings require regular maintenance to sustain their effectiveness. When determining the type of marking to be used, the running type, local climate, and emergency access need to be considered. The design, use and placement of markings must comply with the Manual on Uniform Traffic control Devices (MUTCD).

Running way guidance technologies permit higher speeds in narrower lanes. The Healthline in Cleveland uses horizontal rubber guidewheels on the tires to follow the curb. The Phileas guided bus in Eindhoven, Netherlands utilizes magnets embedded into the pavement as guides along the route. In France the Civic bus uses optical guidance with video sensors on the vehicle that read painted lines on the pavement.

BRT RUNNING WAY ELEMENTS

- Running way segregation
- Running way marking
- Guidance

Dedicated busway

Exclusive on-street lanes

Queue jumps

Bus on shoulder

HOV

Figure 1-2. BRT Running Way Types

1.2 Stations

BRT stations help develop the brand and are typically attractive and provide a safe and comfortable place to wait. They should have a sheltered waiting area, be well lit, clearly delineate which routes utilize which bays if multiple routes serve it, be fully accessible, have passenger amenities, multimodal access, passing capabilities for routes that do not serve the station, and

have security through the use of cameras, guards, or other safety enhancing technologies.

Figure 1-3. BRT Station – CTfastrak

The station, along with the vehicle, ideally should allow for platform-level boarding, that is, the station platform and bus entry and floor are at the same level. This reduces the time needed to board and disembark the vehicles and improves accessibility. By reducing the platform gap, typically to less than two inches, safety can also be increased. Multiple techniques such as alignment markers, guided docking, and Kassel curbs (a beveled curb) can be used to reduce the gap. It is important also to ensure that it is possible to board the vehicle without the presence of a platform using steps in the bus doorways. Routes often leave the BRT corridor and must be able to serve stops without a platform. Stations along arterial roads should be placed on the far side from intersections to minimize delay and conflicts and to take full advantage of transit signal prioritization.

BRT STATION ELEMENTS

- Station type
- Platform height
- Platform layout
- Passing capability
- Station access

1.3 Vehicles

Vehicles serving the stations should be modern, attractive, and branded. At a minimum, 40' vehicles should be used, but often the demand warrants 60' articulated buses, which offer increased passenger capacity. High quality BRT vehicles often have wider doors that improve boarding and alighting speeds and passenger circulation. Some BRT vehicles offer boardings from both sides of the bus, such as vehicles used on the Cleveland HealthLine. BRT vehicles also often have aesthetic enhancements such as larger windows and superior lighting and seating to improve the passenger experience.

Figure 1-4. Bus with Boarding on Both Sides – Cleveland Healthline

The recent trend is to operate environmentally-friendly vehicles such as hybrids, electric, ultra-low sulfur, CNG, and others as part of an overall marketing and branding effort. Nearby, the design for CTfastrak meets many of the marks of high quality vehicle design. The articulated low floor buses are the flagship vehicle of the CTfastrak fleet and have three doors to speed up boarding and alighting. These hybrid diesel-electric vehicles have super low emissions and use less fuel than a traditional diesel city bus.

Figure 1-5. Level Boarding - CTfastrak

BRT VEHICLE ELEMENTS

- Vehicle length
- Propulsion
- Vehicle configuration
- Aesthetic enhancements

BRT FARE COLLECTION ELEMENTS

- Collection process
- Payment options
- Fare structure
- Fare media

1.4 Fare Collection

Fare collection includes the collection process, payment options, media types and fare structure. Off-board fare collection is the preferred method for BRT systems as it reduces the dwell time of vehicles at a station so passengers are able to load faster and use all vehicle doors. This increases the speed along the corridor and improves the passenger experience. There are two ways to conduct off-board fare collection: turnstiles or proof-of-payment. With turnstiles, passengers pass through a gate into a paid zone where their fare is verified upon entering the system. With proof-of-payment systems, passengers pay at a kiosk prior to boarding and carry the ticket on-board where they may be asked by an inspector to show proof of payment. Proof-of-payment is how CTfastrak administers their fare collection with off board ticket vending machines and random on-board fare inspectors. Turnstiles minimize fare evasion, reduce personnel needs for inspectors, provide a better method for collecting passenger data, and can be easier to implement at stations with multiple routes. However, this system can be more expensive to implement initially and requires routine maintenance.

Figure 1-6. Off-Board Fare Collection - VelociRFTA

1.5 Intelligent Transportation Systems (ITS)

Intelligent transportation systems (ITS) elements can improve the transit system's performance through the use of advanced communication technologies. ITS also allows for users to access real time information from smart phones to follow bus progress along a route. Technology can fall into one of four categories (running way, station, vehicle, off-corridor) and be used enhance the experience for the customer or to aid in operations. ITS can include Transit Signal Priority (TSP), automatic vehicle location (AVL) for dispatch and operational controls, computer aided dispatch (CAD), automated scheduling, automatic passenger counters (APC) if proof-of-payment fare collection is used, collision warning, precision docking, vehicle monitoring systems, real time information at the stations to inform passengers of vehicle arrival times, and in-vehicle automatic annunciation of stops (which is now required by the ADA).

One highly effective treatment to speed up buses, especially along congested corridors, is signal control for transit vehicles. There are two types of TSP, signal preemption and signal priority. Signal preemption is ending a red light early to switch to green. Signal priority extends a green light to allow a vehicle to pass through and may use actuation to switch the red light to green only if it is within a defined set of signal-cycle design parameters.

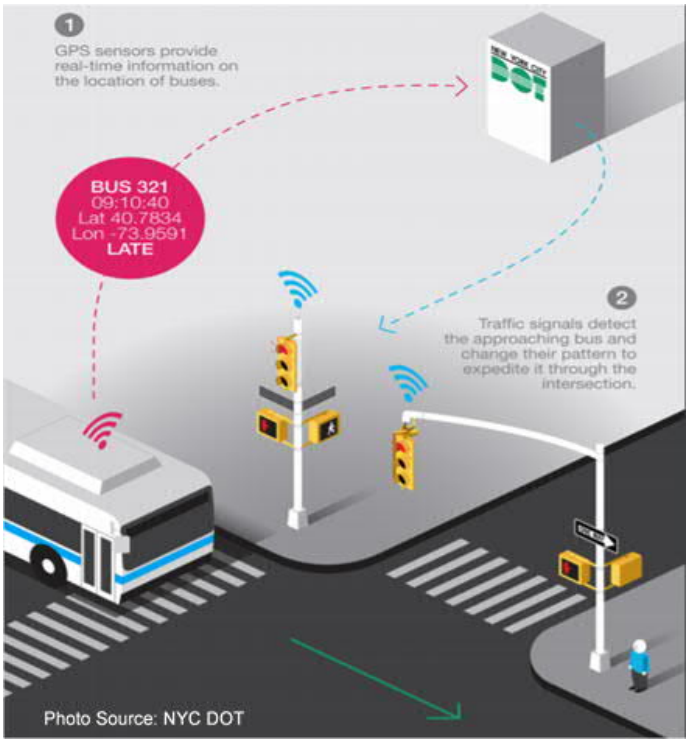


Figure 1-7. Transit Signal Priority

BRT ITS ELEMENTS

- Passenger information
- Vehicle prioritization
- Driver assist/Automation technology
- Operations management technology
- Safety and security

1.6 Service and Operating Plans

BRT systems are typically characterized as having a high level-of-service due to the high volume passenger loads. Ideally, service would operate seven days a week for at least 18 hours a day. Headways during the peak hours are typically 8 to 10 minutes and 12- to 15 minutes during the off-peak. The corridor also often has multiple routes serving it, with a variety of route types such as express, feeders, connecting routes, and all-stop routes.

BRT SERVICE AND OPERATIONS PLANS

- Service span
- Route structure
- Frequency of service
- Station spacing
- Schedule control

1.7Branding Elements

Marketing often involves branding the corridor to clearly differentiate the service as BRT. BRT is often delineated from other services using a unique naming/numbering system, separate colors or logos, and its own fleet of vehicles. A good branding program will have promotional materials, such as brochures that provide concise information, which can easily be transported to events and displayed on information tables. To meet the needs of residents in the service area, materials should be printed in additional languages as required and have accessible alternatives for people with disabilities.

Figure 1-8. Branding of the sbX line for San Bernardino

BRT BRANDING ELEMENTS

- Promotional material
- Branding devices
- Marketing classification

2.BRT ALTERNATIVES

This section details each of the five alternatives and the running ways for each. It provides a description of the alignment for each, outlines any constraints, describes operating requirements and presents the pros and cons. Optimizing stationing, introducing new vehicle design, intelligent transportation systems (ITS), and a high frequency and reliable service, paired with distinct marketing can be applied to any of the alternatives under consideration and would advance the service overall.

A summary of each alternative, how it incorporates the different BRT elements, travel time and order of magnitude for capital costs is presented in Table 2-1. Three of the alternatives have separated guideways and two would operate in mixed traffic. Given existing ridership on the WBL and GBT routes that service derby and Shelton it is anticipated that 40 foot low floor vehicles would be used on all of the alternatives except number 4 which would use a commuter Express Bus because of the length of the trip. Off board fare collection would be available at all stations, except under alternative 4 which would use on-board fare collection. To speed up fare collection on Alternative 4 mobile payments could be implemented, allowing passengers to purchase their fare before boarding.

ITS elements could be deployed on all of the Alternatives, and several elements are already in place on the Greater Bridgeport Transit (GBT) and CTtransit – Waterbury Fleet. For example GBT has real-time information available and CTTransit has deployed APC and AVL on their fleet. Proposed ITS elements are similar across all alternatives, except TSP which would only be implemented on the Alternatives which did not operate on Route 8.

Travel time varies by alternative and ranges from 27 minutes to 39 minutes from the Derby/Shelton station to the Bridgeport Bus terminal. This travel time is greater than the WBL travel time of 21 minutes between Derby/Shelton and Bridgeport. Vehicle travel time calculated between the two stations during the peak period is 16 minutes, 10 minutes less than the proposed BRT travel time Travel from Waterbury to Bridgeport is only proposed on Alternative 4 which has a proposed one-way travel time of 54-78 minutes depending on the time of day. This is longer than the WBL train which is 52 minutes, GBT Route 15 which is 52-56 minutes and driving which is 36 minutes. Driving assumes a direct trip between Waterbury and Bridgeport with no intermediate stops at WBL stations.

ALTERNATIVES

1. Median Running BRT
2. Shoulder Running BRT
3. Enhanced GBT Route 22X
4. Waterbury Express Bus Service
5. Full BRT

Table 2-1. Alternatives BRT Elements

Alternative	Dedicated ROW	Stations	Vehicle	Fare Collection	ITS							Service/ Operating Plan	Branding	One-way Travel time (min)	Magnitude of Capital Cost
					TSP	AVL	APC	CAD	Automated scheduling	Real-time info	Vehicle safety/monitoring				
Alternative 1 Median Running on Route 8	Yes - Wholly separated facility	-Derby Rail Station -Downtown Shelton -Shelton Corporate Park -Bridgeport Bus Terminal	40' low floor bus	Off-board		X	X	X	X	X	X	30 minute peak service, 60 minute off-peak	Yes	27-32	3
Alternative 2 Shoulder Running on Route 8	Yes - Shoulder	-Derby Rail Station -Downtown Shelton -Shelton Corporate Park -Bridgeport Bus Terminal	40' low floor bus	Off-board		X	X	X	X	X	X	30 minute peak service, 60 minute off-peak	Yes	27-32	1-Highest
Alternative 3 Enhanced GBT Route 22X along Bridgeport Avenue	No	-Derby Rail Station -Downtown Shelton -Shelton Corporate Park -Bridgeport Bus Terminal	40' low floor bus	Off-board	X	X	X	X	X	X	X	Peak service only, 60 minute headways	Yes	32-39	4
Alternative 4 Express Bus on Route 8	No	WBL Train Stations	Commuter Bus	On-Board		X	X	X	X	X	X	Between rail trips, every 30 min	Yes	54-78	5 – lowest
Alternative 5 Full BRT on Bridgeport Avenue	Yes – dedicated lane	-Derby Rail Station -Downtown Shelton -Shelton Corporate Park -Trumbull Corporate Park -Barnum Station -Lake Success	40' low floor bus	Off-board	X	X	X	X	X	X	X	20 minute peak service, 45 minute off-peak	Yes	30-34	2

2.1 Median Running BRT System

Alternative 1 connects downtown Bridgeport and the Derby/Shelton Train Station using the median of Route 8. Median running BRT is a bus rapid transit system that is a wholly separated facility, in this case, a busway built within the center right-of-way of Route 8. Access to and from the busway would be via grade-separated ramps that connect to an adjacent station or local roads. It is anticipated that service would operate with 30 minute headways during the peak and 60 minutes headways in the off peak. One-way travel time between the terminal stations is anticipated to be 27-32 minutes and there would be four stops/stations; the existing Derby/Shelton Train Station, a new transit hub in downtown Shelton and at the Shelton Business Park and the bus terminal in Bridgeport.

The minimum width of a busway is 10.5 feet, with a desirable width of 12 feet. In addition, at least two feet of shoulder distance should be provided on both sides of the busway, increasing the preferred curb-to-curb width to 16 feet. The unobstructed vertical clearance over a busway is a minimum of 15.5 feet with a preferred clearance of 16.5 feet. For a bi-directional, two lane busway, a raised separator must be installed because of the high operating speeds. It must be at least 2 feet wide. This would result in a minimum cross section width of 34 feet for a bi-directional busway.

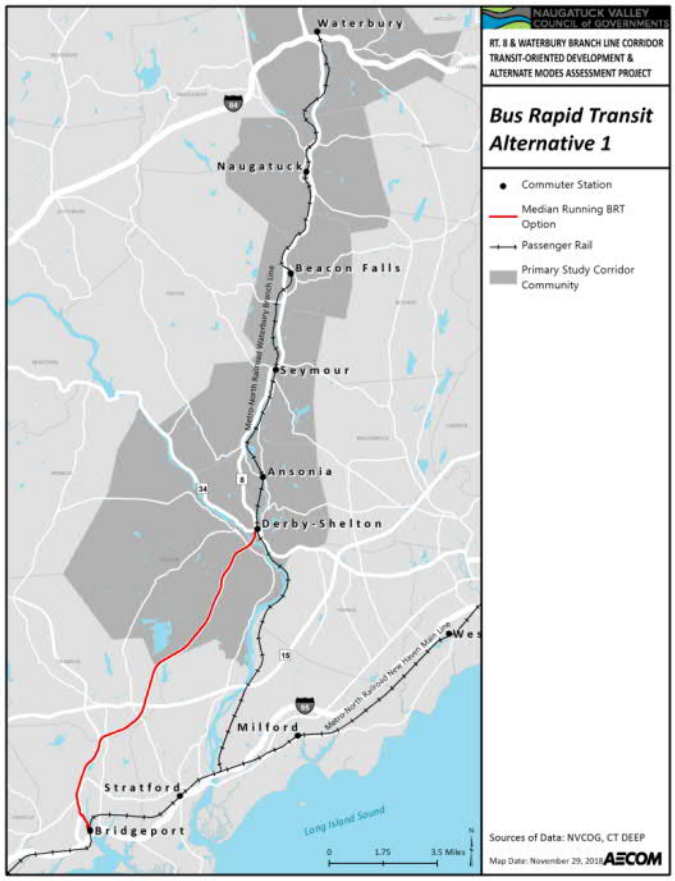


Figure 2-1. BRT Alternative 1 Map

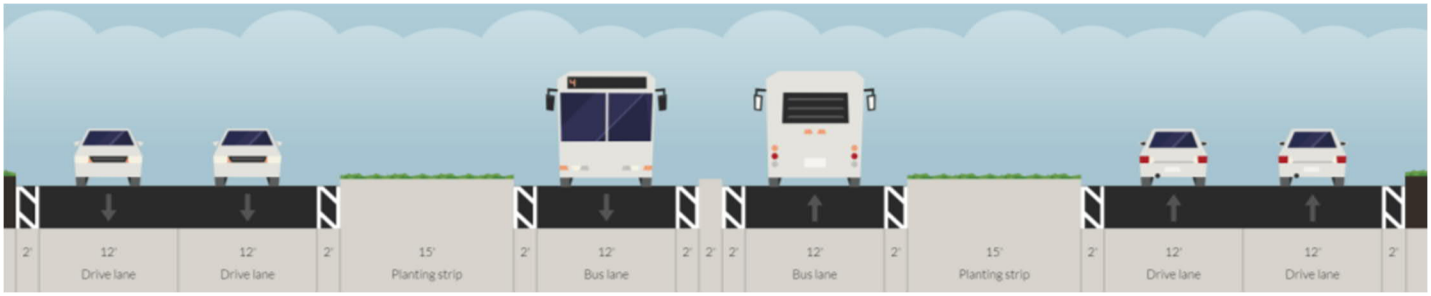


Figure 2-2. Median Running way BRT Cross-section

Route 8 south of the Commodore Hull Bridge is a combination of an older section built in the 1960s and newer sections completed in the early 1980s. The advantage of the newer section, approximately from the underpass of Constitution Boulevard to the merge with Route 25, is that the median ranges between approximately 65 feet and over 100 feet, more than sufficient space to accommodate a two-lane, bi-directional busway. The constrained sections are from the Commodore Hull Bridge to the Constitution Boulevard underpass, a distance of just under one mile (±0.91 miles),and from where Route 8 and Route 25 merge to where the route would depart Route 8 at Exit 3. In these sections, the northbound and southbound travel lanes are

separated by either a "Jersey" style barrier and have no median or the median is not of sufficient width.

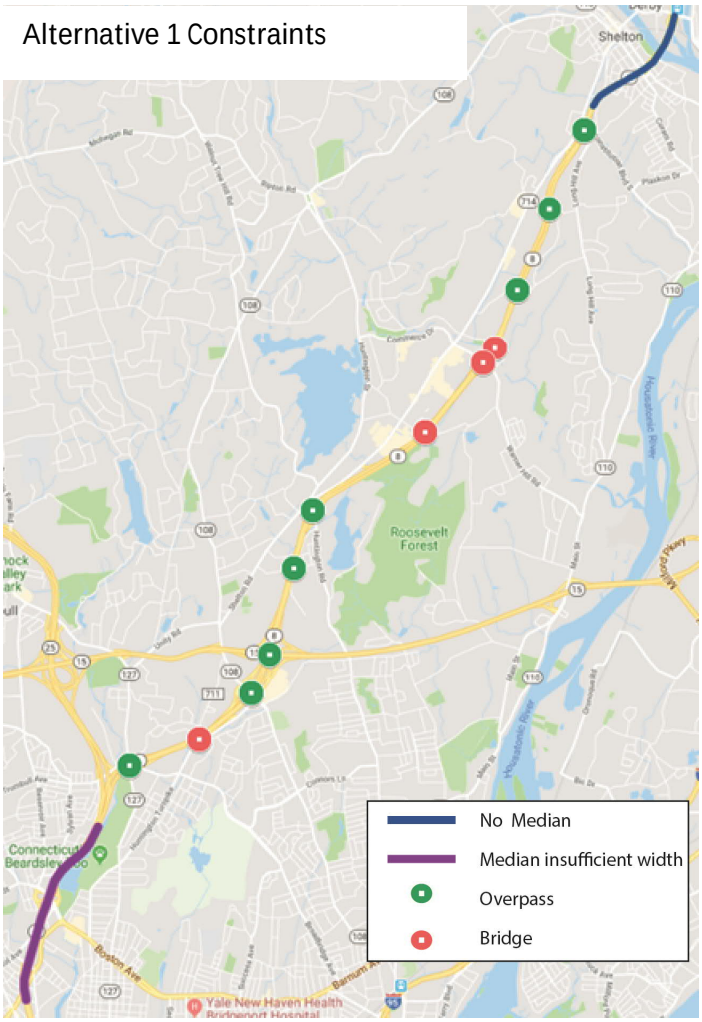


Figure 2-3. Alternative 1 Constraints Map

To operate in the median running busway, buses would enter and merge onto Route 8 from the Derby/Shelton Train Station using the Exit 15 southbound on-ramp from Route 34. Buses would then need to traverse across the two travel lanes over the one-mile stretch between the Commodore Hull Bridge and the Constitution Boulevard underpass to enter the median running separated facility that would start just north of Exit 13. The bus would travel along the separated facility for approximately 6.5 miles to the junction of Route 25 and Route 8. Here the routing and roadway geometry would require the vehicle to operate in the general travel lanes and exit the expressway at Exit 3 (Main Street) in Bridgeport. From Main Street, BRT buses would travel along local streets to the Bridgeport Transit Center, which would be the terminus of the BRT route. The Greater Bridgeport Transit operates local bus service from the BTC and the Bridgeport Train Station is connected to the BTC by an elevated, covered walkway. Terminating the BRT system at the BTC provides an efficient transfer point to not only to GBT bus service but commuter rail service operated along the New Haven Main Line.

With the median running way, the route would have dedicated BRT lanes on 6.5 of 11.5 miles of the alignment. On the 6.5 mile stretch, there are eight overpasses and four bridges. The overpasses and structural supports appear to have sufficient vertical clearance and the structure supports would not impede the construction of a busway though some bridge construction may be needed if widening the roadway impacts load ratings. However the four bridges on Route 8 range in length from 165 to 350 feet and are not of sufficient width to carry the busway. These structures would need to be widened or reconstructed to maintain the dedicated running busway. The busway could shift into the general traffic lanes and operate in mixed traffic over the bridges. This option would be less desirable and cause conflicts between BRT buses and vehicles.

A median running BRT system, operating on a dedicated busway, would function more closely to a rail system then to a bus system. With this option, buses would not generally exit the busway to pick up passengers; rather stations would be located directly along the busway or in close proximity. Because of this, the buses would have higher speeds than can be achieved by regular fixed-route buses and thus shorter running times. Due to safety and logistical concerns, the stations would not be located in the median but just outside of the highway with access to the stations provided via grade-separated ramps. To provide direct BRT service to large corporate areas, the BRT vehicles would have to leave the dedicated right-of-way, losing any travel time advantage, or local circulators

would be operated to shuttle passengers between the stations and the corporate parks.

The primary disadvantage of this type of system is the higher cost to construct the dedicated busway and stations, the ramps to connect the busway to the stations, and new bridges to maintain a continuous busway. While a busway within the median of Route 8 would avoid rights-of-way acquisition costs, substantial work would still be required to install the busway within the median. Some reconstruction of existing bridge structures may also be needed to accommodate the facility.

Pros

- Limited right-of-way acquisition
- Dedicated lane on over half of the route

Cons

- High capital costs
- Shuttles to connect to corporate centers
- May requires bridge reconstruction
- The section of the route with dedicated ROW is the section with the least congestion

2.2 Shoulder Running BRT

Alternative 2 connects downtown Bridgeport and the Derby/Shelton Train Station using the shoulder of Route 8 as a dedicated bus lane. In this scenario, the right-hand shoulders of Route 8 in both directions would be designated as a bus only lane. It is anticipated that service would operate with 30 minute headways during the peak and 60 minutes headways in the off peak. One-way travel time between the terminal stations is anticipated to be 27-32 minutes from the existing Derby/Shelton Train Station and there would be four stops/stations; the existing Derby/Shelton Train Station, a new transit hub in downtown Shelton and at the Shelton Business Park and the bus terminal in Bridgeport.

The BRT would operate in an express fashion with a very limited number of stations located adjacent to the bus lane. When it exits Route 8, the BRT vehicles would merge into general traffic and use more traditional bus stops, albeit with fewer stops than local services. The bus would exit Route 8 to pick up or drop off riders and then re-enter Route 8. The intent is to maximize travel speeds and minimize delays caused by station stops and off-route diversions. The bus only lane, typically referred to as a "reserved bus lane" or "bus on shoulder," would afford the buses an opportunity to by-pass congestion and maintain a free-flow speed. As with a median-running BRT, a shoulder running system would also require a local circulator or shuttle system to eliminate the need for the BRT vehicle to deviate from the busway to serve the corporate parks.

A major concern with a shoulder-running BRT is the available width of the shoulder and the ability of the pavement material to bear the weight of the vehicles under frequent use. The minimum requirement for a shoulder lane to be used as a bus lane is 13 feet, 11 feet for the travel lane plus an additional two feet of paved area to separate the edge of the running lane from any obstructions. The shoulder width on Route 8 between Derby and Bridgeport varies and, in many sections, is likely narrower than the desired width. In some locations the shoulder could be widened without realigning the roadway, but this may not be possible where insufficient shoulder width exists at underpasses.

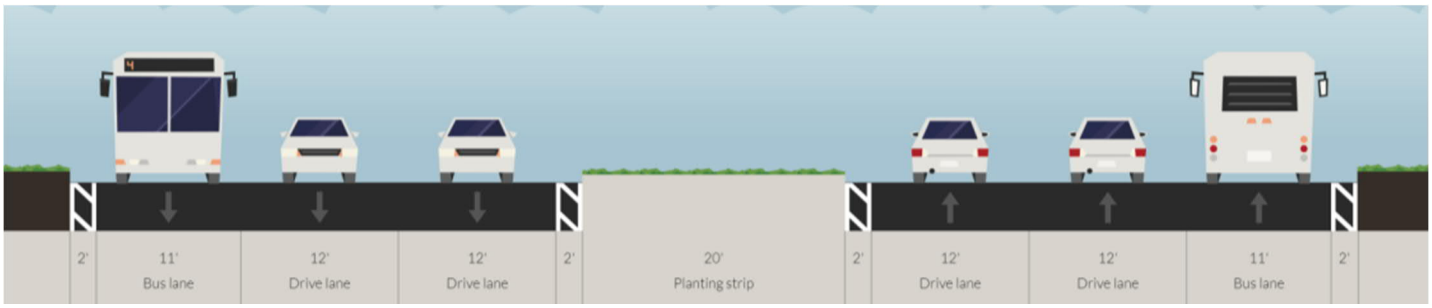


Figure 2-4. Bus on Shoulder BRT Cross Section

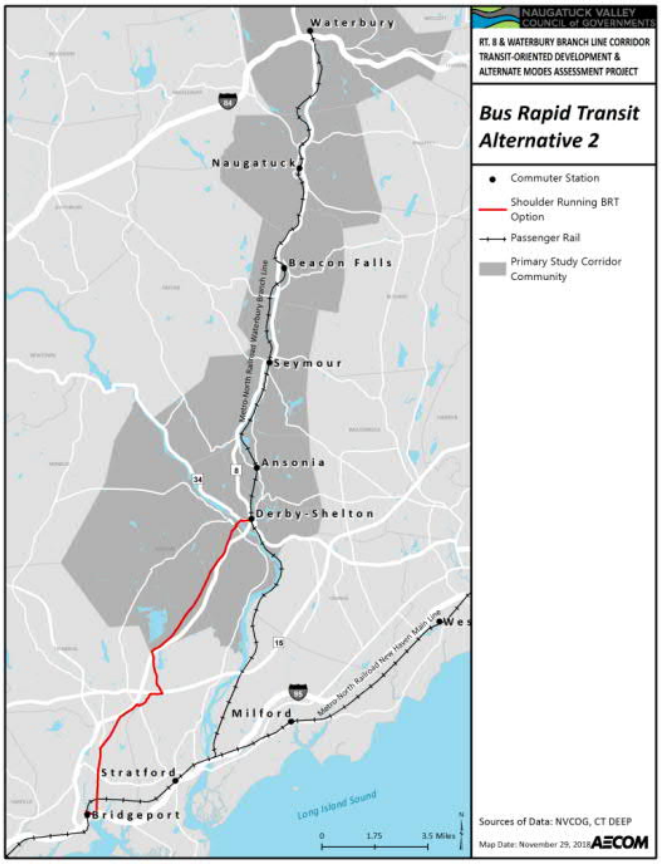


Figure 2-5. BRT Alterative 2 Map

In addition to concerns with available shoulder width along at grade sections of Route 8, there are 13 bridges that have narrow shoulders. These structures would need to be widened to accommodate the minimum acceptable width for a shoulder running busway. This concern is especially acute for the section between Exit 15 and Exit 13. This is an older section of Route 8 that was built prior to the establishment of modern design standards. Along this section, the BRT might have to travel within the general purpose travel lanes, exposing the buses to the same level of congestion as experienced by general traffic. This section also lacks a median, preventing the lanes from being shifted. To accommodate a shoulder running busway, the highway would need to be widened.

In addition to concerns with available shoulder width along at grade sections of Route 8, there are 13 bridges that have narrow shoulders. These structures would need to be widened to accommodate the minimum acceptable width for a shoulder running busway. This concern is especially acute for the section between Exit 15 and Exit 13. This is an older section of Route 8 that was built prior to the establishment of modern design standards. Along this section, the BRT might have to travel within the general purpose travel lanes, exposing the buses to the same level of congestion as experienced by general traffic. This section also lacks a median, preventing the lanes from being shifted. To accommodate a shoulder running busway, the highway would need to be widened.

Shoulder pavement thickness, material, and construction would also need to be evaluated to determine whether or not it would meet bus on shoulder specifications.

While traveling between interchange points, BRT buses in the shoulder running busway would be separated from traffic. However, potential conflicts would occur when the shoulder running BRT crosses the on and off ramps. At these points, the bus only lane would cross the path of traffic exiting and entering the highway. Between downtown Shelton at Exit 15 and the merge of Route 8 with Route 25, the south shoulder running busway would cross six off ramps and four on ramps. From the on-ramp from Huntington Road to the off-ramp to Route 15, there is a continuous auxiliary lane. At the merge with Route 25, the shoulder lane is lost and the busway would need to be shifted across three travel lanes of Route 25 before it can exit the expressway at Exit 3.

In the northbound direction, after the divergence of Route 8 and Route 25, the shoulder running busway would have to navigate across six entrance ramp areas and five exit ramps. As is the setup in the southbound direction, there is a continuous auxiliary lane extending from the entrance lane from Route 15 to the off-ramp to Huntington Road.

There are different types of signal and signage systems that can be used to better define rights-of-way and control traffic flows on shoulder running busways. These systems would provide preference towards the right-of-way of the BRT bus.

A right hand shoulder BRT is costly to construct due to the numerous exits but the use of the shoulder area right shoulder permits buses to enter and exit the highway more freely and without weaving through general traffic.

A left hand shoulder could be used, it would minimize exit ramp conflicts but the vehicle would have to weave through traffic to access and exit the lane and the shoulder is narrower. The entirety of Route 8 would have to be restriped or the shoulder would need to be widened. The main advantage of a left hand shoulder BRT system is that the investment costs to convert the shoulder to a "reserved bus lane" are relatively low and substantially less than the cost of providing a separated busway in the median of Route 8..

Alternative 2 Constraints

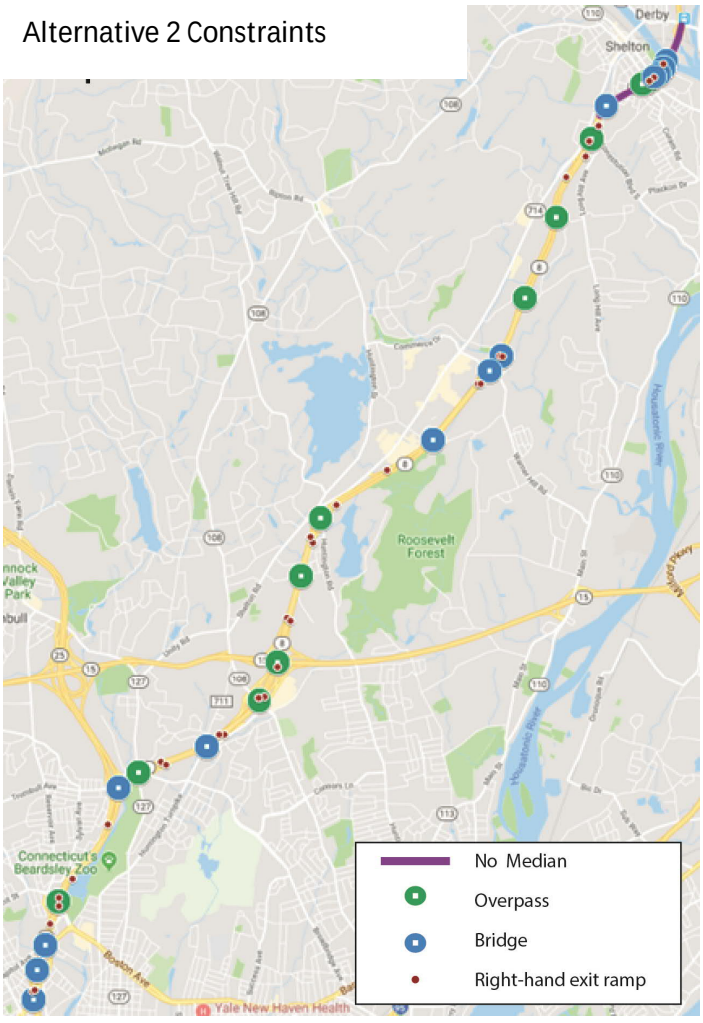


Figure 2-6. Alternative 2 Constraints

Pros

- Limited right-of-way acquisition
- Dedicated lane while on Route 8

Cons

- Conflicts with exit ramps
- Deviations required to connect to corporate centers
- May require bridge reconstruction
- Insufficient shoulder width in many locations

2.3 Enhanced GBT Route 22x

Currently, the GBT Route 22X provides express bus service between the Bridgeport Transit Center (BTC) in downtown Bridgeport and the Shelton Business Park. The service currently operates only during the morning and afternoon peak periods, with three trips in the morning and four in the afternoon using a 60-minute headway. The schedule is oriented towards bringing individuals from downtown Bridgeport to the Shelton Corporate Park in the morning and for the reverse commute in the evening. The first trip in the morning leaves the BTC at 6:35 AM and in the afternoon at 2:40 PM. Existing GBT Route 15 also provides hourly local bus service in the corridor. It is anticipated that service on this alternative would continue to operate during peaks times only at 60 minute headways. There would be four stops/stations; the existing Derby/Shelton Train Station, a new transit hub in downtown Shelton and at the Shelton Business Park and the bus terminal in Bridgeport.

The route takes the Route 8 Expressway from downtown Bridgeport to Exit 11, where it continues service along Bridgeport Avenue. At Trap Falls Road, the route leaves the main road and follows a series of local roads that provide access to and loop through the corporate office buildings. It reconnects with Bridgeport Avenue at the Commerce Drive intersection where in begins its southbound service back to the BTC via Bridgeport Avenue and Route 8.

A complete cycle takes 37 to 42 minutes depending on the time of day. The scheduled travel times are 12 minutes in the morning and 13 in the afternoon between

the BTC and Trap Falls Road and 11 minutes to complete the trip through the Shelton Corporate Park district. The first part of the trip is about 7.5 miles long, resulting in an average travel speed of about 37.5 miles per hour. The path through the corporate area is only about 1.5 miles in length, slowing the buses down to about 18.0 mph.

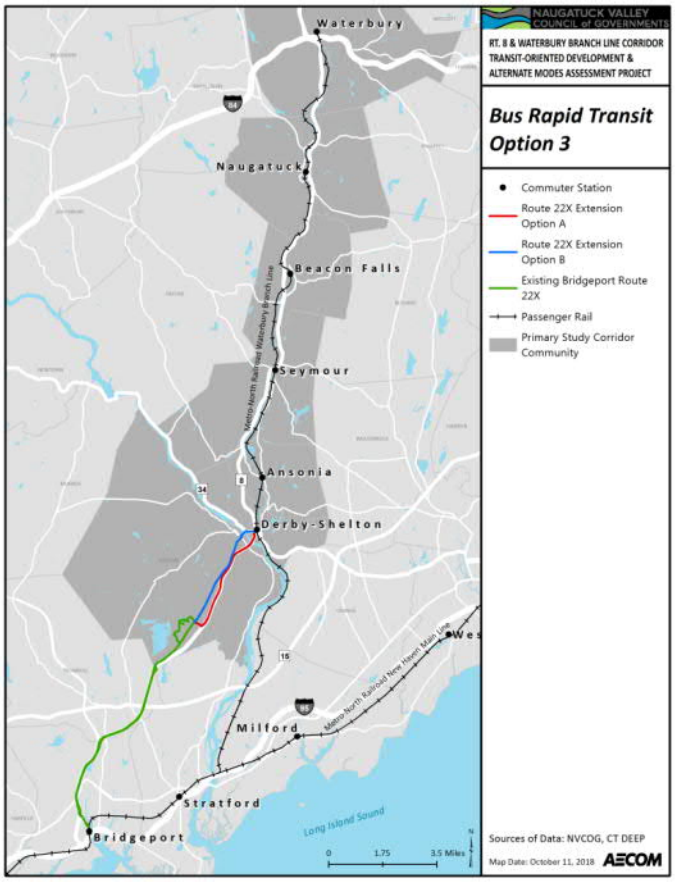
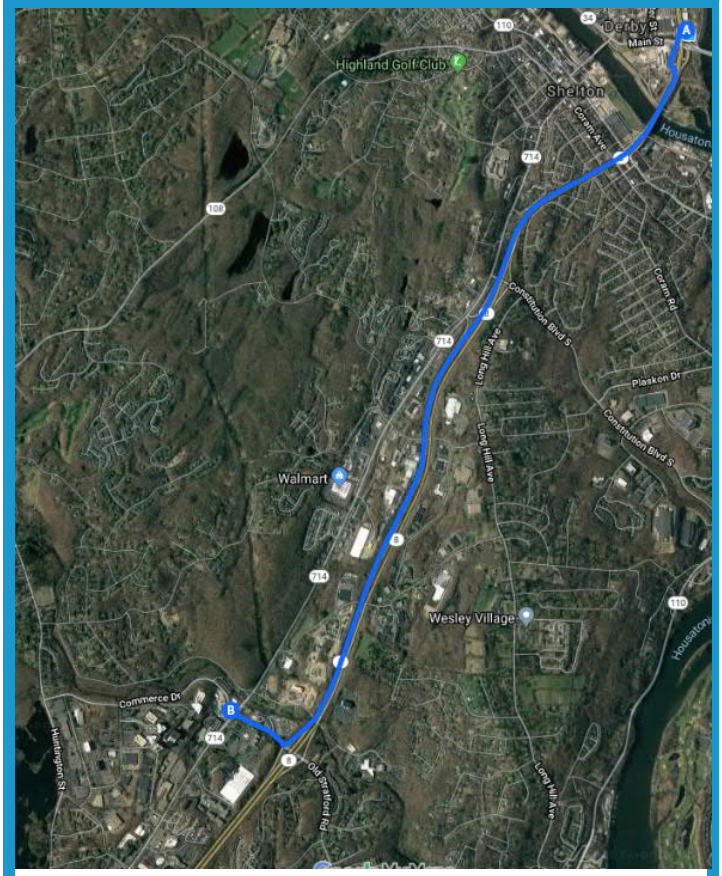


Figure 2-7. BRT Alternative 3 Map

The proposed enhancements to GBT Route 22X would provide increased and extended services by continuing the current routing north to the Derby/ Shelton Train Station, thereby providing a contiguous route between the BTC and the station. Two routing options have been identified to connect the Shelton Corporate Park area to the Derby/Shelton Train Station for Alternative 3. In Option 3A, the route would use Route 8 via Exits 12 and 15 to reach the Derby/Shelton Train Station. Option 3B would travel along Bridgeport Avenue and through downtown Shelton to reach the station. In both options, the route would operate in general travel lanes. To improve travel times, the number of stops would be limited and intersection treatments, such as Transit Signal Priority, installed. The major advantage to this system is that it is deployable without the development or construction of major infrastructure typically associated with BRT. It would only require route definition and asset allocation to implement.

OPTION 3A



Segment	Travel time (min)
BTC to Trapp Falls Road	13
Shelton Corporate Park Circulator	11
Old Stratford Rd to Derby/Shelton	8
Derby/Shelton to Old Stratford Rd	8
Shelton Park Circulator	11
Trapp Falls Rd to BTC	12
Total	**63**

Additional running time per trip required = 26 min

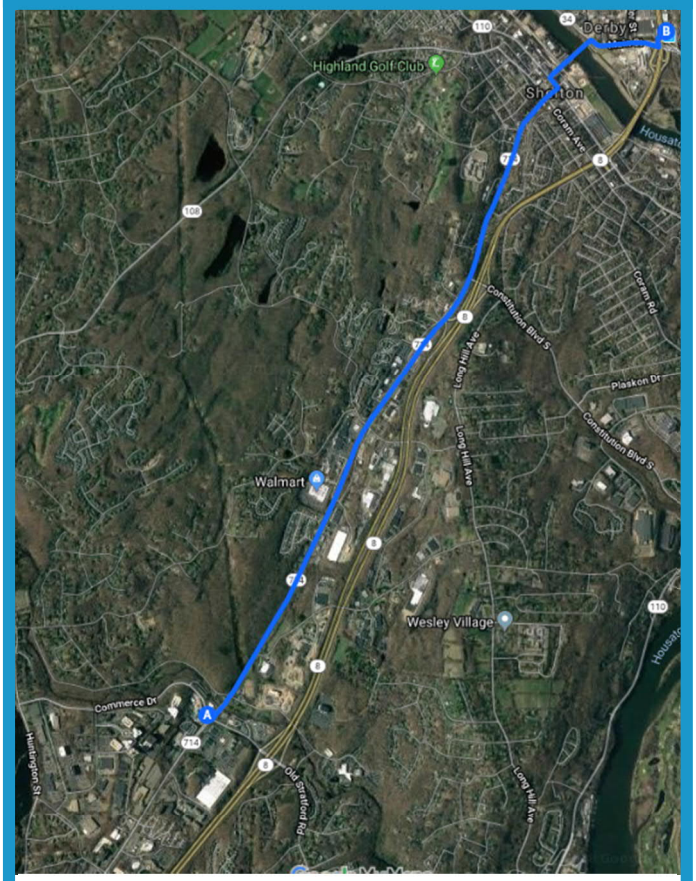
Option 3A is the more direct route and while a faster trip, it would not provide connections to the retail/commercial areas between downtown Shelton and Commerce Drive nor would it provide direct access for those living in the high density residential developments in downtown Shelton. However, for those who may want to travel to the Shelton Corporate Park area via a Waterbury Branch Line train, a direct connection along Route 8 would be preferable. The four-mile trip would take eight minutes based on the existing operating speeds for the route.

Option 3B expands the service area of GBT Route 22X, providing links to the retail and commercial areas along Bridgeport Avenue north of the Shelton Corporate Park. It would also provide a direct connection to and through Downtown Shelton. Under this alternative, bus stops can be located at key points along Route 110 (Howe Avenue) in the downtown area and at the residential developments located on Canal Street. This service extension from Commerce Drive to the Derby/Shelton Station would be about 3.8 miles. Based on the existing bus run times along this same route, it would take a bus about 15 minutes to complete the trips at an average speed of 15.6 mph.

The goal of this service would be to facilitate both southbound and northbound trips. The current GBT Route 22X service is more conducive for those traveling north in the morning and south in the evening. The current Route 22X utilizes one vehicle; in order to extend service north and operate at existing frequencies, additional buses would be needed. More frequent service would further increase the number of vehicles required.

The preferred routing depends on which additional areas of Shelton need to access the system. Option 3A would have a faster travel time, and the alignment of Option 3B through downtown Shelton may be perceived as much slower because of its routing along city streets. Option 3B run time may also be less consistent and more affected by random traffic incidences. Since the goal of this service is to operate at 30-minute headways, alternating service could be operated whereby the Route 8 alignment is run on the hour and the downtown route is followed on the half hour.

OPTION 3B



Segment	Travel time (min)
BTC to Trapp Falls Road	13
Shelton Corporate Park Circulator	11
Old Stratford Rd to Derby/Shelton	15
Derby/Shelton to Old Stratford Rd	15
Shelton Park Circulator	11
Trapp Falls Rd to BTC	12
Total	**77**

Additional running time per trip required = 40 min

Pros

- No right-of-way acquisition
- No infrastructure requirements
- Minimal capital cost
- Augments existing GBT Route 15

Cons

- No dedicated right-of-way
- Duplicates part of existing GBT Route 15

2.4 Waterbury Express Bus Service

The BRT system alternatives described above focus on travel between the Derby/Shelton Train Station and Downtown Bridgeport with opportunities to provide better and more attractive public transit service along the Bridgeport Avenue corporate, commercial, retail and residential corridor. The existing bus services are limited: GBT Route 22X operates on a 60-minute headway and provides only three morning and four evening trips; and GBT Route 15 operates on a 60-minute headway and has a 56-minute run time between the Derby/Shelton Train Station and downtown Bridgeport. The BRT concepts would provide improved and extended service, better headways and shorter travel times.

The goal of the Route 8 and Waterbury Branch Line Transit Alternate Modes Assessment is to promote increased transit options in the Route 8 corridor, including increased operations along the Waterbury Branch Line (WBL). Rail infrastructure improvements are being implemented and the State is considering acquiring new rail equipment for service on the WBL. These actions are intended to work towards meeting the minimum preferred level of service of 30-minute headways during the peak hours. In the short term, however, transit options between Waterbury, Derby and Bridgeport will continue to be limited.

Understanding that it may take upwards to five years before new locomotives and rail cars can be placed into service, an express bus service could be implemented to serve the WBL trains stations along Route 8 to address this deficiency. The service would supplement existing rail service and operate at times between scheduled rail times. Currently, the WBL trains operate on 2½-hour headways. A new express service could operate every 30 minutes and cover the gaps between train departures and make connections to each WBL station. At Derby/Shelton Train Station, the express route would continue along Route 8 directly to the Bridgeport Transit Center. The service would provide greater choice for travelers and greater confidence that a public transit mode would be available to make a trip at a desired time. It would also minimize the concern with missing a connection as riders would know that a complementary express bus run would be scheduled within 30 minutes of the scheduled train departure. The one way travel time between the Waterbury Train Station and the Bridgeport Train Station, stopping at all branch line stops in-between is 54 to 78 minutes.

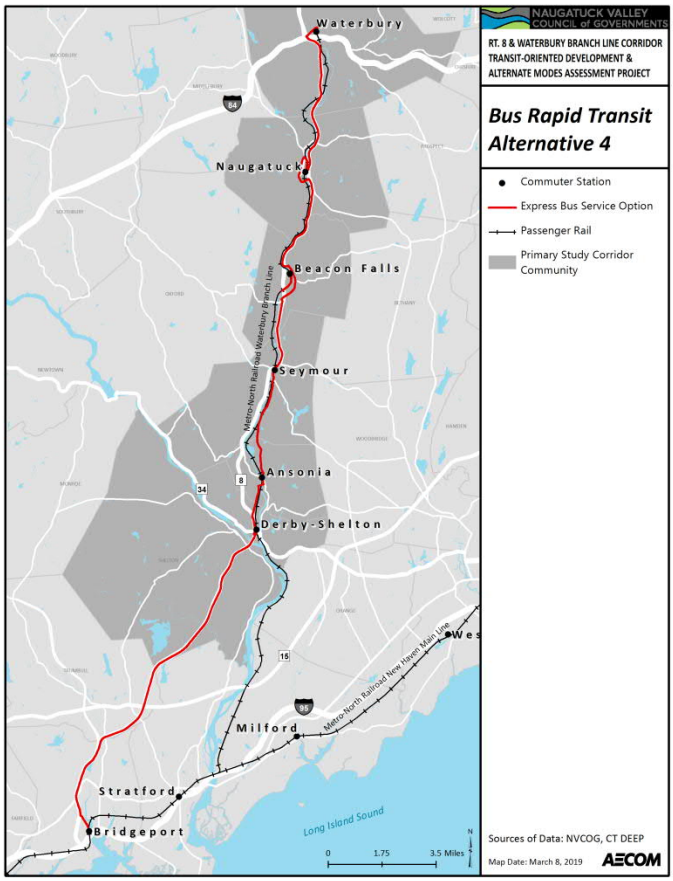


Figure 2-8. Alternative 4 Map

Pros

- No right-of-way acquisition
- No infrastructure requirements
- Minimal capital cost
- Supplements WBL service

Cons

- No dedicated right-of-way
- Would not serve the Shelton Business Park

2.5 Full BRT

Alternative 5 connects the Bridgeport Transit Center and the Derby/Shelton Train Station using several paths: bus lanes along Bridgeport Avenue, operations within mixed traffic on Route 8 with the potential for shoulder or median running BRT in select locations, and on local roads with signal treatments to create mixed-use lanes. The BRT lane would be an exclusive on-street BRT lane and could either be center running or curbside. It is anticipated that service would operate with 20 minute headways during the peak and 45 minutes headways in the off peak. One-way travel time between the terminal stations is anticipated to be 30-34 minutes. There would be six stops/stations; the existing Derby/Shelton Train Station, a new transit hub in downtown Shelton, the Shelton Business Park, Trumbull Corporate Park, Lake Success and the proposed Barnum Station.

Alternative 5 begins at the Derby/Shelton Train Station and there are two alternatives to reaching Bridgeport Avenue. Option 5A travels through Downtown Shelton to reach Bridgeport Avenue. The exclusive bus lane would not begin until Constitution Boulevard but signal treatments or queue jumps could be used at signalized intersections. Option 5B uses Route 8 and takes Exit 13 to reach Bridgeport Avenue. Option 5B is the more direct route, and, while a faster trip, it would not provide connections to those living in the high density residential developments in Downtown Shelton.

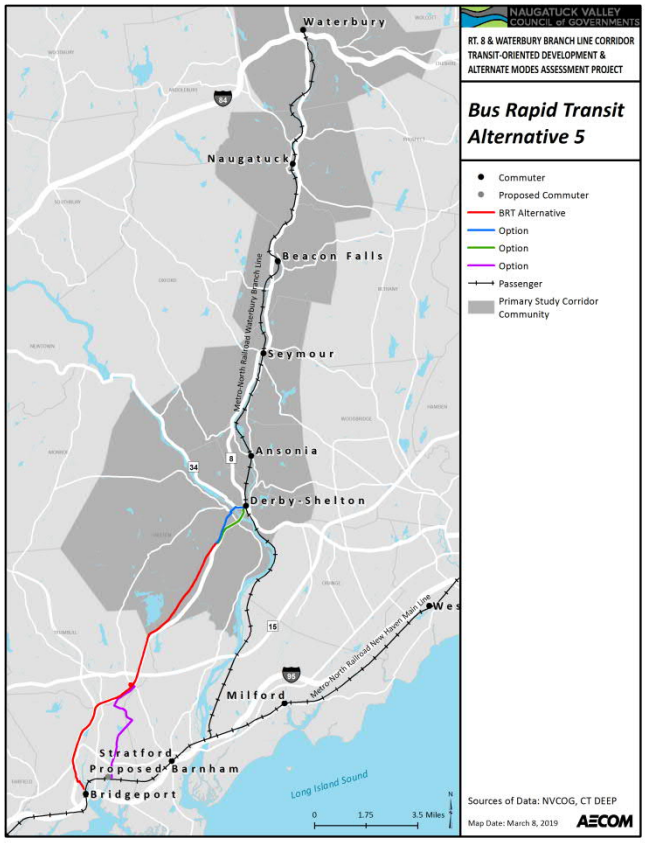


Figure 2-9. Alternative 5 Map

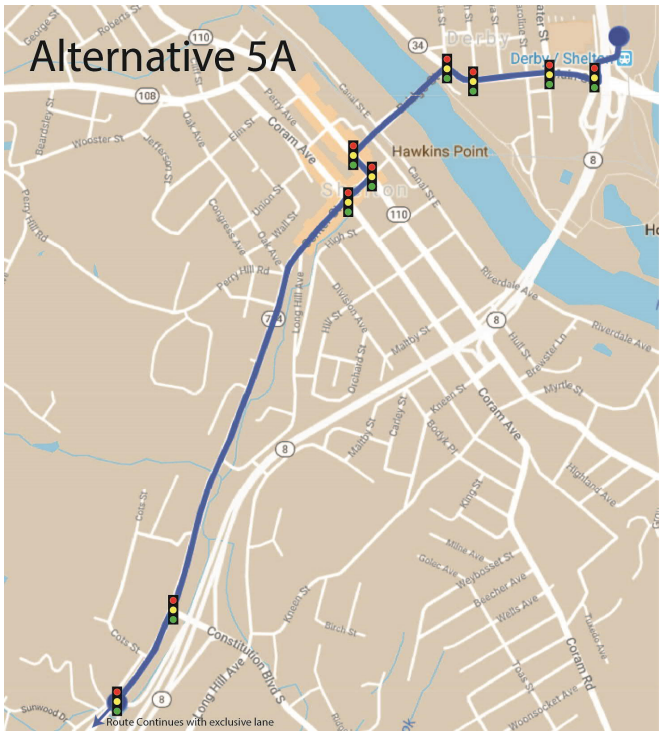


Figure 2-10. Option 5A Routing

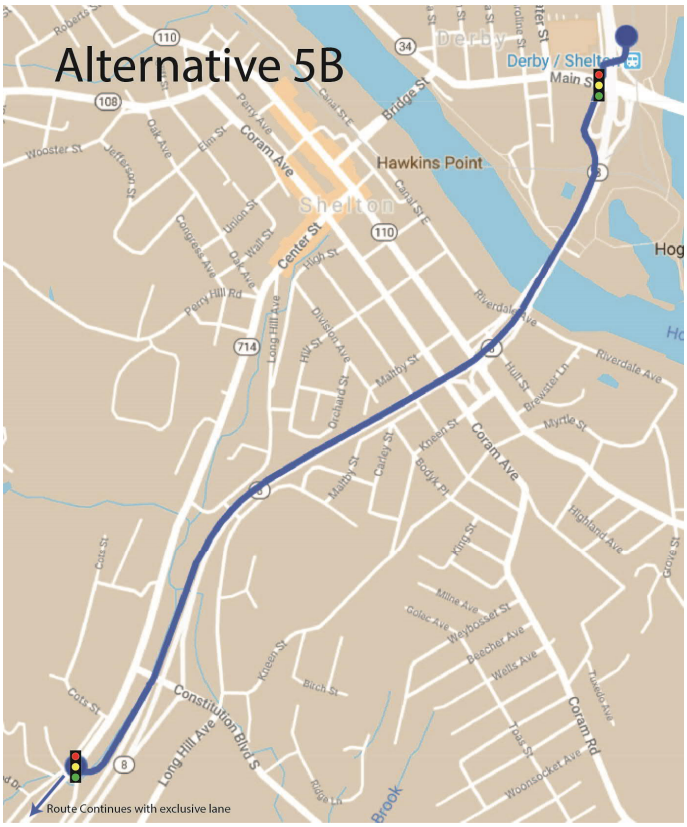


Figure 2-11. Option 5B Routing

The next segment of Alternative 5 is Bridgeport Avenue from the Route 8 Exit 13 southbound ramp to Huntington Street and Route 8 Exit 11 to Exit 8. The Bridgeport Avenue section is 3.9 miles and would have an exclusive right-of-way. The Route 8 section is 1.75 miles and could operate in mixed traffic or in a dedicated right-of-way such as in the shoulder or median. If service to the Trumbull Corporate Park were to be provided, access into and from the park would need to be elevated, grade separated between Route 8 and the corporate park in order to make the service fast and efficient.

Bridgeport Avenue is a two lane road with varying shoulder widths and turning lanes at many of the signalized intersections. Travel lanes are 12 feet wide and the shoulder varies throughout the corridor, and, with the exception of a few locations, is the same width in either direction. Between the beginning of the section and Commerce Drive, the shoulder is on average 10 to 12 feet with narrower shoulders of less than 4 feet in the vicinity of intersections. From Commerce Drive to Trapp Falls Road, the shoulder begins to narrow and averages only six feet in width. From Trapp Falls Road and southward, the shoulder narrows to between two and four feet. This is because of the numerous intersections and associated turning lanes. The minimum width of a bus lane is 10.5 feet, with a desirable width of 12 feet. Due to the existing roadway configuration along Bridgeport Avenue, and to minimize the need for additional pavement, it is anticipated that the bus lane would not be separated from the general traffic lane with a barrier. Instead pavement markings and paint would be installed to delineate the bus only lane from the general traffic lane.

Figure 2-12 depicts the segment between the Exit 13 southbound off-ramp to Bridgeport Avenue and Figure 2-13 shows the Exit 8 southbound off-ramp to Route 108. The BRT route would be aligned along Bridgeport Avenue and then enter Route 8 at the Huntington Road interchange (Exit 11). Cross sections show the existing roadway width compared to what is needed to operate using curbside running lanes. It assumes average shoulder widths for each section, 11 foot bus lanes, 12 foot general purpose travel lanes and a 2 foot shoulder on either side. As can be seen in each cross section, the existing roadway width is insufficient. On the Route 8 section of this segment the route would operate on the right shoulder in a dedicated way.

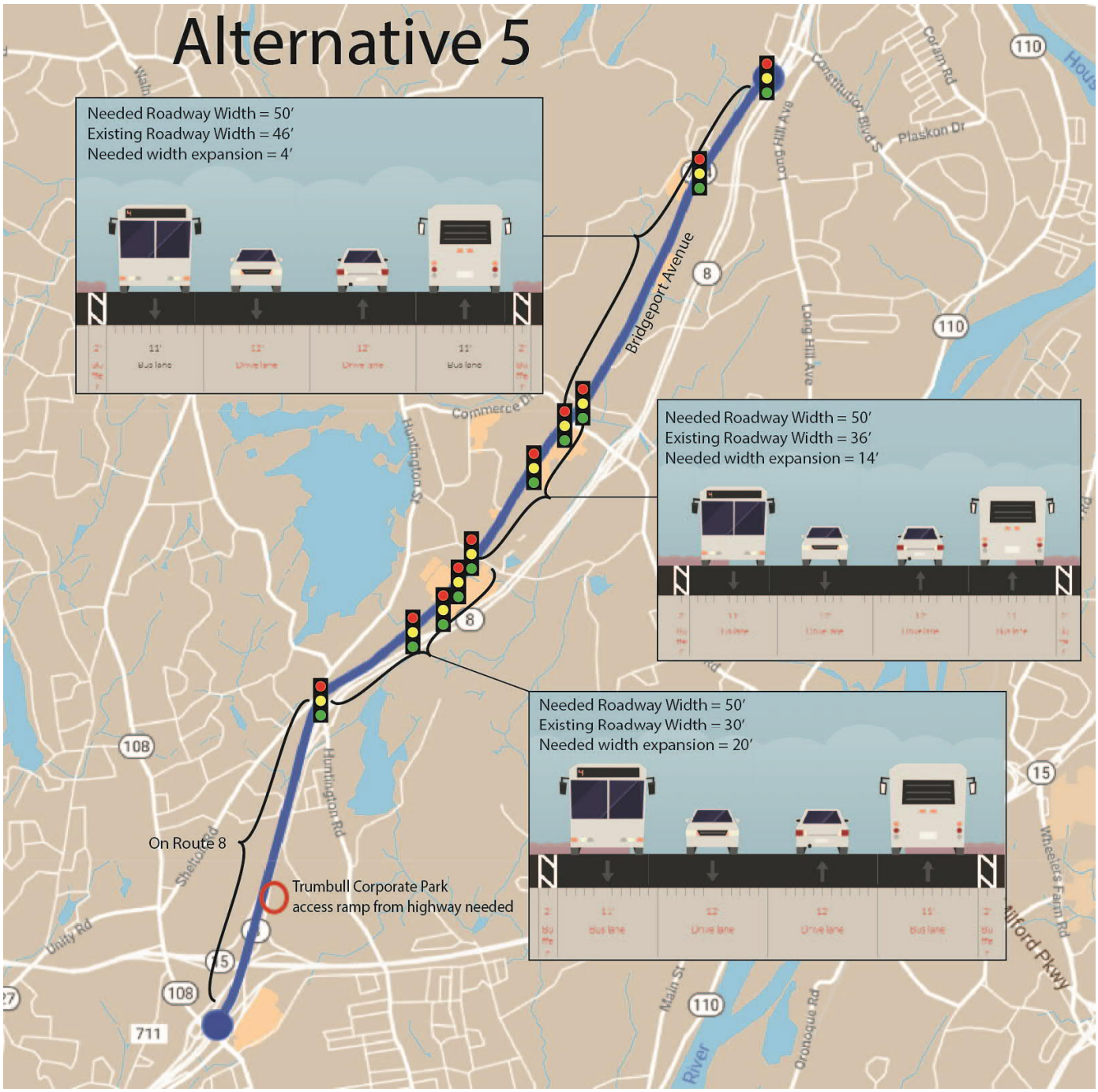


Figure 2-12. Option 5 Bridgeport Ave

South of Exit 8 on Route 8, the BRT alignment would depend on the future development activities in Bridgeport. The City of Bridgeport is working on redevelopment of a large tract of land into a corporate office and industrial park. In addition, plans have been prepared to establish a new rail station on the New Haven Main Line on the East Side of Bridgeport. The new station, preliminarily named the P.T. Barnum Train Station, would serve the lower East Side/East End neighborhoods and provide rail access to possible TOD projects. If these projects are built, the BRT route would be aligned through this section of Bridgeport to connect Naugatuck Valley residents to a new major employment center in Bridgeport. Under this scenario, the BRT route would exit Route 8 at Exit 8 and follow Route 108, Penny Avenue and Broadbridge Road/Broadbridge Avenue to the north

entrance of the Lake Success Business Park. It would then travel through the business park and continue along Seaview Avenue and terminate at the new Barnum Train Station. After exiting Route 8, the BRT vehicles would operate in mixed traffic; a dedicated bus lane is not proposed.

If these projects are not constructed, then the BRT alignment would continue along Route 8 to Exit 3 and into downtown Bridgeport and terminate at the BTC. A median or shoulder running way could be used on Route 8 for the BRT but it would then operate in general traffic lanes at the Route 8 and Route 25 merge.

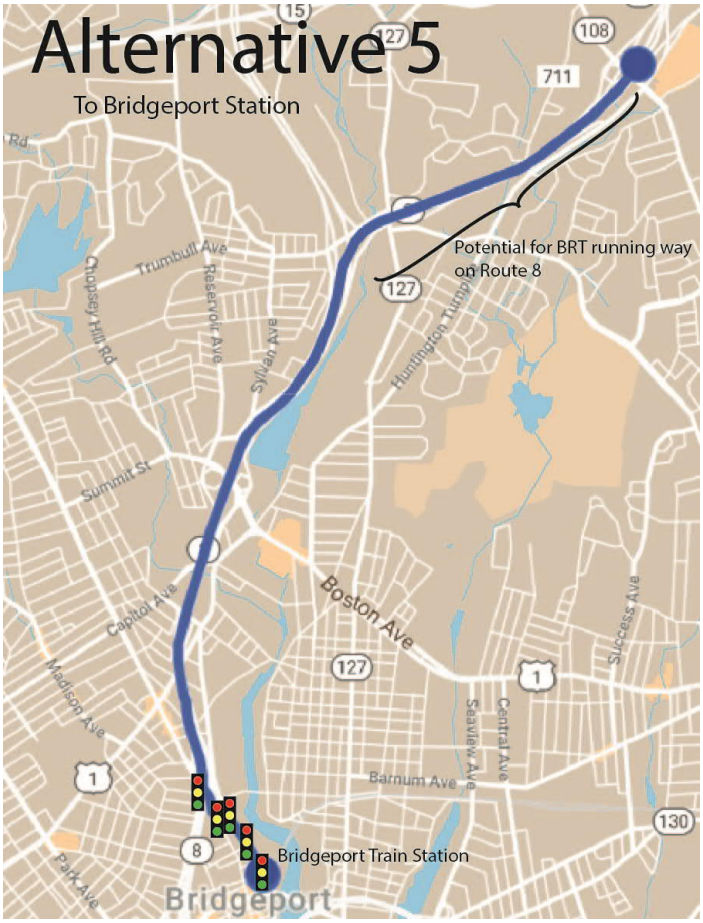


Figure 2-13. BRT to Bridgeport Station

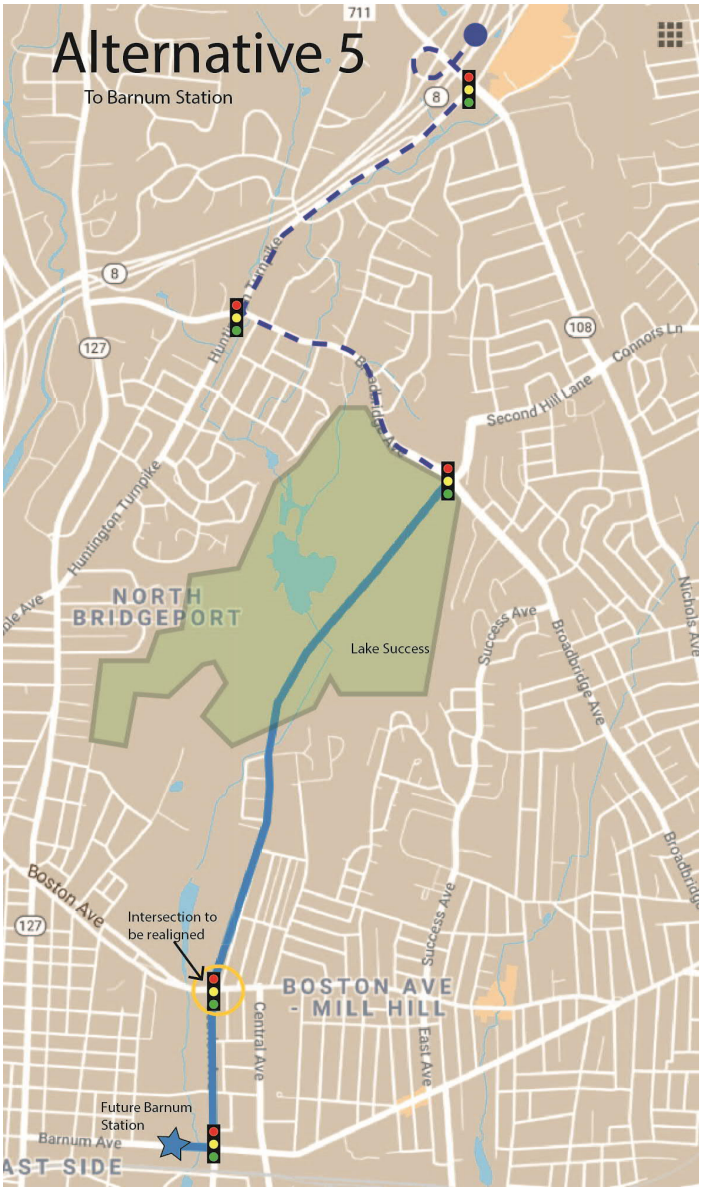


Figure 2-14. BRT to Proposed Future Barnum Station

Pros

- Dedicated lane on over half of the route
- Potential to serve Trumbull Corporate Park and Lake Success

Cons

- High capital costs
- Substantial right-of-way acquisition
- Insufficient shoulder width in many locations
- Duplicates existing GBT Route 22X

3. MAGNITUDE OF COSTS

Capital costs were estimated using information from TCRP Report 118 – Bus Rapid Transit Practioner's Guide, the American Public Transit Association (APTA) resources, and unit values from the Connecticut Central Rail Study which were based off of contractor costs for CTfastrak[1]. The capital costs for each of the seven elements in a BRT system were examined. Figure 3-1 breaks down the different sub elements that were included in the cost estimates.

Each of the seven elements of a BRT system were quantified for each alternative. Additionally Alternative 2 and Alternative 5 were broken down even further based upon possible configurations. The cost was looked at in Alternative 2 for both a right and a left running shoulder BRT. In Alternative 5 a high and low cost are presented based on the various segment alternatives which could be constructed. As shown in Table 3-1 the least costly alternative is Alternative 3 because it has no dedicated right-of-way. The most expensive is Alternative 2, with a right hand running shoulder, because of the numerous exit ramps that would require an overpass be constructed. Table 3-2 provides a breakdown of the capital costs by alternative and Table 3-3 the units. A description of each item, the unit used, unit cost, data source and assumptions made are in Table 3-4.

Table 3-1. Alternatives Capital Cost

Alternative	Capital Cost
1. Median Running BRT	$54,440,000
2. Shoulder Running BRT - Right	$269,900,000
2. Shoulder Running BRT - Left	$59,900,000
3. Enhanced GBT Route 22X	$1,890,000
4. Derby to Waterbury Express Bus	$2,770,000
5. Full BRT (Low)	$42,810,000
5. Full BRT (High)	$152,970,000

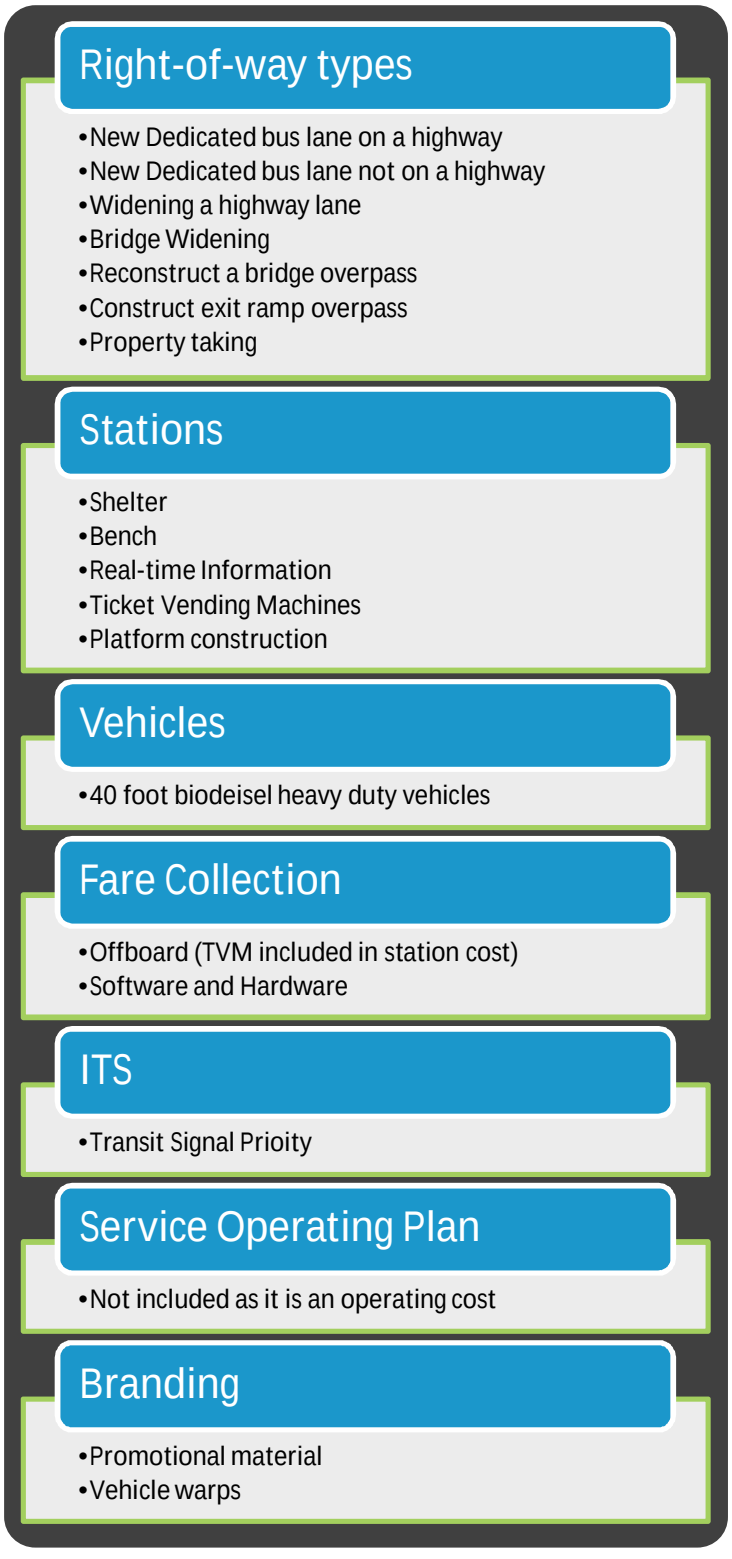


Figure 3-1 BRT Elements Costed Out

[1] All costs were inflated to 2019 dollars

Table 3-2 Alternative Capital Cost by Line Item

Item	Alternative 1 Median Running	Alternative 2 – Right Shoulder Running	Alternative 2 – Left Shoulder Running	Alternative 3 Enhanced Rt 22X	Alternative 4 Express Bus	Alternative 5 (Low) Full BRT	Alternative 5 (High) Full BRT
Signal upgrade for TSP	$0	$0	$0	$360,000	$0	$680,000	$960,000
New Dedicated Bus Lane on Highway	$42,900,000	$0	$0	$0	$0	$12,540,000	$6,600,000
New Dedicated Bus Lane on Local Road	$0	$0	$0	$0	$0	$14,720,000	$35,540,000
Widening of Highway Lane	$0	$18,260,000	$18,260,000	$0	$0	$6,270,000	$3,220,000
Reconstruct Bridge Overpass	$4,800,000	$6,600,000	$6,600,000	$0	$0	$0	$1,800,000
Bridge Widening	$4,800,000	$15,600,000	$15,600,000	$0	$0	$0	$0
Construct Exit Ramp Overpass	$0	$227,500,000	$17,500,000	$0	$0	$0	$87,500,000
Vehicle	$1,230,000	$1,230,000	$1,230,000	$820,000	$2,460,000	$1,640,000	$1,640,000
Stations Hubs	$400,000	$400,000	$400,000	$400,000	$0	$600,000	$800,000
Branding	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Fare Collection	$210,000	$210,000	$210,000	$210,000	$210,000	$210,000	$210,000
Property Taking	$0	$0	$0	$0	$0	$6,050,000	$14,600,000
Total	$54,440,000	$269,900,000	$59,90,000	$1,890,000	$2,770,000	$42,810,000	$152,970,000

Table 3-3. Alternative Unit Quantities

Item	Alternative 1 Median Running	Alternative 2 – Right Shoulder Running	Alternative 2 – Left Shoulder Running	Alternative 3 Enhanced Rt 22X	Alternative 4 Express Bus	Alternative 5 (Low) Full BRT	Alternative 5 (High) Full BRT
Signal upgrade for TSP	0	0	0	9	0	17	24
New Dedicated Bus Lane on Highway	6.5	0	0	0	0	1.9	1
New Dedicated Bus Lane on Local Road	0	0	0	0	0	4.1	9.9
Widening of Highway Lane	0	10.2	10.2	0	0	3.5	1.8
Reconstruct Bridge Overpass	8	11	11	0	0	0	3
Bridge Widening	4	13	13	0	0	0	0
Construct Exit Ramp Overpass	0	13	1	0	0	0	5
Vehicle	3	3	3	2	6	4	4
Stations Hubs	2	2	2	2	0	3	4
Branding	1	1	1	1	1	1	1
Fare Collection	1	1	1	1	1	1	1
Property Taking	0	0	0	0	0	10.25	24.75

Table 3-4. Unit Costs and Descriptions

Item	Unit	Unit Cost	Source	Assumption
Signal upgrade for TSP	Acre	$40,000	TCRP 118	Only for Alternatives where it would be running along local road ways for the majority of the route
New Dedicated Bus Lane on Highway	Mile	$6,600,000	TCRP 118	Off-street busway grade separated elevated. Exhibit S-1 TCRP Report 118
New Dedicated Bus Lane on Local Road	Mile	$3,590,000	TCRP 118	Arterial lane reconstructed mid-point (exhibit 4-12)
Widening of Highway Lane	Mile	$1,790,000	TCRP 118	Cost for striped lane + 1/4 cost of at grade separated off-street busway to assume some reconstruction of road will be needed to widen, reinforce and drainage
Reconstruct Bridge Overpass	Each	$560,000	Central CT Rail	1/2 the cost of Bridge widening
Bridge Widening	Each	$1,200,000	Central CT Rail	Assumes bridge length of 250 feet and widening by 15' at a cost per SF of $442
Construct Exit Ramp Overpass	Each	$17,500,000	TCRP 118	Assumes elevated and each is 1/4 mile. Off-street busway grade separated elevated from TRCP 118
Vehicle	Each	$410,000	2016 APTA vehicle database	Average price paid per vehicle by CTDOT for last round of Biodiesel busses as reported
Stations Hubs	Each	$200,000	TCRP 118	Includes cost of large shelter, bench, ticket vending machine, real-time information, and platform construction
Branding	Lump Sum	$100,000		Cost to develop the brand
Fare Collection	Lump Sum	$210,000	TCRP 118	Backend software
Property Taking	Acre	$590,000	Central CT Rail	Assumes when operating along non highway there is a taking of 2.5 acres per 1 mil of road